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Active protection from electromagnetic field hazards of a high voltage power line

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Abstract

Transmission lines are a source of electromagnetic field (EMF) in a wide space and affect many electronic devices. It is also believed that the influence of electromagnetic field is harmful to the health of humans.

It is known that in a limited space it is possible to suppress EMF with the help of Helmholtz coils, which, however, are not applicable in wide spaces.

In the present research it is shown that active suppression of EMF from a transmission line can be achieved by the use of a long loop fed by a controlled current. The loop is placed lengthways on the transmission line, or nearby, in the protected area. The parameters of the loop and the exact place of its arrangement are defined by the proposed calculation, and the current in the loop is set by an automatic control system.

The device was checked on a model and its prototype was successfully used in an actual residential zone.

1 Introduction

Recently numerous users and developers of electronic devices have come across the phenomenon of the electromagnetic effect of power lines.

This phenomenon is especially damaging to electro-optical devices, such as electron microscopes, oscilloscopes or computer screens [1]. Also, it is believed that the influence of electromagnetic field (EMF) is harmful to the health of humans [2, 3, 8]. The present paper suggests a method for the active suppression of EMF by creating anti-EMF. This is accomplished by analyzing the existent EMF and synthesizing an electromagnetic field analogous to the existent field in form and amplitude, but opposite in phase.

The recommended level of EMF allowable for people in different countries various, starts from 4mG. The recommendation of the Ministry of Environment of Israel is 10mG. However this level is sometimes considerably exceeded. Thus, in Table 1 the results of the EMF measurements in one of the resort areas are shown. As can be seen, in some of the sites the level of EMF exceeds 80mG.

The present paper suggests a method for the active suppression of EMF by creating anti-EMF. This is accomplished by analyzing the existent EMF and synthesizing EMF analogous to the existent field in form and amplitude, but opposite in phase.

The proposed method has been used for suppressing the EMF surrounding the three-phase power line on models and in actual situations.

Number of the step	Radiation B mG	Number of the step	Radiation B mG
1	14	9	63
2	32	10	62
3	41	11	42
4	33	12	6
5	9	13	74
6	8	14	50
7	33	15	84
8	6	16	75

Table 1: EMF of a power line (zone of the resort areas, length of 4 km, a step 250 m, height 1m from the ground).

2 Electromagnetic field generated by power line and by suppressing loop

Suppression of EMF in a limited space is based on the well-known method of creating the anti-EMF using Helmholtz coils, usually of three components, which are placed around the protected object. The system is useful for the protection of different electronic devices, which are sensitive to EMF, such as electronic microscopes, computer monitors, etc. [7]. However, this method is not suitable for protecting large spaces like in the case of transmission lines. In order to protect large spaces from the influences of EMF of industrial frequency, which arises from transmission lines, a simple method based on a loop current protection has been developed by the authors.

To analyze the magnetic field of the power line and suppressing loop, the magnitudes of both the vertical and horizontal components of the magnetic flux density at each point of the space have to be known.

There are known analytical [4] and numerical [5] methods for such an analysis, which is based on the computation of the magnetic flux density vector of the line field. A practical method for the numerical computation of the vertical and horizontal EMF components of the power line with an arbitrary number of conductors, suggested in [6], is used in this paper. The schematic illustration of a three-phase power line and suppressing loop is shown in Fig. 1.

From Biot-Savart law the magnetic flux density produced by infinite conductor is:

$$B_i(x,z,t) = \frac{\mu_0}{2\pi}\frac{I_{mi}\sin(\omega t - a_i)}{R_i(x,z)} \tag{1}$$

where μ_0 is the magnetic permeability of air, $I_{mi}\sin(\omega t - a_i)$ the current carried by the conductor, $P(x,z)$ is the point where we wish to calculate the magnetic field (the point of observation), x, z- the coordinates of the point of observation, $R_i(x,z)$ is the distance from i-phase to the point of observation, $R_i(x,z) = \sqrt{(x_i(x))^2 + (z_i(z))^2}$, $x_i(x) = x - \mathrm{X}_i$, $z_i(z) = z - \mathrm{Z}_i$, i - number of a wire (phase) of a power line, X_i, Z_i - coordinates of a i-phase.

