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ELECTROMAGNETIC RADIATION FIELD NEAR POWER LINES AND ITS ENVIRONMENTAL IMPACT

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Electromagnetic fields (EMF) are a combination of invisible electric and magnetic fields of force. The EMF is present in every place where electricity is used and it is surrounding every object electrically charged.

The purpose of this paper is to study how the electromagnetic map of a three phase power line impacts over the electrical equipment, the surrounding environment and never the less over the human body.

The paper also presents the results of the monitoring and diagnoses techniques based on electromagnetic radiation field and of ATP simulation.

Keywords*:* electromagnetic pollution, EMF impact, three phase power line

1. Introduction

In the last years, the technological progress concerning data transmission and the development and expansion of the power systems worldwide, has increased the electromagnetic field level as well as the bio-organism and human body exposure to the electromagnetic radiation. The electromagnetic field, present in all the environments that are using electricity, is generated especially by the power systems. The knowledge and the measuring of these electromagnetic fields it is very important in order to design and explore the electric systems because of:

- their sensibility to electromagnetic field perturbation (natural or artificial);
- their behavior as field sources with a certain impact over the technical and biological systems, [1].

The purpose of this paper is to study the impact of the electromagnetic map generated by a three phase power line on the electrical equipment, the surrounding environment and on the human body. To study the equipment behavior, while in service, and the electromagnetic field level it is generating, magnetic sensors can be used for monitoring and diagnoses operations.

Magnetic sensors differ from most other detectors in that they do not directly measure the physical property of interest. Devices that monitor properties such as temperature, pressure, strain or flow provide an output that reports the desired parameter (fig. 1). Magnetic sensors detect changes or disturbances in magnetic fields that have been created or modified and from them derive information on properties such as direction, presence or electrical currents. The

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output signal of these sensors requires signal processing in order to get the desired parameter. Although magnetic detectors are somewhat more difficult to use, they do provide accurate and reliable data — without physical contact [2], [3].

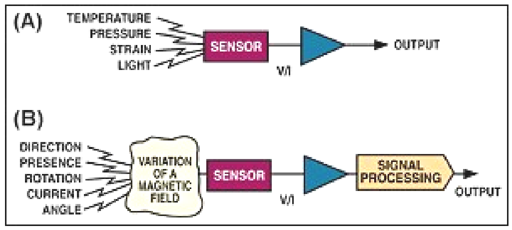

Fig. 1. Conventional sensors (A); magnetic sensors (B)

The magnetic sensors can be used to determine the magnetic field security zones around high voltage power lines. In the figures below is presented the distribution zone of the magnetic field (MF) for a 220 kV three phase power lines considering a balanced system of current for the 3 phases. In figures 2 and 3 are shown the corresponding zone to B ≥ 100 μT and to B ≥ 0.4 μT.

