METHOD FOR ACTIVE SUPPRESSION OF AN INDUSTRIAL FREQUENCY ELECTRO-MAGNETIC FIELD

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It was shown that the suppression of electromagnetic field (EMF) created by a transmission line could be done by using a long loop wire feed by an appropriate current. The loop wire is situated on the line-poles under the line wires along the protected area.

I. INTRODUCTION

Numerous users and developers lately come across the phenomenon of electromagnetic effect of power line on electronic devices. This phenomenon is especially damaging for electro-optical devices, such as electron microscopes, oscilloscopes or computer screens [1]. Also, there is an opinion that the influence of electromagnetic fields is harmful to the health of humans [2,3,4]**.** The present research suggests methods for active suppression of EMF by creating anti-EMF. This is accomplished by analyzing the existent EMF and synthesizing electromagnetic field analogous to the existent by form and amplitude, but of opposite sign.

It is shown possibility creation necessary anti-EMF for suppression EMF around of three-phase power line.

II. ELECTROMAGNETIC FIELD GENERATED BY POWER LINE

To analyze the magnetic field of the power line it is necessary to compute the magnitudes of the vertical and horizontal components of magnetic flux density at each point of the space. There are known analytical [5] and numerical [6] methods for analysis of such fields, purposed for computation of magnetic flux density vector of the line.

Authors use a practical method for numerical computation of vertical and horizontal components of EMF of the power line with arbitrary number of conductors suggested in [7].

First, let us solve this problem for three-phase power line shown in Fig. 1.

From Biot-Savart law [8] the magnetic flux density produced by infinite conductor is:

$$B(x,z,t) = \frac{\mu_0}{2\pi}\frac{I_m \sin \omega t}{R(x,z)} \qquad (1)$$

where μ_0 is the magnetic permeability of air, $I_m \sin \omega t$ the current carried by the conductor, $P(x,z)$ is the point in the x,z plane, where we wish to calculate the magnetic field.

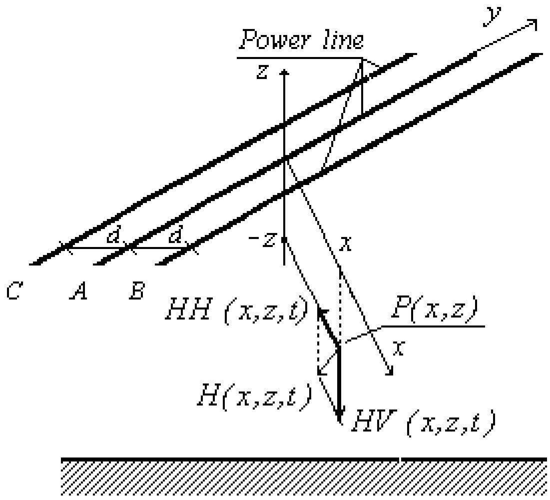


Fig. 1. Schematic illustration of the three-phase power line.

For the magnitude of electromagnetic field H of the power line we may write:

1) For line A:

$$HV_1(x,z,t) = \frac{xI_{m1} \sin \omega t}{2\pi(x^2+z^2)} \qquad (2)$$

$$HH_1(x,z,t) = \frac{zI_{m1} \sin \omega t}{2\pi(x^2+z^2)} \qquad (3)$$

2) For line B:

$$HV_2(x,z,t) = \frac{(x-d)I_{m2} \sin\left(\omega t - \frac{2}{3}\pi\right)}{2\pi\left((x-d)^2+z^2\right)} \qquad (4)$$

$$HH_2(x,z,t) = \frac{zI_{m2} \sin\left(\omega t - \frac{2}{3}\pi\right)}{2\pi\left((x-d)^2+z^2\right)} \qquad (5)$$

3) For line C:

$$HV_3(x,z,t) = \frac{(x+d)I_{m3}\, sin\left(\omega t - \frac{4}{3}\pi\right)}{2\pi\left((x+d)^2 + z^2\right)} \qquad (6)$$

$$HH_3(x,z,t) = \frac{zI_{m3}\ sin\left(\omega t - \frac{4}{3}\pi\right)}{2\pi\left((x+d)^2 + z^2\right)} \qquad (7)$$

where $I_{m1}\ sin\,\omega t$, $I_{m2}\ sin\left(\omega t - \frac{2}{3}\pi\right)$, $I_{m3}\ sin\left(\omega t - \frac{4}{3}\pi\right)$

are currents in the conductors A, B, C respectively, *d*-distance between lines wires.

