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A New Approach to Monitoring Low Frequency Electromagnetic Fields

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The article contains the analysis of energy characteristics of low frequency electromagnetic fields; shows the relationship between the value and the direction of active and reactive intensity and the borders of near- and far-field zones, and distance to the source of radiation. It also shows in theory the possibility to determine the integrated intensity of the low frequency electromagnetic field. A measuring device was developed, and experiments on examination of the active intensity in the near-field zone of an electromagnetic field source were carried out. The article suggests a new approach to monitoring low frequency electromagnetic fields based on determination of energy characteristics, which will allow to estimate overall spatial distribution of energy, total energy impact, and also to develop the most effective methods of protection.

Key words: low frequency electromagnetic field, monitoring, energy parameters, integrated intensity, active intensity, reactive intensity, near-field zone, cross spectrum.

The negative impact of low frequency electromagnetic fields on humans, the environment, and territories intended for building is a generally known fact[1-8]. The main sources of low frequency electromagnetic fields (EMF) in urban environment are power lines, power transformer substations, distributive points of the power supply system, overhead electric systems, traffic, power grid for electric transport etc. Currently, low frequency EMF are monitored only by measuring of crest values of the electrical and magnetic field intensity at various distances from the source of radiation, which does not represent the overall energy pattern of EMF and allow to size up its harmful effect objectively.

Considering the similarity of wave processes that occur in a sound and electromagnetic field and having certain experience in this area of knowledge[9-11], the authors believe that at electromagnetic monitoring, it is necessary to switch from measuring the crest values of the electrical and magnetic fields intensity to energy characteristics of EMF.

In the near-field zone of EMF, two processes that are qualitatively different in energetic terms take place. The first process is the process of periodic energy exchange between the energy source and the near-field zone (the reactive intensity I_i). Energy is either taken from the source and accumulated in the near-field zone electromagnetic field or is directed back to the source.

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The second process is the process of energy radiation (the active intensity I_a). It describes the wave process in the near-field zone. The radiated energy has a rather small value in comparison with the energy periodically accumulated in the electromagnetic field of the near-field zone and then directed to the power supply[12].

As well as in the general theory of wave processes, there is a concept of the integrated intensity in the electromagnetic field theory, which includes the active and reactive components:

$$\vec{I}_k = \vec{I}_a + i\vec{I}_i \qquad ...(1)$$

where $\vec{I}_a$ is the vector of the active intensity of EMF, w/m²;

is the vector of the reactive intensity of EMF, w/m².

Determination of the EMF energy performance (integrated intensity) will allow gaining a new strong effect of monitoring – electromagnetic energy spatial directional distribution.

Components of the integrated intensity vector can be determined as follows: at a certain point of space, the mutually transverse vectors E and H as well as the temporal shift $\Delta\varphi_{EH}$ between them are measured. Based on these data, the active I_a and reactive I_i intensity of EMF is calculated:

$$I_a = E \,.\, H \,.\, \cos\Delta\varphi_{EH} \qquad ...(2)$$

$$I_i = E \,.\, H \,.\, \sin\Delta\varphi_{EH} \qquad ...(3)$$

If the ratio is equal to 0, a far-field EMF zone is present. If the ratio is not equal to 0, it is a near-field zone.

Determination of the active intensity of EMF allows determining the direction to the radiation source.

With several sources of EMF radiation present in the near-field zone, their identification using only one active intensity is more difficult. In this case, reactive intensity is especially useful, as it originates from the area of the maximum stream of electromagnetic energy or from sources of radiation if measuring is made in their proximity.

Distance to radiation source R is calculated by the formula:

$$R = \frac{I_a}{I_i} k, \qquad ..(4)$$

where k=2hπ/λ is the wave number;
λ is the wave length, m;
I_a is the active intensity of EMF W/m²;
I_i is the reactive intensity of EMF W/m² .

Also, integrated intensity can be determined by means of the cross spectrum function, which spectrum is computed by multiplication of one spectrum by the complex conjugation of the second spectrum.

The cross spectrum is a complex value. The cross spectrum amplitude characterizes the total energy of EMF in the given point, and the phase is a difference of phases between the intensity of the electrical field and the intensity of the magnetic field[13].

