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THE INVESTIGATION OF DISTRIBUTION OF THE MAGNETIC FLUX DENSITY OF OPERATING TWO-CIRCUIT POWER LINE 110 kV «CHTPP-CHERNIHIV-330» IN THE RESIDENTIAL AREA AND METHODS OF ITS DECREASING TO A SAFE LEVEL

Purpose. The problem of evaluation and analysis of magnetic flux density of overhead power lines is very relevant now, since the magnetic field of industrial frequency can have a negative effect on human health. The analysis of the magnetic field of the operating double-circuit overhead transmission line was made in this work. This overhead line is in the residential area of Chernihiv, Ukraine. The purpose of this work is to determine safe habitation conditions as a function of the magnetic flux density along the route of two-circuit power line with the voltage 110 kV «ChTPP-Chernihiv-330». Real modes of operation are taken into account. Recommendations are given for reducing the magnetic flux density level in the residential area to a value that will not exceed the standard value. Methodology. Methods of electromagnetic field theory were used to calculate the magnetic field of power lines. The location of the phase wires on different types of supports of the existing power transmission line and the minimum distance between the conductors and the ground were taken into account. The current value of the current in the phases of the transmission line was taken from the Company «Chernihivoblenergo». Also, the calculation of the magnetic flux density was made for the perspective loads of the transmission line. Estimation of the value of the magnetic flux density was made for the zone of one-story and multi-story buildings near power lines. The option of uniform loading of two power transmission lines was considered and the case where the entire load is transferred along one circuit was also considered. Results. In this work, the distribution of magnetic flux density at a height of 1.8 m in the direction perpendicular to the power transmission line for the sections built on supports of the U110-2 and PB110-2 types was obtained. The graphs show that the magnitude of the magnetic flux density at the boundary of the protection zone of the transmission line will be exceed twice the standard value 0.5 μT for the existing and perspective loads. This problem is relevant in the case of transmission lines in single-circuit mode. The graphs of distribution of magnetic flux density on the facade of an apartment building, located at a distance of 20 m from the axis of symmetry of the transmission line, were constructed. As a result, it is shown that at a height of 11 m from the earth's surface, magnetic flux density will be 1.5-2 μT. Practical value. It is determined that safe habitation along the route of two-circuit power line with the voltage 110 kV «ChTPP-Chernihiv-330» can be achieved when facades of an apartment building are removed from the axis of symmetry of the transmission line at a distance of 33 m for high-rise buildings and at a distance of 27 m for one-storey buildings. Recommendations for reducing the magnetic flux density of this power transmission line have been developed. References 16, figures 19.

Key words: **overhead transmission line, electric loads, magnetic flux density, residential building.**

За існуючих та перспективних електричних навантаженнях досліджено рівень магнітного поля двоколової повітряної ЛЕП напругою 110 kV «ЧТЕЦ – Чернігівська-330», яка проходить по території одноповерхової та багатоповерхової забудови у м. Чернігів. Показано, що індукція магнітного поля в зоні забудови та на межі охоронної зони може перевищувати безпечний для людини рівень, особливо у випадку роботи ЛЕП у одноколовому режимі. Визначено безпечні умови для проживання населення поблизу даної ЛЕП, зокрема, безпечну відстань від осі траси ЛЕП до місць розташування одноповерхових та багатоповерхових будинків. Показано, що застосування векторної компенсації дозволяє досягти значного зменшення рівня магнітного поля. Бібл. 16, рис. 19.

Ключові слова: **повітряна ЛЕП, електричні навантаження, індукція магнітного поля, житлова забудова.**

При существующих и перспективных электрических нагрузках исследовано уровень магнитного поля двухцепной воздушной ЛЭП напряжением 110 kV «ЧТЕЦ – Черниговская-330», которая проходит по территории одноэтажной и многоэтажной застройки в г. Чернигов. Показано, что индукция магнитного поля в зоне застройки и на границе охранной зоны может превышать безопасный для человека уровень, особенно в случае работы ЛЭП в одноцепном режиме. Определены безопасные условия для проживания населения вблизи данной ЛЭП, в частности, безопасное расстояние от оси трассы ЛЭП до мест размещения одноэтажных и многоэтажных домов. Показано, что применение векторной компенсации позволяет достичь значительного уменьшения уровня магнитного поля. Библ. 16, рис. 19.