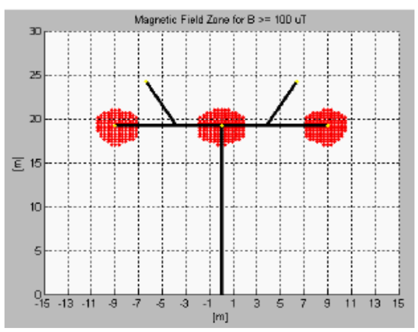

Fig. 2. MF Zone for 220 kV – B ≥ 100 μT

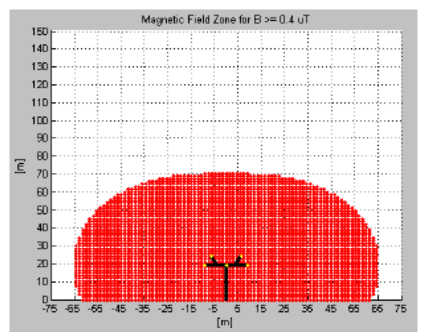

Fig. 3. MF Zone for 220 kV –B ≥ 0.4 μT

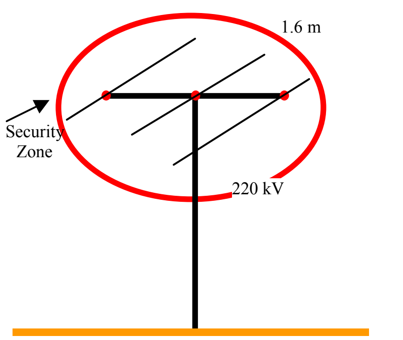

Fig. 4. MF Security Zones for B ≥ 100 μT

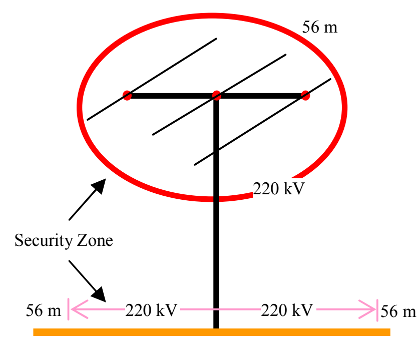

Fig. 5. MF Security Zones for B ≥ 0.4 μT

Analyzing the results for the distribution of the magnetic field with the limits of 100 μT and 0.4 μT we can define a schematic picture of the magnetic field security zones around high voltage power lines of 220 kV which is presented in Fig. 4 and Fig. 5, [4]. All electric flows have an associated electric field and magnetic field. The intensity of both electric and magnetic fields decreases with distance from the field source. Electric fields are more easily shielded or blocked than magnetic fields, [5].

The present paper concentrates in applying monitoring and diagnoses techniques in one part of the power system, the three phase power line. To ease the data acquisition process a laboratory three phase power line has been created.

2. Methods

2.1. Measuring the electromagnetic field on a three phase power line

The electromagnetic field present in the electric substations of the power system has a direct impact on the human factor. Monitoring the exposure to the electromagnetic radiation field, of low or high frequency implies the use of a very complex and expensive logistic.

The magnetic field is generated by conduction, convection, displacement and Roentgen currents, as well as by the bodies with residual magnetization.

The magnetic induction B of a high voltage (HV) charged transmission line could be calculated in any point of his corridor with the Ampere's law (1):

$$B = \mu_0 \frac{i}{2\pi r}, \tag{1}$$

where $\mu_0 = 4 \times 10^{-7}$ H/m - the magnetic permeability in air.

The magnetic field of power transmission lines is also elliptical and can be calculated in a plan perpendicular to the conductors, using the conductors image method. The soil surface is substitute with a plan situated at depth *p*. To calculate the magnetic induction components B_x (x, y) and B_y (x, y), in a certain point N(x,y), equation 2 is used:

$$\begin{aligned} \underline{B}_x(x,y) &= \frac{\mu_0}{2\pi}\sum_{k=1}^{n}\underline{I}_k\left[\frac{-(y-y_k)}{(y-y_k)^2+(x-x_k)^2}+\frac{y+y_k+2p)}{(y+y_k+2p)^2+(x-x_k)^2}\right] \\ \underline{B}_y(x,y) &= \frac{\mu_0}{2\pi}\sum_{k=1}^{n}\underline{I}_k\left[\frac{-(x-x_k)}{(y-y_k)^2+(x-x_k)^2}+\frac{-(x-x_k)}{(y+y_k+2p)^2+(x-x_k)^2}\right] \end{aligned} \tag{2}$$

where p is the penetration depth and can be calculated using equation 3:

$$p = \frac{1}{\sqrt{\mu_0 \sigma \omega}} \tag{3}$$

μo – magnetic permeability of the soil; ω = 100 π, σ = 0,02 S.
For the values of μ_o, ω and σ mentioned above the penetration depth is 356 m. Since p values are quite high, the field due to image conductors can be neglected, thus the equation (4) can be written in a simplified way as shown in equation 4:

$$\underline{B}_x(x,y) = -\frac{\mu_0}{2\pi}\sum_{k=1}^{n}\underline{I}_k \frac{(y-y_k)}{(y-y_k)^2+(x-x_k)^2}$$
$$\underline{B}_y(x,y) = -\frac{\mu_0}{2\pi}\sum_{k=1}^{n}\underline{I}_k \frac{(x-x_k)}{(y-y_k)^2+(x-x_k)^2} \quad (4)$$

