Calculation of the Electrical Component of the Underground Stretched Communication Field

Petro Drabych, Petro Dub, Vitalij Nichoga, Eugeniusz Grudziński, Ihor Yavors'kyi

***Abstract* — Character of overground changes of the electrical component of the electromagnetic field of a stretched underground metallic communication in the shape of the infinitely long linear wire which is situated under ground with taking into account the parameters of ground and air is considered.**

I. Introduction

Continuous growth of new objects of power engineering, various branches of industry and agriculture leads to increase of number and concentration of stretched underground communications (new cables, pipes, telecommunications), that guarantee communication and power supply. More accurate information about such communication situation and technical state inspection (in particular, determination of insulation covering damages and investigation of corrosion processes) is a condition of their effective usage and trouble-free operation.

Electromagnetic methods, based on the measurement of some parameters of the electromagnetic field caused by the alternating current that flows along the axis of a underground communication and is introduced there by special generators or by a station of cathodic protection, is now the most effective method for solution of the mentioned problems [1-3].

Existent electromagnetic searching-measuring systems, that use more effective non-contact methods, measure, as a rule, only the magnetic component of the electromagnetic field radiated by a communication [1-3]. And the electrical component, which has some additional information about an investigated object, is measured now only in contact methods. Thus problems of determination, investigation and usage of new informative characteristics of electrical component of underground communications electromagnetic fields are, without doubt, very actual (especially, elaboration of non-contact methods of electrical field measurement).

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2. The Expression for Calculation of Electrical Field in the Air

In the report the problem of determination of the electrical component of electromagnetic field of a metallic underground communication which model is represented as a stretched conductor (wire) with taking into account presence of boundary between two mediums (ground and air in our case) is considered according to methods described in [4-6].

The considered model of a communication is a wire with current *I*, infinite length and infinitesimal thickness (Fig.1) situated in ground at a depth *h*.

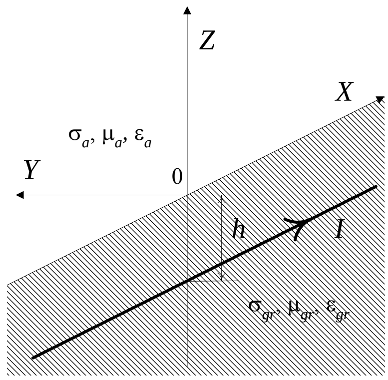

Fig.1. An infinite wire with sinusoidal current in ground

It is shown in [5] that vector-potential A in this case has only *X*-component. It satisfies the Helmholtz's equation in the medium without off-site sources (air in our case) if it is equal to

$$A_{Xa} = \frac{I}{2\pi}\int_0^\infty \Big[f_{1a}(\lambda) e^{Z\sqrt{\lambda^2+k_a^2}} + f_{2a}(\lambda) e^{-Z\sqrt{\lambda^2+k_a^2}} \Big] \cos\lambda Y d\lambda , \qquad (1)$$

and in the medium with the off-site source (ground in our case) it must be equal to

$$A_{Xg} = \frac{I}{2\pi}\int_0^\infty \Bigg[\frac{e^{-|h+Z|\sqrt{\lambda^2+k_g^2}}}{\sqrt{\lambda^2+k_g^2}} + f_{1g}(\lambda) e^{Z\sqrt{\lambda^2+k_g^2}} + f_{2g}(\lambda) e^{-Z\sqrt{\lambda^2+k_g^2}} \Bigg] \cos\lambda Y d\lambda , \quad (2)$$

where $k^2 = j\omega\mu\sigma - \omega^2\varepsilon\mu$ is wave number, the first member in (2) appears after usage of Sommerfeld's integral as a representation of McDonald's function which expresses the vector-potential component caused by the wire current.

$f_{1a}(\lambda)$ and $f_{2g}(\lambda)$ must be equal to 0 because of necessity of integral convergence. $f_{2a}(\lambda)$ and $f_{1g}(\lambda)$ must satisfy the boundary conditions

$$A_{X_{a,Z=0}} = A_{X_{g,Z=0}}, \qquad \left(\frac{\partial A_{X_a}}{\partial Z}\right)_{Z=0} = \left(\frac{\partial A_{X_g}}{\partial Z}\right)_{Z=0}. \quad (3)$$