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

$$HV(x,z,t) = \sum_{i=1}^{3} HV_i(x,z,t) \qquad (8)$$

$$HH(x,z,t) = \sum_{i=1}^{3} HH_i(x,z,t) \qquad (9)$$

As example, dependence of $HV(x,z,t)$ and $HH(x,z,t)$ for the *x* and *t* coordinate is shown in Fig 2.

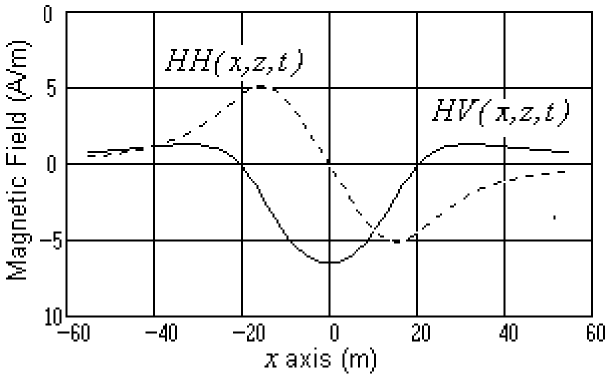


Fig. 2. Vertical ($HV(x,z,t)$) and horizontal ($HH(x,z,t)$) components, generated by the three-phase power line (*i(t)=700sinωt A, d=14m, z=-15m, t=0).*

Similarly, the components of EMF generated by a power line with arbitrary number of conductors can be calculated.

III. ELECTROMAGNETIC FIELD GENERATED BY SUPPRESSING LOOP

The section shows that EMF of power line can be suppressed by electromagnetic field of rectangular loop. The location of such a loop relatively to the line is shown of Fig. 3, where 1-2-3-4 is the loop, *h* is distance of the loop from the line, *d* is the distance between line conductors, *a=2d* the width of the loop*, b* the length of the loop (*b>>a*), $I_{ml}\ sin(\omega t - \varphi)$ the current of the loop.

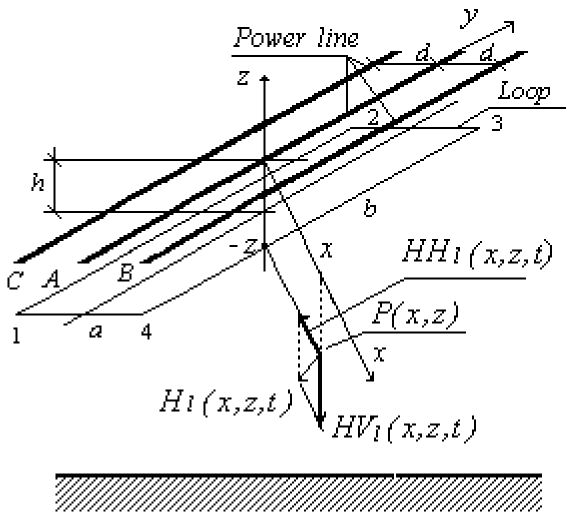


Fig. 3. Schematic illustrations of suppressing loop.

Let us compute the electromagnetic field created by conductors 1-2 and 3-4 of the loop:

1) For conductor 1-2:

$$HV_{l1}(x,z,t) = \frac{\left(x + \frac{a}{2}\right) I_{ml}\ sin(\omega t - \varphi)}{2\pi\left(\left(x + \frac{a}{2}\right)^2 + (z-h)^2\right)} \qquad (10)$$

$$HH_{l1}(x,z,t) = \frac{(z-h) I_{ml}\ sin(\omega t - \varphi)}{2\pi\left(\left(x + \frac{a}{2}\right)^2 + (z-h)^2\right)} \qquad (11)$$