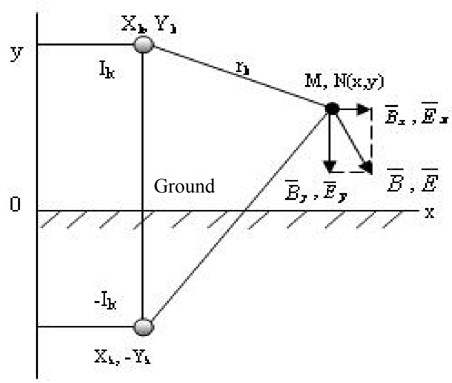

Fig. 6. Electric and magnetic field components

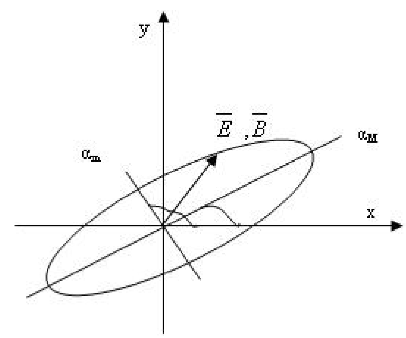

Fig. 7. Resultant electric and magnetic field

2.2. Electromagnetic pollution

Because electricity is so much a part of our lives, there are electromagnetic fields around us most of the time. People are exposed to electric and magnetic fields from many sources including high, medium and low voltage power lines, electric wiring inside buildings and electric appliances.

Strong electromagnetic fields (EMFs) of about 50 to 60 Hz and the related electromagnetic radiation (EMR) [6] are harmful to humans. Long-term exposure may aggravate any existing health problems or diseases and may cause or intensify especially lack of energy or fatigue, irritability, aggression, hyperactivity, sleep disorders and emotional instability.

Electric and magnetic fields can be measured in practically every environment or estimated from other parameters. Environmental levels of ELF fields are very low, 5-50 V/m for electric fields and 0.01-0.2 μT for magnetic fields. Much higher exposures can take place in some workplaces and possibly outside the workplace, for shorter durations.

2.2.1. Problems caused by the electromagnetic field

The effects of the electromagnetic fields generated nearby high voltage power systems over the environment can be analysed by taking into account the next factors [7]: electric and magnetic field solicitation; corona discharge effect, radioelectric perturbation; acoustic noise of corona discharge.

2.2.2. Exposure limit values

Based on frequency, to define exposure limit values for electromagnetic field the following units might be used:

a. <= 1Hz exposure limit values are foreseen for current density for time variable fields, in order to prevent possible effects on cardiovascular and central nervous systems;

b. 1 Hz – 10 MHz for current density with the purpose to prevent the effects on the central nervous system functions;

c. 100 kHz - 10 GHz exposure limit values are foreseen regarding SAR and current density, in order to prevent the thermal stress over the entire body;

d. 10 GHz – 300 GHz exposure limit values are foreseen for power density, with the purpose to prevent an overheating of the tissues at the body surface or near this surface [8].

2.3. Modeling and simulation in EMTP -ATP software

For the simulation of a three phase power line electromagnetic radiation field the EMTP – ATP software was used. The mathematic model was build in ATP Draw for each of the three configuration of the power line (horizontal, vertical and tringular) and the graphical results were generated with the help of MC’s Plot XY.