The vertical and horizontal components of B_i are defined by the expressions:

$$BV_i(x,z,t) = B_i(x,z,t)\frac{x_i(x)}{R_i(x,z)} \tag{2}$$

$$BH_i(x,z,t) = B_i(x,z,t)\frac{z_i(z)}{R_i(x,z)}. \tag{3}$$

EMF of a power line can be suppressed by EMF of a rectangular loop. The location of such a loop relative to the line is shown in Fig. 1, where 1-2-3-4 is the loop, h is the distance between the loop and the line, d is the distance between the line conductors, a is the width of the loop and b is the length of the loop ($b >> a$).

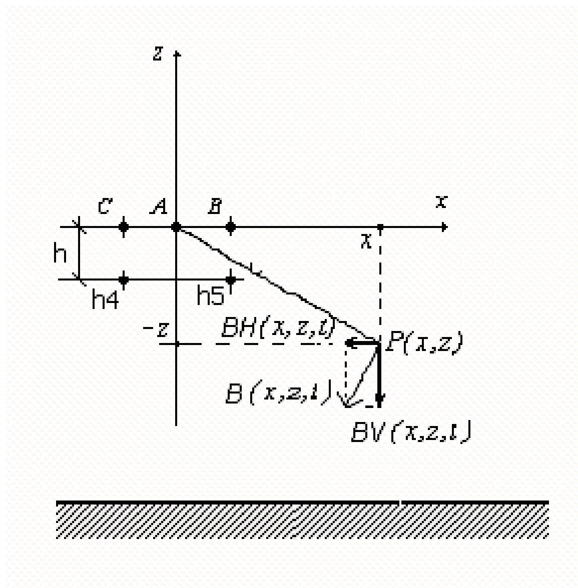


Figure 1: Schematic illustration of a three-phase power line and suppressing loop.

The sum of the vertical and horizontal components at a point $P(x,z)$ for the three-phase line is defined as:

$$BV(x,z,t) = \sum_{i=1}^{3} BV_i(x,z,t) \tag{4}$$

$$BH(x,z,t) = \sum_{i=1}^{3} BH_i(x,z,t). \tag{5}$$

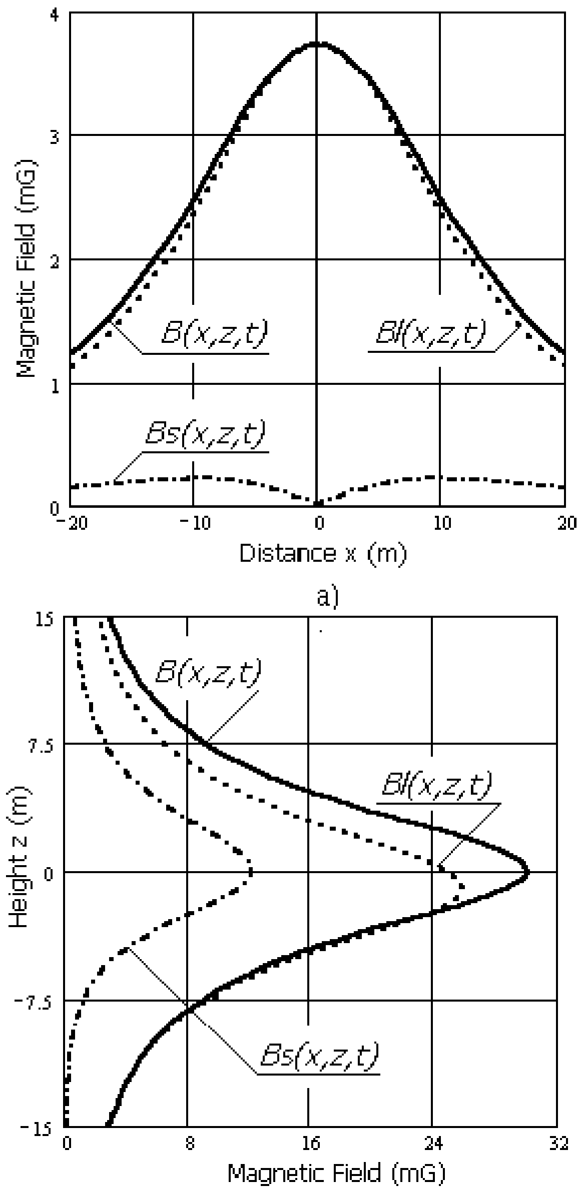
The module of EMF for the three-phase line is defined by:

$$B(x,z,t) = \sqrt{(BV(x,z,t))^2 + (BH(x,z,t))^2} \tag{6}$$

EMF of the loop is the sum of the vertical and horizontal components of the both wires (1-2, 3-4):

$$BV_l(x,z,t) = BV_{l1}(x,z,t) + BV_{l2}(x,z,t) \tag{7}$$

$$BH_l(x,z,t) = BH_{l1}(x,z,t) + BH_{l2}(x,z,t). \tag{8}$$



b)

Figure 2: The magnetic flux density of a three-phase line, of the loop, and of their difference as a a) function of the distance x, (x = -20, -19 .. 20m, z = -14m, t = 0.01s, $h4$ = -1m, $h5$ = -1m), b) function of the height z, (x = 5m, z = -15, -14.5 .. 15m, t = 0.01s,$h4$ = -1m, $h5$ = -1m).

The module of EMF of the loop is defined by:

$$B_l(x, z, t) = \sqrt{(BV_l(x, z, t))^2 + (BH_l(x, z, t))^2} \tag{9}$$

The suppressed field, ($BVs(x,z,t)$, $BHs(x,z,t)$) is found as the sum of the line field ($BV(x,z,t)$, $BH(x,z,t)$) and the loop field ($BVl(x,z,t)$, $BHl(x,z,t)$):

$$BV_s(x, z, t) = BV(x, z, t) + BV_l(x, z, t) \tag{10}$$

$$BH_s(x, z, t) = BH(x, z, t) + BH_l(x, z, t). \tag{11}$$

The module of suppressed EMF is:

$$B_s(x, z, t) = \sqrt{(BV_s(x, z, t))^2 + (BH_s(x, z, t))^2}. \tag{12}$$

The calculation of the magnetic field magnitude is performed for a three-phase transmission line and suppressing loop under the following conditions.

Conductors of a three-phase line are located horizontally in the order C, A, B; the distance between the line conductors is d=1m; the current of each phase is 200A (RMS); the height of the line is 15 m; the suppressing loop is situated under the power line at distance h=1m and characterized by 150 amper-turns.

The calculated results for the module of EMF for the transmission line, loop, and suppressed field are shown in Fig. 2.

As can be seen from Fig. 2, the suppression of EMF under the line is more than 10 times, and at the level of the line is 2.5 times.

For the considered disposition of the loop, EMF is suppressed in the whole space around the line. Sometimes it is enough to suppress the magnetic field only on one side from the line (for example, to protect a many-storied building located near the line).

3 EMF created by a transmission line near a building

The schematic illustration of a three-phase power line and suppressing loop near a building is shown in Fig. 3. It can be seen (Fig. 2b) that the magnitude of the magnetic field for floors located at the same height as the transmission line are very high and might be harmful for health [8].