Ключевые слова: **воздушная ЛЭП, электрические нагрузки, индукция магнитного поля, жилая застройка.**

Introduction. Recently, more and more attention is paid to the impact of magnetic fields on humans. One of the powerful sources of magnetic field of power frequency is overhead power lines, near which can be located residential buildings or offices. People who permanently live or work near power lines are in the area of the magnetic field influence. In developed countries, such as the United States, Canada, France, Sweden and others there are rather strict restrictions on the level of magnetic flux density of power frequency, it is constantly monitored in buildings and outdoors near overhead and cable power lines, on the territory of substations and outside them. There are a number of medical studies that show that the magnetic field acts on living organisms at the cellular level, and it is noted that prolonged exposure to even a weak magnetic field over time leads to a variety of health problems [1]. Thus, according to the recommendations of the World Health Organization, the level of magnetic flux density of 0.2-0.4 μT is acceptable for long-term exposure to the population.

Much attention is paid around the world to the problem of reducing the level of the magnetic field [2, 3] to minimize its impact on the environment. It should be noted that in Ukraine the problem of normalization of the magnetic field level has not been finally resolved since Electrical Installation Regulations [4] contains a norm only for the magnetic field of cable lines, which is 0.5 μT inside the premises. In [5], the problem of calculating the induced losses in overhead power lines is considered and it is shown that the reduction of the magnetic field also leads to an increase in the efficiency of electric energy transmission.

The problem of reducing the magnetic field becomes especially relevant in the conditions of increasing electric loads. In large cities, new neighborhoods are constantly being built, entire neighborhoods and residential complexes with multi-storey and single-storey buildings are being built, with appropriate infrastructure – shopping and entertainment complexes, commercial and communal enterprises, industrial enterprises, etc. As a result, the load on existing overhead power lines, which supply power to such cities and individual areas, is increasing. For example, in the city of Chernihiv in the last 15 years there is an active construction of new residential areas, such as Masany and N. Podusivka. These areas are supplied through substations connected to the existing 110 kV overhead transmission line «Chernihiv Thermal Power Plant (ChTPP) – Chernihiv-330», respectively, the load of this line has increased significantly in recent years and will continue to grow in the future. The above transmission line passes through the residential area which includes multi-storey and single-storey buildings. Therefore, there is a need to determine the safe living conditions of the population of the city of Chernihiv in the area adjacent to the specified transmission line, as well as, if necessary, the choice of methods to reduce the magnetic field to a safe level.

It should be noted that the problem of studying the magnetic field of overhead power lines [6, 7], as well as methods for reducing it, is being actively studied in Ukraine and around the world. For example, in [8, 9] the distribution of magnetic flux density of transmission lines in residential areas in the general case is considered and analyzed. It should be noted that a similar analysis should also be performed for a specific transmission line, taking into account the conditions of its operation, current and future loads, operating modes, distance of residential buildings from the transmission line route and the protection zone boundaries, features of construction in a residential area near transmission line (one-storey, multi-storey), etc.

In order to comply with the conditions of safe living of the population near overhead power lines, it is necessary to assess the distance from the route of the power line, on which one-storey and multi-storey buildings should be located. However, such measures are appropriate at the stage of designing new overhead power lines or when planning the construction of vacant land plots near power lines. But, in cities there is often a situation where the overhead power line already passes in the immediate vicinity of residential buildings, which can be located even in the protection zone of the power line. In this case, with a significant load of the transmission line, it is necessary to apply techniques of reducing the level of the magnetic field in the residential area.

There are a number of methods for reducing the level of the magnetic field of overhead power lines, which are considered in [10, 11]. Among those that can be applied to existing transmission lines, we should highlight the shielding and optimization of the geometry of the suspension of conductors (vector compensation method). The latter method can be quite effective, as noted in [10].

In the case of a two-circuit overhead transmission line, the location of the phases of different circuits on the support is usually chosen to be the same in accordance with Fig. 1.