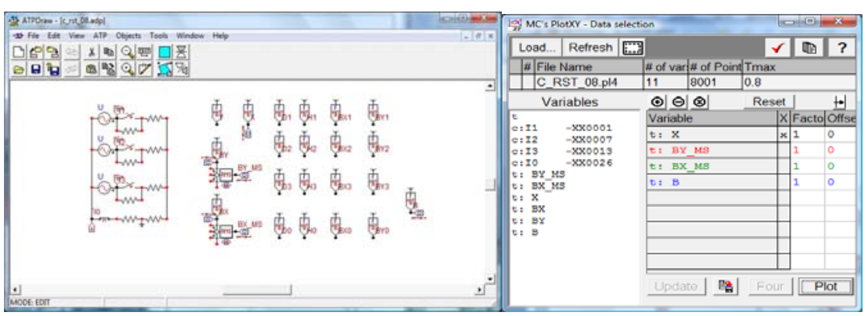

Fig. 8. Three phase power line model

2.3.1. Simulation of the magnetic field for horizontal configuration

The next parameters were taken into account for the horizontal distribution of the conductors: the distance between conductors plan and the measuring point – 2m; the distance between conductors – 0,5 m. The final results of the simulation process show the magnetic induction horizontal and vertical components (B_x and B_y) as well as the resultant induction B, [9].

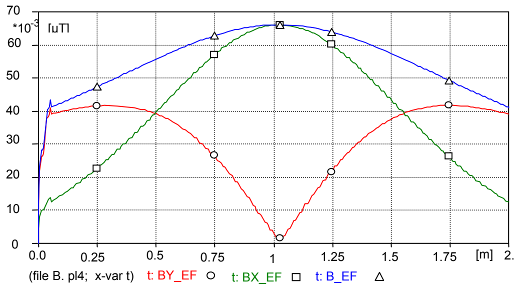

Fig. 9. Magnetic field induction – orizontal plan

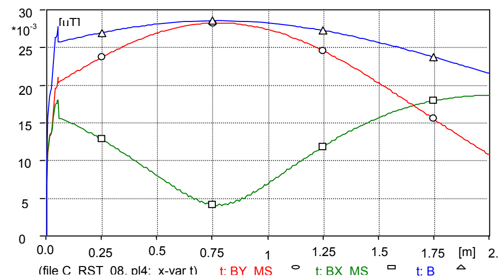

Fig. 10. Magnetic field induction– vertical plan

2.3.2. Simulation of the magnetic field for vertical configuration

In this case only the distance between each conductor and the measuring point modifies: phase R - 245 cm, phase S – 195 cm, phase T – 145 cm, neutral wire – 95 cm. The graphic results of the magnetic induction for vertical distribution of the power line conductors are shown in the figure 10.

2.3.3. Simulation of the magnetic field for triangular configuration

The new parameters for the conductors triangular shape distribution are: phase R – 170 cm, phase S – 179 cm, phase T – 210 m, neutral wire – 230 cm.

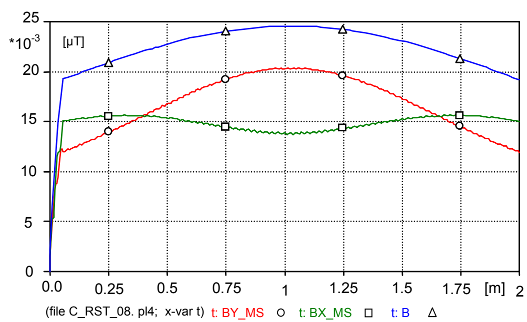

Fig. 11. Magnetic field induction– triangular configuration
B_y – vertical component, B_x – horizontal component, B – rezultant induction

The simulation results show that the electromagnetic radiation filed changes its magnetic induction values according to the conductors layout. This values can be influenced by conductors distance from the measuring equipment and the distance between conductors. It must also be taken into account the presence of electrical equipment interference while in service.

3. Results

The electromagnetic field is characterized, in a certain point in space, by the superposition of an electric and magnetic field, variable in time, which depend one on each other and are mutually generating.