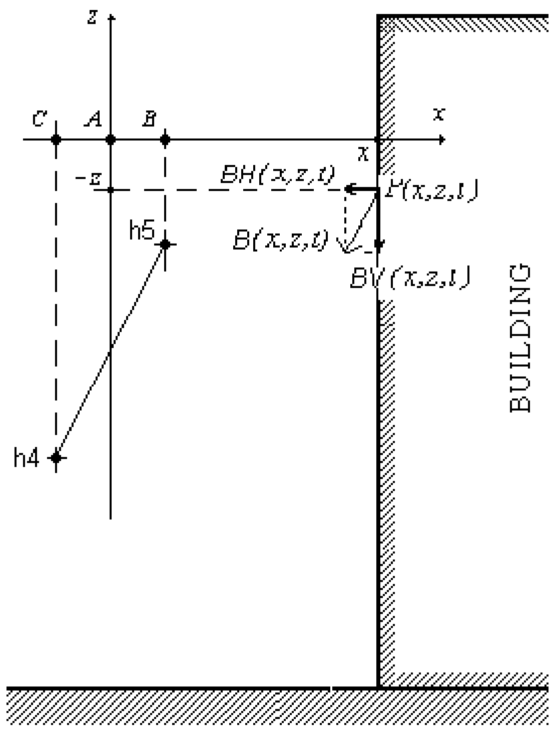


Figure 3: Schematic illustration of a building situated near a three-phase power line with a suppressing loop.

For suppressing EMF at one side of the line the loop must be disposed as shown in Fig. 3. The loop is situated under the power line at distance $h4$ = -6 m, $h5$ = -2 m. The amper-turns of the loop should be 70 AT.

For the case shown in Fig. 3 the magnitudes of the magnetic fields for the transmission line, loop, and the suppressed fields for a many-storied building situated 5 m from the transmission line, are shown in Fig. 4. As can be seen from Fig. 4, the suppression of EMF on one side of the line is up to 6 times.

For suppressing EMF only on one floor of a building the loop must be located according to Fig. 5. The loop is located at the coordinates $h4$ = -0.8 m, $x4$ = 3 m, $h5$ = -0.75 m, $x5$ = 4 m. The amper-turns of the loop are 21 AT.

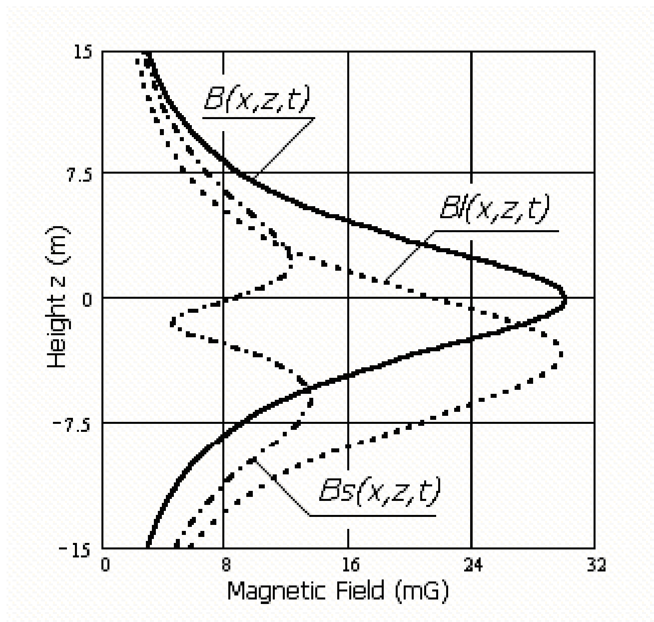


Figure 4: The magnetic flux density of a three-phase line of a loop, and their difference as a function of the height z, (x = 5m, z = -15, -14.5 .. 15m, t = 0.01s, $h4$ = -6m, $h5$ = -2m)

For the case of a three-storey building located 5 m from the transmission line shown in Fig. 5, the magnitude of the magnetic fields for the transmission line, loop, and suppressed field are presented in Fig. 6. In this case the suppression of EMF exceed 10 times.

The verification of suppressing electromagnetic field executed on the three-storey dwelling. The top floor is situated on the distance of the power line 5 meters from the central conductor.

The general view of the house and the suppressing loop near power line is shown in Fig. 7. The cost of the laboratory model of the system for the suppression EMF shown on Fig. 7 is about 1000 dollars.