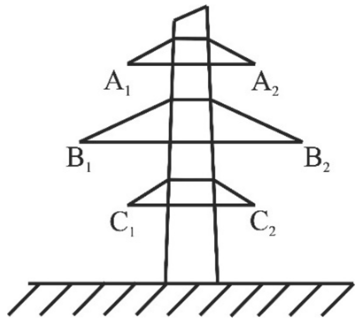


Fig. 1. Typical arrangement of phases of two circuits on the support of the two-circuit overhead transmission line

This phase arrangement option provides the highest level of magnetic field in the space around the transmission line. The most effective in terms of reducing the level of the magnetic field is the location of the phases of the two circuits in mirror symmetry [10], as shown in Fig. 2.

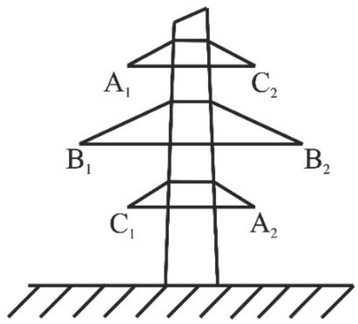


Fig. 2. Mirror arrangement of the phases of two circuits on the support of the two-circuit overhead transmission line

This method of reducing the level of the magnetic field of a two-circuit transmission line is quite easy to be implemented in practice, however, its efficiency for each transmission line may be different depending on the geometry of a particular line.

The goal of the paper is to determine the conditions for safe living of the population at the level of the magnetic field along the route of the two-circuit 110 kV transmission line «ChTPP – Chernihiv-330» taking into account the real modes of its operation and to develop recommendations to reduce the magnetic field of this transmission line o the regulatory level.

The main materials of the study. The calculation of the electric and magnetic fields of overhead and cable transmission lines was performed in accordance with the method [12], which was substantiated in [13].

According to the method [12], for some calculation point $P(x_p, y_p)$ the effective values of the components or spatial components of the magnetic flux density induction vector from the current in each of the phase conductors of the transmission line should be determined by the formulas:

$$B_{xA} = \frac{\mu_0}{2\pi} \cdot \sum_{k=1}^{2} \frac{I_k \cdot (y_p - y_{A\kappa})}{(x_p - x_{A\kappa})^2 + (y_p - y_{A\kappa})^2}; \quad (1)$$

$$B_{xB} = \frac{\mu_0}{2\pi} \cdot \sum_{k=1}^{2} \frac{I_k \cdot (y_p - y_{B\kappa})}{(x_p - x_{B\kappa})^2 + (y_p - y_{B\kappa})^2}; \quad (2)$$

$$B_{xC} = \frac{\mu_0}{2\pi} \cdot \sum_{k=1}^{2} \frac{I_k \cdot (y_p - y_{C\kappa})}{(x_p - x_{C\kappa})^2 + (y_p - y_{C\kappa})^2}; \quad (3)$$

$$B_{yA} = \frac{\mu_0}{2\pi} \cdot \sum_{k=1}^{2} \frac{I_k \cdot (x_p - x_{A\kappa})}{(x_p - x_{A\kappa})^2 + (y_p - y_{A\kappa})^2}; \quad (4)$$

$$B_{yB} = \frac{\mu_0}{2\pi} \cdot \sum_{k=1}^{2} \frac{I_k \cdot (x_p - x_{B\kappa})}{(x_p - x_{B\kappa})^2 + (y_p - y_{B\kappa})^2}; \quad (5)$$

$$B_{yC} = \frac{\mu_0}{2\pi} \cdot \sum_{k=1}^{2} \frac{I_k \cdot (x_p - x_{C\kappa})}{(x_p - x_{C\kappa})^2 + (y_p - y_{C\kappa})^2}; \quad (6)$$

where I_k is the current in the phase of the k-th circuit of the transmission line, A; x_{Ak}, y_{Ak} are the coordinates of the location of phase A of the k-th circuit of the transmission line; x_{Bk}, y_{Bk} are the coordinates of the location of phase B of the k-th circuit of the transmission line; x_{Ck}, y_{Ck} are the coordinates of the location of the phase C of the k-th circuit of the transmission line; μ_0 is the magnetic permeability of vacuum ($4\pi \cdot 10^{-7}$ H/m).

Also in formulas (1)-(6) it is taken into account that the transmission line to be considered is two-circuit.

