THE ACCURACY OF DETERMINING OF THE ZONES OF RESTRICTED USE OF TERRITORIES ALONG THE TRANSMISSION LINES TAKING INTO ACCOUNT THE MAGNETIC FIELD INFLUENCE

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Abstract
The article highlights the issue of accuracy of determining of the zones of restricted use of the territories along the transmission lines taking into account the magnetic field influence around the wires of transmission line during the passage of electric current. The procedure of establishing of such zones near transmission lines requires a clear substantiation of limits of physical parameters of the electric and magnetic fields` influence of transmission lines on human resources and environment that leads to the establishment of scientifically based boundaries of safe and rational management of land use.
The authors` task was the substantiation of a mathematical expression that describes the relationship between the accuracy of determining the radius of dissemination of the magnetic field along the transmission lines and physical parameters of the magnetic field.
As a result of the conducted research the formulas for determining the standard deviation (SD) of the radius of dissemination of the magnetic field were presented taking into account the value of magnetic induction, capacity, voltage and amperage that were inherent to the particular transmission line.
Keywords: zone of restricted use, electrical transmission line (ETL), magnetic field.

Introduction
Due to the negative impact of electric and magnetic fields of transmission lines (TL) and difficulties in their exploitation, the territories of restricted use are established along the objects of TL. One of the major problems that needs solving is substantiation of the sizes and accuracy of determining the zones of restricted use of the territories to ensure normal conditions of their exploitation, to prevent the injuries and to reduce their negative impact on people, environment, adjacent lands and other natural objects. Cadastral land zoning within the influence of electrical networks is based on geodetic support. It is necessary to envisage the possibility of application of the geodetic surveying methods that are sufficiently providing the requirements for the accuracy of determining the zones of restricted use of the territories and safe conducting of the works in zones of influence of transmission lines.
Many studies of modern scientific world are devoted to the problem of the influence of electrical networks on the environment and, in particular, on human and land resources. In the works of the group of European experts (Jack M. Lee, 1989), (Mileusnic, 2006), (Elschenbroich, 1996), (Bundesamtes fur Strahlenschutz, 2010) fundamental research was conducted on the influence of electric and magnetic fields of transmission lines on the environment. However, the question about the accuracy of determining the zones of restricted use of the territories along the transmission lines taking into account the influence of magnetic field remains open.

Methodology of research and materials
The methods of analysis and synthesis were used during the research. Studies that have been conducted during the last years in this field (Perovych, Tkachyk, 2011), (Bundesamtes fur Strahlenschutz, 2010), (Gaida, 2011) as well as mathematical and physical laws as the basis for the substantiation of the formula of mean square error of the radius of dissemination of magnetic field along the transmission lines were used as initial data.

Discussions and results
The research (Perovych, Tkachyk, 2011) conducted in 2011 showed that during the installing of zones of restricted use of the territories along the transmission lines the influence of magnetic and electric fields that arise in the wires due to the passage of electric current should be taken into account. At the same time, it was found that the permissible value of the magnetic field has significantly greater influence during the determining the limiting distances of the zones of restricted use of the territories along the transmission lines than electric, when it comes to safety of population. And that is why it is

necessary to pay more attention to the influence of the magnetic field during the formation of the boundaries of the territories of restricted use.
The zone of dissemination of magnetic field depends largely on:

- structural and operational parameters of electrical networks;
- amperage which are flowing through the wires;
- the number of wires and their spatial arrangement;
- sagging of overhead transmission lines and depth of underground cables;
- mutual arrangement of phase wires and current asymmetry;
- proximity arrangement of elements of electrical networks;
- climatic conditions.

One of the basic physical parameters characterizing the magnetic field is the magnetic induction, the value of which can be determined by the expression (Bundesamtes fur Strahlenschutz, 2010):

$$B = \frac{\mu_0}{2\pi} \cdot \frac{I}{r} \qquad (1)$$

Where:

B - magnetic induction, T;
I - the current in the wire, A;
r - the distance to the wire, m;
$\mu_0 = 4\pi \cdot 10^{-7}$ - magnetic constant, T * m / A.