Thus, the integrated intensity of EMF is equal to:

$$I_k = E \cdot H^* = (|E| \cdot \cos\varphi_1 + i|E| \cdot \sin\varphi_1) \cdot (|H| \cdot \cos\varphi_2 - i|H| \cdot \sin\varphi_2 = |E| \cdot |H| \cdot (\cos(\varphi_1 - \varphi_2) + i \cdot |E| \cdot |H| \cdot \sin(\varphi_1 - \varphi_2)), \qquad ...(5)$$

where E is the electric field intensity, V/m;
$\vec{I}_i$ H is the magnetic field intensity, A/m;
H* is the complex conjugate value of the magnetic field intensity, A/m.

At time averaging (for a period), the reactive intensity is converted to zero, and there remains only the active intensity, which can be measured.

For determination of the reactive intensity, is added to the initial phase of the electric field intensity and its value is gained at the spectrum analyzer's output:

$$R_e[I_{\varphi e}+90°]=Re[(I_a+i \cdot I_i)e^{-i\pi/2} = Re[-i \cdot I_a+I_i]=I_i \qquad ...(6)$$

where is I_a the active intensity of EMF, W/m² ;
I_i is the reactive intensity of EMF, W/m²;
φ_e is the electric field intensity initial phase, grad.

Thus, in any point of the low frequency EMF, it is possible to find the integrated intensity – the energy parameter of EMF.

The authors carried out experimental measuring of the active intensity of the low frequency EMF. A measuring system was developed, which consisted of the Pb-70 and Pb-71 measuring antennas, an Octaphone, a sound card, and also a two-channel spectrum analyzer (SpectralLAB).

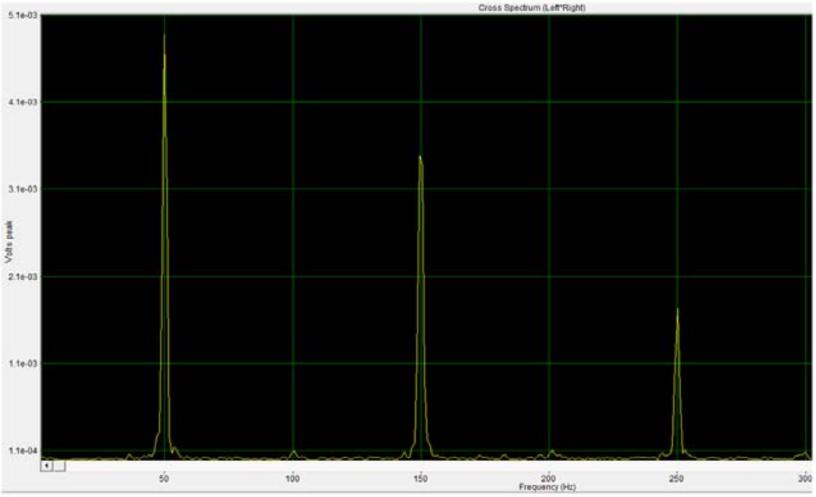

Fig. 1. Spectrum of active intensity of the low frequency EMF in the short-field zone of the radiation source

At conducting intensity measuring in the proximity of a power supply cable, which was the source of power-line frequency EMF radiation, simultaneously the levels of electrical and magnetic fields intensity were measured, and, after that, the signal conversed by means of the sound card was transmitted to the spectrum analyzer, and the active intensity was found in relative units. Thus, the angle between antennas made 90 degrees; the Pb-70 antenna measuring the magnetic field intensity was positioned parallel to the electrical wire; and the Pb-71 antenna measuring the electric field intensity was positioned transversely to it. The experiment resulted in gaining the spectrum of active intensity of the low frequency EMF in the near-field zone of the radiation source (Figure 1).

The direction of the active intensity vector at the 50 Hz frequency evidences that energy comes from the electrical wire (the source of EMF radiation).

Monitoring low frequency electromagnetic fields on the principally new basis (switch from measuring of amplitude characteristics to determination of energy parameters of EMF) will allow evaluating the energy directional distribution pattern and developing the most effective methods of protection.

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