The effective value of the components or spatial components of the vector of magnetic flux density at the calculation point is found by the expressions:

$$B_x(x_p, y_p) = [B_{xA}{}^2 + B_{xB}{}^2 + B_{xC}{}^2 - B_{xA} \cdot B_{xB} - B_{xB} \cdot B_{xC} - B_{xC} \cdot B_{xA}]^{0.5} \quad (7)$$

$$B_y(x_p, y_p) = [B_{yA}{}^2 + B_{yB}{}^2 + B_{yC}{}^2 - B_{yA} \cdot B_{yB} - B_{yB} \cdot B_{yC} - B_{yC} \cdot B_{yA}]^{0.5} \quad (8)$$

The effective value of the magnetic flux density at the calculation point is found from the expression:

$$B(x_p, y_p) = \sqrt{B_x(x_p, y_p)^2 + B_y(x_p, y_p)^2}. \quad (9)$$

Overhead power lines often pass through areas with dense multi-storey and single-storey buildings, especially in large cities, including the city of Chernihiv. One such example is a two-circuit 110 kV transmission line «ChTPP – Chernihiv-330», the structural diagram of which is shown in Fig. 3.

Some sections of this transmission line in dense residential areas are made on supports type U110-2 and PB110-2. The dimension of this overhead transmission line according to its support scheme is 7.3 m (minimum distance from the lower wire of the transmission line to the ground). All the geometric dimensions necessary for the calculation of the magnetic field of the transmission line are shown in Fig. 4, 5 for sections on supports U110-2 and PB110-2, respectively.

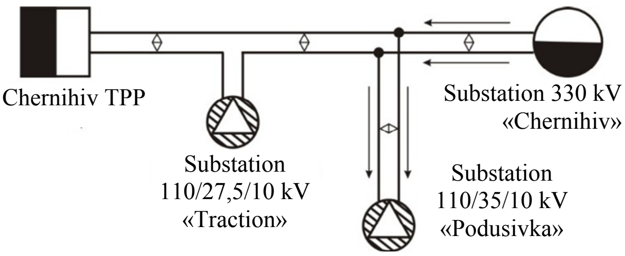


Fig. 3. Structural diagram of the electric network with 110 kV overhead transmission line «ChTPP – Chernihiv-330»

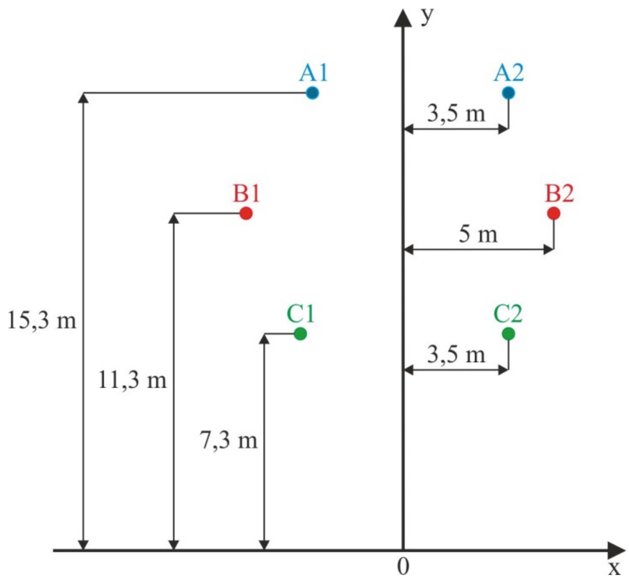


Fig. 4. Geometric model of the section of the 110 kV transmission line «ChTPP – Chernihiv-330» on U110-2 supports