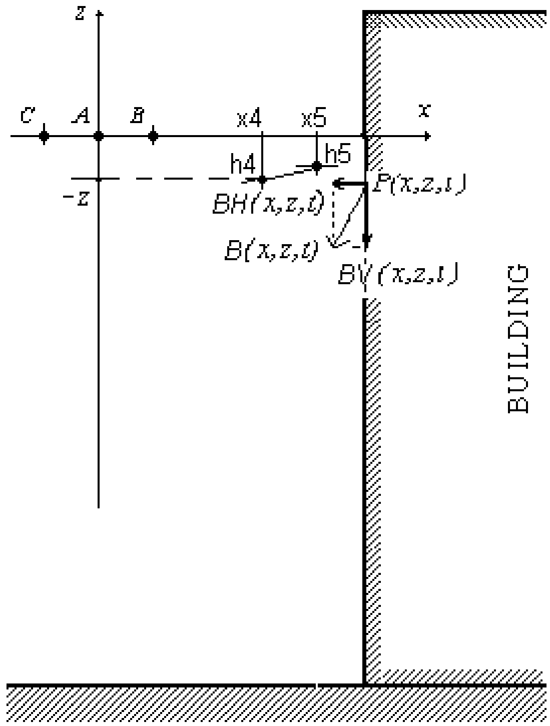


Figure 5: Schematic illustration of a building situated near a three-phase power line and suppressing loop.

4 Automatic control system for suppressing EMF

The block scheme of the controlling system is shown in Fig. 8.

Here “1” is a one-component electromagnetic probe for measuring EMF in the protected area, i.e., EMF of the form $B\sin(\omega t-\varphi)$ which is applied to the input; “2” is an amplifier and phase shifter, “3” is a power amplifier, “4” is a loop which produces EMF in an opposite phase and ”5” is the feedback (dependent on the probe and loop coordinates). Therefore we have an automatic control system with negative feedback. The magnitude and phase of the loop current is controlled automatically (if the loop contains n turns, the loop current is reduced n times).

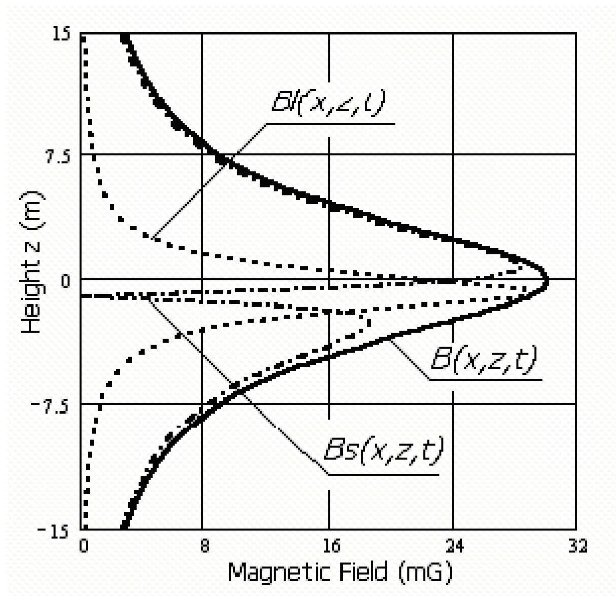


Figure 6: The magnetic flux density of a three-phase line, a loop and their difference as a function of the height z, (x = 5m, z = -15, -14.5 .. 15m, t = 0.01s, $x4$ = 3m, $h4$ = -0.8m, $x5$ = 4m, $h5$ = -0.75m).

Figure 7: A house and a model of suppressing loop near a power line.

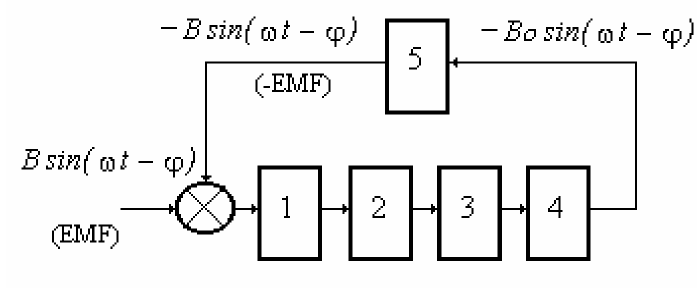


Figure 8: Block diagram of a controlling system.

5 Conclusion

In this research, a system for actively suppressing the electromagnetic field of industrial frequency power transmission lines in large spaces is considered. The system for such protection contains a loop placed under a line (or aside) along the protected area and an automatic control device.

The results were verified by a simulation program, on an experimental model, and on a real power line located near a residential area.

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