2) For conductor 3-4:

$$HV_{l2}(x,z,t) = \frac{(-1)\left(x - \frac{a}{2}\right) I_{ml}\ sin(\omega t - \varphi)}{2\pi\left(\left(x - \frac{a}{2}\right)^2 + (z-h)^2\right)} \qquad (12)$$

$$HH_{l2}(x,z,t) = \frac{(-1)(z-h) I_{ml}\ sin(\omega t - \varphi)}{2\pi\left(\left(x - \frac{a}{2}\right)^2 + (z-h)^2\right)} \qquad (13)$$

The sum of the vertical and horizontal components at point *P(x,z)* is defined by:

$$HV_l(x,z,t) = HV_{l1}(x,z,t) + HV_{l2}(x,z,t) \quad (14)$$

$$HH_l(x,z,t) = HH_{l1}(x,z,t) + HH_{l2}(x,z,t) \quad (15)$$

The dependence of $HV_l(x,z,t)$ and $HH_l(x,z,t)$ on x coordinate at given z, t, I_{ml} is shown in Fig. 4.

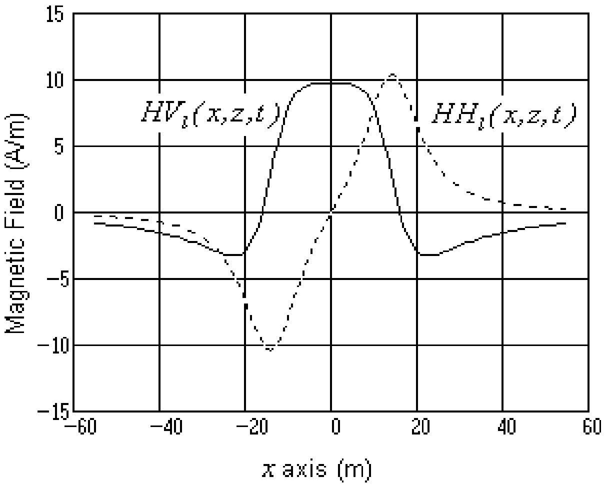


Fig. 4. Vertical ($HV_l(x,z,t)$) and horizontal ($HH_l(x,z,t)$) components generated by the loop 1-2-3-4 ($il(t)=565\sin\omega t$ A, $d=14m$, $z=-15m$, $h=7m$, $t=0$).

From comparison between Fig. 2 and Fig. 4 it can be seen, that the components of the magnetic field of the loop and magnetic field of the three-phase line are nearly similar by their form and opposite sign.

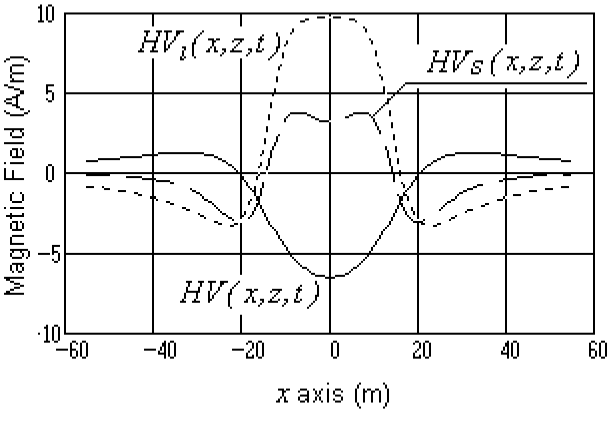


Fig.5. Vertical components of three-phase line ($HV(x,z,t)$), of the loop ($HV_l(x,z,t)$) and their difference ($HV_s(x,z,t)$) as function of x.

The difference between the components of the line and of the loop is defined by the following expressions:

$$HV_s(x,z,t) = HV(x,z,t) + HV_l(x,z,t) \quad (16)$$

$$HH_s(x,z,t) = HH(x,z,t) + HH_l(x,z,t) \quad (17)$$

The magnitude of magnetic fields for vertical components and their difference are shown in Fig. 5 and Fig. 6, for horizontal components are shown in Fig. 7.

