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Determination of the Magnetic Field Strength of the Two-chain High-voltage Overhead Power Transmission Line For the Distance of Projection of the Outermost Wire

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Abstract. The difficulty in researching the impact of high-voltage overhead power lines on human health lies in the fact that, unlike the impact of an electric field, a person cannot feel the effect of a magnetic field. In this regard, all conducted studies will be reduced to the consideration of the probable mechanism of magnetic field influence. At the same time, the impact of the magnetic field on a person has a cumulative character, that is, changes in the human body do not occur instantly, but accumulate over time and can manifest themselves in subsequent generations.

Keywords: electromagnetic field; high voltage; inductance; magnetic field tension; power transmission line.

Introduction

For several decades, there has been a worldwide discussion about the impact of industrial frequency magnetic fields on human health. In various technical literature, scientists and specialists have expressed two diametrically opposed points of view on this issue. According to some authors, there are marginally permissible values of the magnetic field strength that do not affect human health, and there is no need to revise them. In addition, various periodicals have reported an increased risk of oncological diseases, namely, leukemia in children during prolonged exposure of the source of the magnetic field of a high-voltage power transmission line. According to other authors, the existing standards are too high or insufficient to assess the degree of influence on the

human body. These contradictions arise as a result of the absence of a complex medical-biological study of the impact of the magnetic field on the human body.

Main Part

The document according to which the impact of electromagnetic fields, created by industrial frequency overhead power transmission lines on the human body is regulated in the republics of the former Soviet Union, is the "Sanitary Norms and Rules", issued in 2005 [1]. According to this document, the maximum allowable value of the magnetic field strength inside the building is 4 A/m, at the maximum allowable value of the magnetic field induction 5 μT, and 8 A/m (10 μT) in the populated area. The limited values of the magnetic field induction of 0.2-0.3 μT (0.16-0.24 A/m) are recommended as safe for human health by International Agency for Research on Cancer (IARC) and World Health Organization (WHO).

One of the strongest sources of industrial frequency magnetic fields are high voltage power transmission lines. In this regard, the purpose of the present (ed) work is to determine the magnetic field strength of the two-chain high-voltage overhead power transmission line, and to determine the distance from the projection of the outermost wire of the line, in which the limited values of the magnetic field induction, recommended by World Health Organization are satisfied.

For example, consider the strength of the magnetic field created by a two-chain 220 kV overhead power transmission line, when the load on both chains is the same (Fig. 1).

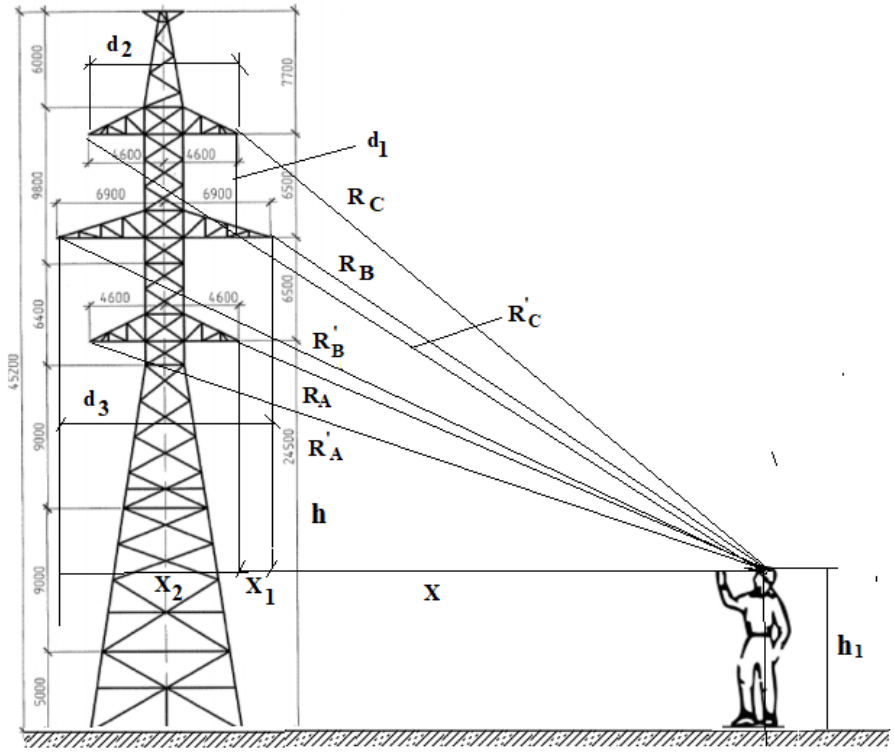

Fig. 1. Scheme for calculation of the magnetic field strength of two-chain overhead power transmission line

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To calculate the magnetic field strength, we use the full current law [2].