Using Eqs. (1)-(3) we can obtain for air

$$A_{X_a} = \frac{I}{\pi}\int_0^\infty \frac{e^{-h\sqrt{\lambda^2+k_g^2}-Z\sqrt{\lambda^2+k_a^2}}}{\sqrt{\lambda^2+k_g^2}+\sqrt{\lambda^2+k_a^2}}\cos\lambda Y d\lambda \quad (4)$$

and

$$E_{Xa} = -\frac{\dfrac{\partial^2 A_X}{\partial Y} + \dfrac{\partial^2 A_X}{\partial Z}}{\sigma_a + j\omega\varepsilon_a} =$$

$$= -\frac{Ij\omega\mu}{\pi}\int_0^\infty \frac{e^{-h\sqrt{\lambda^2+k_g^2}-Z\sqrt{\lambda^2+k_a^2}}}{\sqrt{\lambda^2+k_g^2}+\sqrt{\lambda^2+k_a^2}}\cos\lambda Y d\lambda. \quad (5)$$

3. Some results of calculation of the electrical field of a stretched underground conductor

Using (5) we carried out calculation that show the level of influence of such parameters as the current frequency, the conductor location depth, the underground measuring point height, conductivity and dielectric permittivity of ground and air on the electrical field value (some examples are given at Figs.1-4). In these calculation were assumed that $Y=0$, I=1 A, $\mu_{a,g}=1$, $\varepsilon_a=1$, $\sigma_a = 2{,}2\cdot 10^{-18}$ S/m.

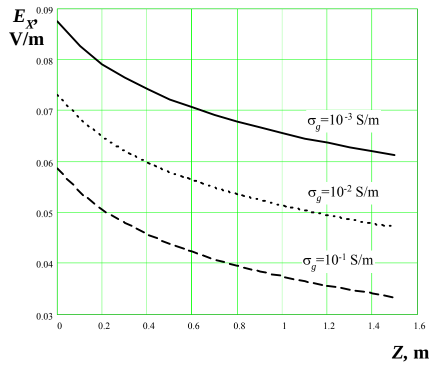

FIG. 2. Field dependency on the height for various values of ground conductivity ($\varepsilon_g = 2$, h=0.2 m, $f = 10^4$ Hz)

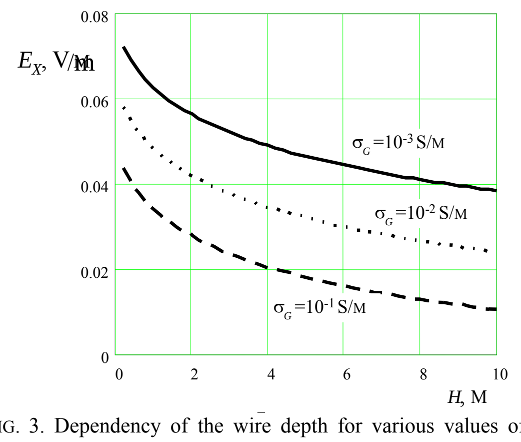

FIG. 3. Dependency of the wire depth for various values of the ground conductivity ($\varepsilon_g = 2$, Z=0.2 m, $f = 10^4$ Hz)

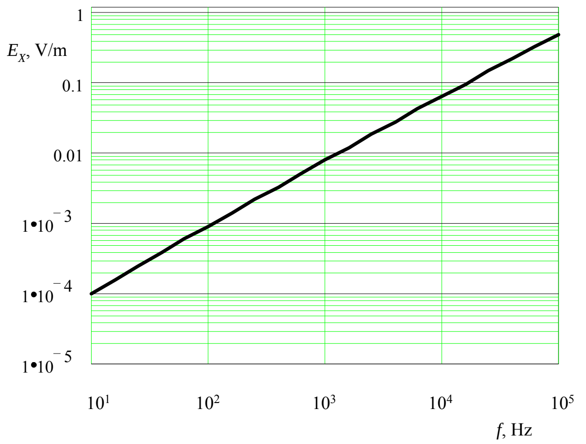

Fig. 4. Field dependency on frequency ($\varepsilon_g = 2$, h=2 m, Z=0.2 m, $\sigma_g = 1\cdot 10^{-3}$ S/m)

4. Conclusions

Using results of calculation of the overground electrical component of the electromagnetic field of a stretched underground metallic communications we can draw a conclusion that non-contact measurement of alternating electrical field for determination of underground conductors location and their currents is very promising. As a perspective we can consider a possibility of estimation of presence of conductor insulation damages that cause appearance of currents in ground that flow non-parallel to a conductor.

Results of calculations show that level of the electrical field of most kinds of stretched underground current-currying communications is sufficient to realize successfully measurements of such fields by usage of electrical antennas (for example, flagpole antennas).

In the future investigations it is necessary to carry out calculation for more complicated models of underground stretched metallic communications, to realize corresponding experimental researches, to determine the frequency range which could be the most appropriate for measurements, to optimize parameters of receiving antennas, to analyze interference and distortions.

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