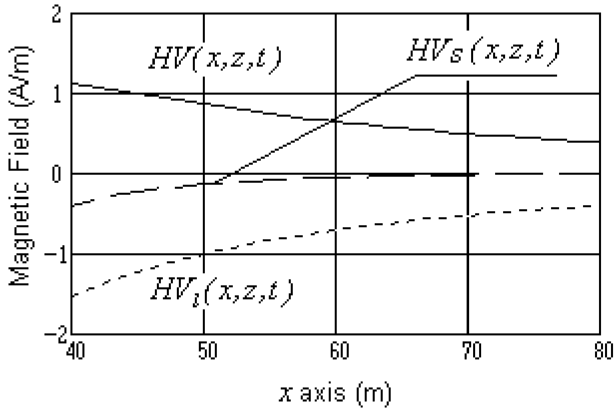


Fig.6. Vertical components of three-phase line ($HV(x,z,t)$), of the loop ($HV_l(x,z,t)$) and their difference ($HV_s(x,z,t)$) as function of x.

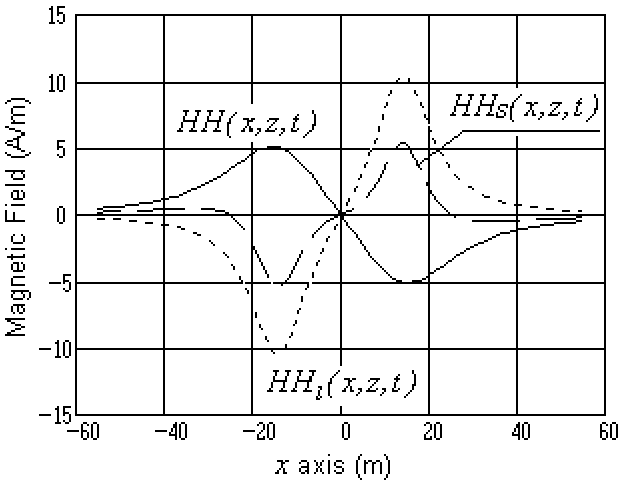


Fig.7. Horizontal components of three-phase line ($HH(x,z,t)$), of the loop ($HH_l(x,z,t)$) and their difference ($HH_s(x,z,t)$) as function of x.

IV. SIDE ELECTROMAGNETIC FIELD GENERATED BY SUPPRESSING LOOP

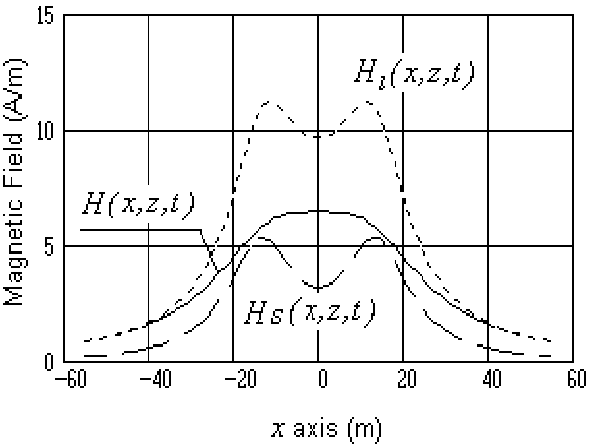
The magnitudes of the vectors electromagnetic field power line *H(x,z,t),* suppressed loop *Hl(x,z,t)* and their difference *Hs(x,z,t)* is defined by:

$$H(x,z,t) = \sqrt{(HV(x,z,t))^2 + (HH(x,z,t))^2} \qquad (18)$$

$$H_l(x,z,t) = \sqrt{(HV_l(x,z,t))^2 + (HH_l(x,z,t))^2} \qquad (19)$$

$$H_s(x,z,t) = \sqrt{(HV_s(x,z,t))^2 + (HH_s(x,z,t))^2} \qquad (20)$$

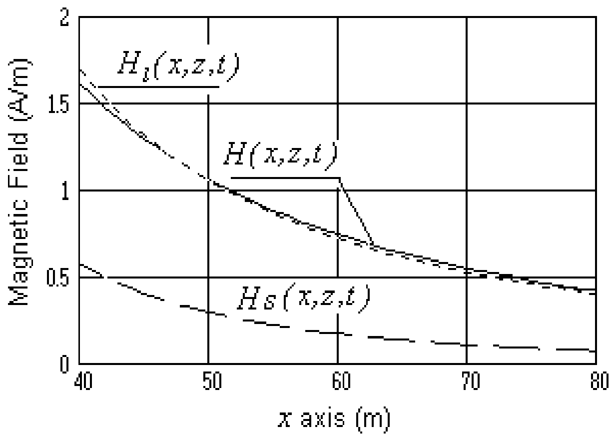
The dependence of *H(x,z,t)*, $H_l(x,z,t)$, and *Hs(x,z,t)* on *x*



coordinate at given z,h,t, I_m, I_{ml} is shown in Fig. 8,9.