According to the full current law, the magnetic field strength for a single infinite conductor is expressed in the complex form as follows:

$$\dot{H} = \frac{\dot{I}}{2\pi R} \quad (1)$$

According to the superposition principle, for a two-chain power transmission line we write:

$$\dot{H} = \frac{\dot{I}_A}{2\pi}\left(\frac{1}{R_A}+\frac{1}{R'_A}\right)+\frac{\dot{I}_B}{2\pi}\left(\frac{1}{R_B}+\frac{1}{R'_B}\right)+ \frac{\dot{I}_C}{2\pi}\left(\frac{1}{R_C}+\frac{1}{R'_C}\right) \quad (2)$$

where $\dot{I}_A$, $\dot{I}_B$, $\dot{I}_C$ are the complex values of the linear currents in the chains, R_A, R_B, R_C, R'_A, R'_B , R'_C are the distances from the observation point to the corresponding lines.

Let's assume that the load in both lines is symmetrical and the sequence of phases is the same, then for the complex values of the currents we write:

$$\begin{cases} \dot{I}_A = I_b \\ \dot{I}_B = I_b e^{-j120^0} \\ \dot{I}_C = I_b e^{j120^0} \end{cases} \quad (3)$$

After substituting the values of the linear currents from the expression (3) into (2), the formula for calculation the magnetic field strength will be the following:

$$\dot{H} = \frac{\dot{I}_b}{2\pi}\left(\frac{1}{R_A}+\frac{1}{R'_A}\right)+\frac{\dot{I}_b e^{-j120^0}}{2\pi}\left(\frac{1}{R_B}+\frac{1}{R'_B}\right) + \frac{\dot{I}_b e^{j120^0}}{2\pi}\left(\frac{1}{R_C}+\frac{1}{R'_C}\right) = \frac{I_b}{2\pi}\times$$
$$\times\left[\left(\frac{1}{R_A}+\frac{1}{R'_A}\right)+e^{-j120^0}\left(\frac{1}{R_B}+\frac{1}{R'_B}\right)+e^{j120^0}\left(\frac{1}{R_C}+\frac{1}{R'_C}\right)\right] \quad (4)$$

where the distance of a person from overhead power transmission lines for this case is calculated by the formulas:

$$R_A = \sqrt{(X+X_1)^2+(h-h_1)^2};$$
$$R_B = \sqrt{X^2+(h+d_1-h_1)^2};$$
$$R_C = \sqrt{(X+X_2)^2+(h+2d_1-h_1)^2}$$
$$R'_A = \sqrt{(X+X_1+d_2)^2+(h-h_1)^2};$$
$$R'_B = \sqrt{(X+d_3)^2+(h+d_1-h_1)^2}$$
$$R'_C = \sqrt{(X+X_1+d_2)^2+(h+2d_1-h_1)^2} \quad (5).$$

Since the permissible values of both magnetic field strength and magnetic field induction are given in the sanitary-epidemiological normative documents, let us calculate at first for the magnetic field strength and then the magnetic field induction for a specific example using the following formula:

$$B = 1.25\ H,\ \mu T.$$

Define the values of the magnetic field strength and inductance of the high-voltage overhead power transmission line in the real mode of operation. Fig. 1 shows two-chain intermediate mast of type У220-2m+14 type 220 kV. Vertical distance between wires d1= 6.5 m.; maximum distance between wires d3 = 13.8 m; minimum distance between wires d2 = 9.2 m; X1= 2.3 m; h = 24.5 m; The brand of the wire is AC-400/51, the long-term permissible current of which is $I_{per.}$ = 825 A. Let's do calculation for the case when the wires on the above-mentioned supports are separated from the earth's surface at the height of h = 8.0 m. This height was taken based on the fact that according to table 2.5.22 of the rules for the arrangement of electrical installations (ПУЭ 7) in populated areas, the minimum distance of the cable of the 220 kV overhead power transmission line from the surface of the earth is allowed to be 8.0 m.

The results of the calculation of magnetic field strength are presented in the Table 1.

Table 1.

X, m	0	5	10	15	20	25	30	35	40	45	50
H, A/m	15,46	8,3	3,84	2,0	1,52	0,76	0,58	0,46	0,35	0,26	0,22
B, μT	19,32	10,37	4,8	2,5	1,9	0,95	0,727	0,575	0,44	0,325	0,275

Table 1.

continuation

X, m	55	60	65	70	75	80	85	90	95	100
H, A/m	0,16	0,14	0,10	0,09	0,065	0,047	0,037	0,019	0,019	0,019
B, μT	0,20	0,175	0,125	0,11	0,082	0,058	0,046	0,024	0,024	0,024

Conclusion

It is determined by calculation that for the case of the two-chain 220 kV overhead power transmission line supports of the type У220-2m+14 the limited values of the safe magnetic field induction - (0.2-0.3 μT), established by the International Agency for Research on Cancer (IARC) and recommended by the World Health Organization (WHO) take place only in the case when the outermost wire of the two-chain 220 kV overhead power transmission line is located at the distance of more than 50 m from the planned one on the earth.

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