From the formula (1) we can find the possible radius of dissemination of the magnetic field around the wire depending on the available value of magnetic induction:

$$r = \frac{\mu_0}{2\pi} \cdot \frac{I}{B} \qquad (2)$$

The value of the amperage can be determined by knowing the value of natural capacity for transmission lines of appropriate voltage. For transmission lines of alternating current as a practical interest is an average over periods value of capacity (Gaida, 2011):

$$P_c = \frac{1}{2} \cdot U \cdot I_c \text{ , або } I_c = \frac{2 \cdot P_c}{U} \qquad (3)$$

Where:

I_c - operating value of amperage, A;
P_c – the capacity of transmission line, Watts;
U – the intensity of electrical grid, V.

Taking into account (3), formula (2) will be rewritten as:

$$r = \frac{\mu_0}{\pi} \cdot \frac{P_c}{B \cdot U} \qquad (4)$$

The radius of magnetic field dissemination characterizes the zone of restricted use in the form of a cylindrical space, the axis of which is the outer wire of ETL. The zone of restricted use is a part of the territory of the land which boundaries are defined from the projection of the wire to the ground in the perpendicular to the electric line direction, and therefore we take into account the dissemination of the magnetic field of ETL on the earth`s surface (Fig.1).

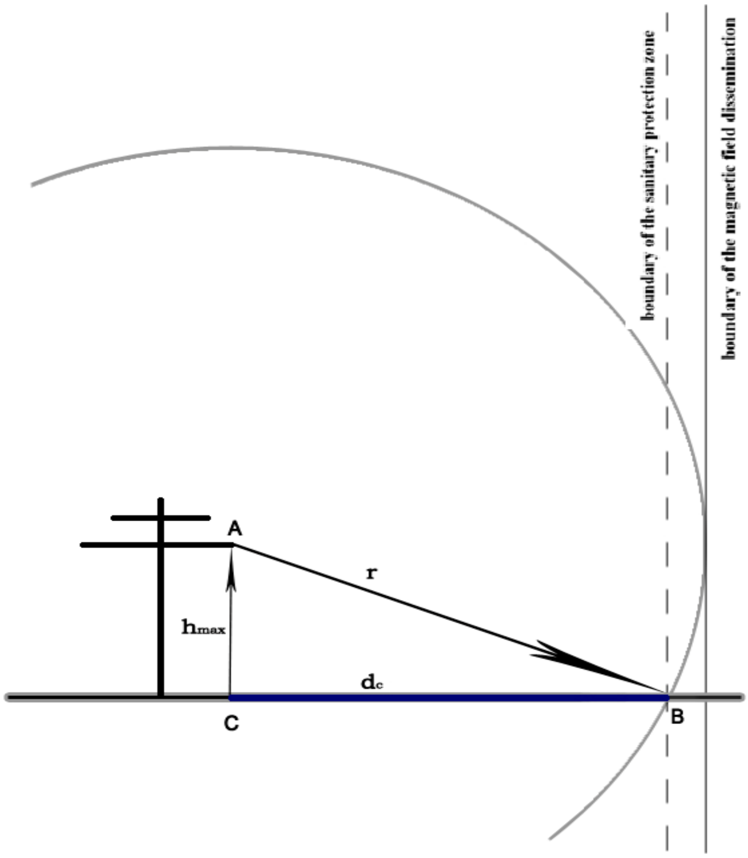

Fig. 1. Determination of zone of restricted use along the ETL

In Fig. 1 the triangle ABC displays: A - the point of outer wire; B - an intersection of the radius of the magnetic field dissemination with the physical surface of the earth; C - the projection of the outer wire (p.B) on the physical surface of the earth; segment AC = h_{max} - the height of the outer wire; AB = r - the radius of magnetic field dissemination; BC - the width of sanitary protection zone.
Thus, the boundaries of sanitary protection zone can be defined by the formula:

$$d_c = \sqrt{r^2 - h_{\max}{}^2} \tag{5}$$

Where
- d_c – the width of sanitary protection zone, m;
- r – the radius of the magnetic field dissemination, m;
- h_{max} - the height of the outer wire above the ground, m.