Fig.8. Electromagnetic field *H(x,z,t)*, $H_l(x,z,t)$, and *Hs(x,z,t)* (*i(t)=700sinωt A, il(t)=565sinωt A, d=14m, z=-15m, h=7m, t=0).*

Fig.9. Electromagnetic field *H(x,z,t)*, $H_l(x,z,t)$, and



Hs(x,z,t) (*i(t)=700sinωt A, il(t)=565sinωt A, d=14m, z=-15m, h=7m, t=0).*

It is seen that the suppression of EMF of such as three-phase line begins 14m from the center of the line and after 40m obtain 0.5A/m (6mG for air), which is sufficient for practical purposes.

It can be seen, that direct under power line and suppressed loop there is no suppretion, but the sum EMF power line and loop no exceed the EMF , existent up to suppretion.

V. AUTOMATIC SUPPRESSION OF EMF

Suppression of EMF in the wide range of frequency in limited space is based on the well-known method of creating the anti-EMF using three components Helmholtz coils, which are placed around the protected object. This was used for protection of electronic microscope, by a complex method given in [9].

In order to protect the space of much larger size but subject to EMF of industrial frequency only we propose a simple method based on a loop and electronic control device.

The functional scheme for controlling the currents in the loop is shown in Fig. 10.

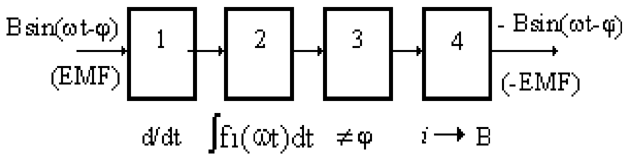


Fig. 10. Functional electronic scheme.

Here: “1” is a one-component electromagnetic probe to which an input EMF in the form of $B\,sin(\omega t - \varphi)$ is applied; “2” is a amplifying integrated element; “3” is a controlled phase shifter element; “4” is a loop which converts current into an electromagnetic field.

This is the automatic control system with negative feedback through electromagnetic field. Magnitude and phase of the loops current controlling automatically (if the loop contains *n* windings, I_{ml} decreases in n times).

VI. CONCLUSIONS

The paper shows how to calculate and actively suppress the electromagnetic field of industrial frequency (EMF), created by power line in a large space. Device for protection from power line contains a loop, placed under the line along the protected area. The results were verified experimentally on models.

VII. REFERENCES

[1] Ernst Habiger, *Electromagnetische Verträglichkeit*, Hüthig Verlag, 1992.

[2] A. Bossavit, “Theoretical approach to the question of biological effects of low frequency field”, *IEEE Trans. Magnetics*, vol. 29, No. 2, March 1993, pp. 1399-1402.

[3] Tekla S. Perry, ”Today's view of magnetic field”, *IEEE Spectrum*, December 1994, pp. 14-23.

[4] The Institution of Electrical Engineers, ”The Possible Biological Effects of Low-frequency Electromagnetic Field”, Supplement to the Public Affairs Board Report No 10, IEE, Sovoy Place, London WC2R OBL, June 1994.

[5] W. T. Kaune, L. E. Zafanella “Analysis of magnetic fields produced far from electric power

[6] A. Geri, ”Magnetic fields generated by power lines”, *IEEE Trans. Magnetics*, vol. 31 No. 3, May 1995, pp. 1508-1511.

[7] A. Beltzer, A. Schenkman, N. Sonkin,” A system of active protection from hazards of industrial frequency electro-magnetic field”, *Abstract records of the 1999 International Conference on Electric Power Engineering PowerTech`99*, pp. 58, August 29-September 2, Budapest.

[8] John D. Kraus, *Electromagnetic*, International student edition, fourth edition, McGraw-Hill Book Co., 1992.

[9] US Patent Number 5,465,012, Nov. 7, 1995. C. Dunnam “Active feedback system for suppression of alternating magnetic field”.