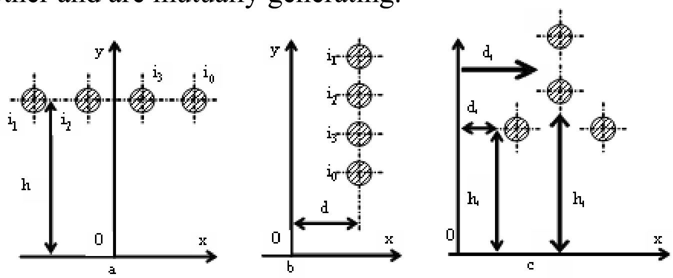

Fig. 12.Three phase system: a – horizontal plan, b- vertical plan, c – triangular plan

The study was conducted on a laboratory network for the three different configurations as shown in fig. 12. The results for the three phase power line (fig.13) are presented in this chapter in fig. 14, 15 and 16.

Fig. 13. Laboratory modeled network

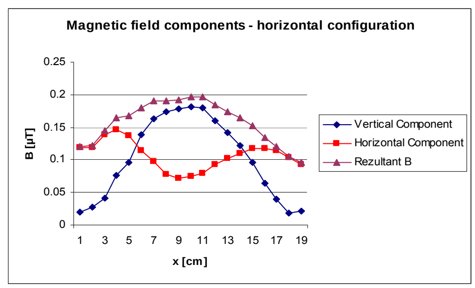

Fig. 14. Magnetic field variation curves – a

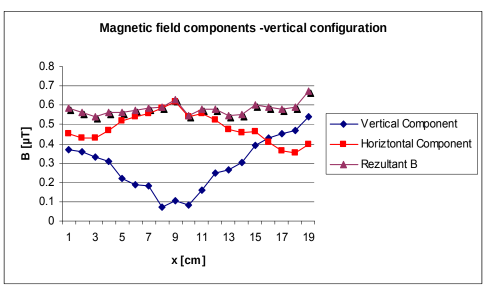

Fig. 15. Magnetic field variation curves – b

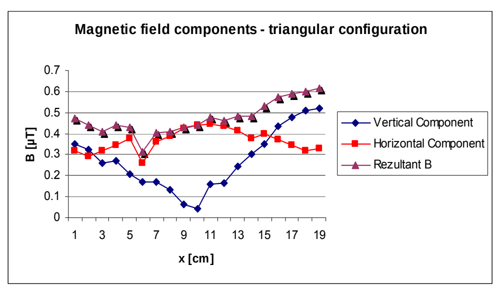

Fig. 16. Magnetic field variation curves – c

a - horizontal configuration; b - vertical configuration; c - triangular configuration

Monitoring the magnetic field as close as possible to the conductors, the registered data have a very good accuracy. At this point the level of interferences is almost reduced to zero. As the distance grows, the process goes the other way; different kinds of interferences, provided by the electrical equipment and installations in service, are influencing the data accuracy. Taking into account the electromagnetic pollution matter for the laboratory network, the data have shown different level of pollution for the electric and magnetic field. The level of magnetic pollution is quite high; the maximum value registered is reaching 0.672012 μT, knowing that exposure limit value is 0.01 - 0.2 μT.

6. Conclusions

Through the monitoring and diagnoses of the electromagnetic field, the purpose of the present paper is to systemize the knowledge about the electromagnetic field present in the conductors area in order to see the level of exposure the exploring staff is facing.

Nowadays, different actions are taken in order to limit the electromagnetic fields effects on living organism. Some of this actions are mentioned below:

- establishing a standard for EMF intensity;
- protection measures against exposure to EMF sources: ferromagnetic shields; acoustic and optic warning devices to mitigate the exposure time; the distance from the EMF source, which is harmless to human body.

The recent research concerning the influence of the electromagnetic field on the living organisms have demonstrated that these influences had a different impact on intracellular phenomena, cells, organs and the organism its self.

The present research are conducted in order to elaborate new normatives of the pollution sources and to implement new protection techniques of the human body against the electromagnetic field influence.

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