Geodetic support of the establishment of zones of restricted use of the territories on the terrain includes two main aspects: the accuracy of determining the boundaries of the zones of restricted use and safe conducting of geodetic works in these zones.
From the formula (5) we can determine the accuracy of the width of the zone of restricted use taking into account the magnetic field dissemination:

$$m_d^2 = \frac{1}{d_c^2}\left(r^2 m_r^2 + h^2 m_h^2\right) \tag{6}$$

Where
- m_d - mean square error of the width of the zone of restricted use, m;
- d_c – the width of the zone of restricted use, m;
- r – the radius of the magnetic field dissemination along the ETL, m;
- h - the height of the outer wire of ETL above the ground, m;
- m_h – the accuracy of determining the height of the outer wire, m;
- m_r – the accuracy of determining the radius of the magnetic field dissemination, m.

The formula for calculating the mean square error of the radius of the magnetic field dissemination for the function (4) will be as follows:

$$m_r^2 = \left(\frac{\partial r}{\partial P_c}\right)^2 m_{P_c}^2 + \left(\frac{\partial r}{\partial B}\right)^2 m_B^2 + \left(\frac{\partial r}{\partial U}\right)^2 m_U^2 \quad (7)$$

Where

r – the radius of magnetic field dissemination, m;

P_c – the capacity of transmission line, MW;

B - magnetic induction, μT;

U – the intensity of electrical grid, kV;

$\frac{\partial r}{\partial P_c}$, $\frac{\partial r}{\partial B}$, $\frac{\partial r}{\partial U}$ – the partial derivatives from the function (4) for variables P_c, B, U;

m_{Pc}, m_B, m_U– the accuracy of determining the function`s (4) variables P_c, B, U.

The calculation of partial derivatives is disclosed in the formulas (8) - (10).

$$\left(\frac{\partial r}{\partial P_c}\right)^2 = \left(\frac{\mu_0}{\pi} \cdot \frac{1}{B \cdot U}\right)^2 = r^2 \cdot \frac{1}{P_c^2}; \quad (8)$$

$$\left(\frac{\partial r}{\partial B}\right)^2 = \left(-\frac{\mu_0}{\pi} \cdot \frac{P_c}{B^2 \cdot U}\right)^2 = r^2 \cdot \frac{1}{B^2}; \quad (9)$$

$$\left(\frac{\partial r}{\partial U}\right)^2 = \left(-\frac{\mu_0}{\pi} \cdot \frac{P_c}{B \cdot U^2}\right)^2 = r^2 \cdot \frac{1}{U^2}; \quad (10)$$

Thus, the formula for calculating the mean square error of determining the radius of magnetic field dissemination can be written as an expression:

$$m_r^2 = r^2 \left(\frac{1}{P_c^2} m_{P_c}^2 + \frac{1}{B^2} m_B^2 + \frac{1}{U^2} m_U^2 \right), \quad (11)$$

If among the available data on the magnetic field parameters there are the value of current in the wire and the value of magnetic induction, as described in formula (2), then the formula for calculating the mean square error of determining the radius of magnetic field dissemination will be as follows:

$$m_r^2 = r^2 \left(\frac{1}{I^2} m_I^2 + \frac{1}{B^2} m_B^2 \right), \quad (12)$$

In order to achieve the specified accuracy of determining of the coordinates of zones of restricted use of the territories along the transmission lines we can use as terrestrial and aerial geodetic methods and means of surveying.

Conclusions and proposals

As a result of conducted research on the issue of accuracy of determining the zones of restricted use of the territories along the transmission lines a methodical approach is proposed on the basis of consideration of the errors of dissemination of the magnetic field, which can be characterized by different physical parameters.

Depending on the physical values that are inherent to the proposed magnetic field two mathematical expressions that solve this problem are received. In the first case, the mean square error of the radius of magnetic field dissemination and, thus, the mean square error of the width of zone of restricted use of the territories can be defined taking into account magnetic induction, capacity of electrical grid and

voltage, and in the second case, it can be defined taking into account a function of magnetic induction and amperage in the wires.
These mathematical expressions should be used in the cadastral zoning of lands located in the zone of influence of transmission lines as well as in geodetic surveying of electrical grids.

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