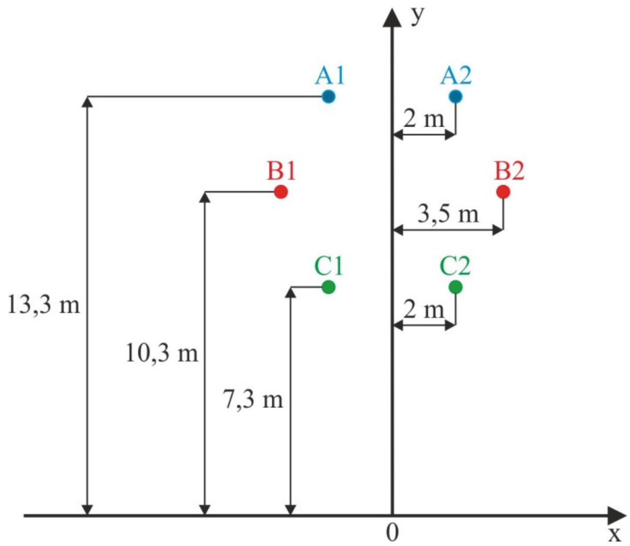
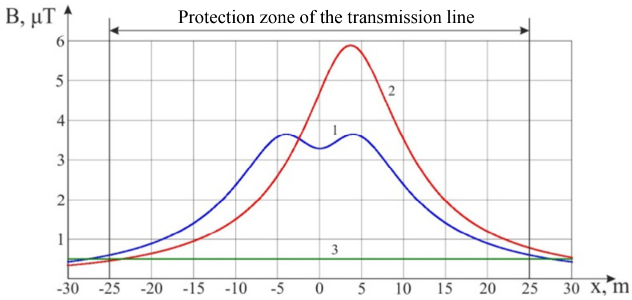


Fig. 5. Geometric model of the section of the 110 kV transmission line «ChTPP – Chernihiv-330» on PB110-2 supports

The calculation of the magnetic field level for the section of the above-mentioned transmission line, made on the supports U110-2, is performed at the level of 1.8 m from the ground surface in the direction perpendicular to the route of the transmission line. According to the data of JSC «Chernihivoblenergo» on electrical loads, the calculation maximum current of one circuit of the 110 kV overhead transmission is about 150 A, which may change insignificantly during the day. In case of repair or emergency shutdown of one circuit, the second circuit will take over the entire load – about 300 A.

The results of the calculation of the distribution of the magnetic flux density of the transmission line along the coordinate «*x*» are shown in Fig. 6. It is obvious that at the boundary of the protection zone of the transmission line (at $x = \pm 25$ m) the magnetic flux density practically corresponds to the normative value of 0.5 μT under the current value of 150 A in the phases of both circuits. However, if one circuit is switched off, the magnetic flux density on the boundary of the protection zone on the right side of the transmission line (on the operating circuit side) is 0.77 μT, and the point with safe magnetic flux density value is at a distance of 30 m from the transmission line axis. It should also be noted that some private houses, in particular, two-storey, are located almost below the extreme phases of this transmission line. In this case, the normative value of magnetic flux density will be exceeded several times.



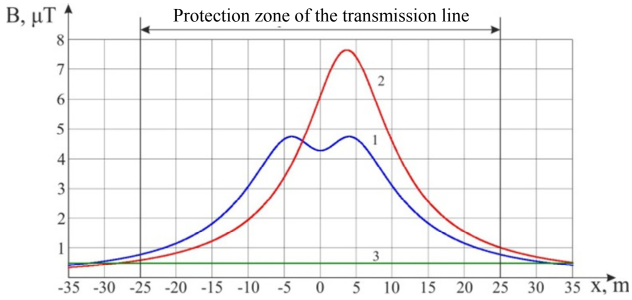
1 – at the effective value of the current in the phases of both circuits of 150 A;
2 – at disconnection of one circuit (effective value of the current of the second circuit is 300 A);
3 – line of the normative level of magnetic flux density of 0.5 μT

Fig. 6. Distribution of the magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» at the level of 1.8 m from the earth's surface along the «*x*» coordinate for the section made on the U110-2 type supports

According to the predicted level of load growth for 10 years [14], the current in the section of this two-circuit transmission line can increase to 195 A for each circuit. The results of the calculation for this case are shown in Fig. 7.

The curves in Fig. 7 indicate an even higher level of magnetic flux density with a promising increase in electric loads. For example, with a uniform load of both circuits, the magnetic flux density at the boundary of the protection zone can reach 0.77 μT, and when disconnecting one circuit is even equal to 1.0 μT, the safe value of the magnetic flux density corresponds to the distance from the axis of 32 m and 35 m, respectively, i.e. beyond the protection zones.

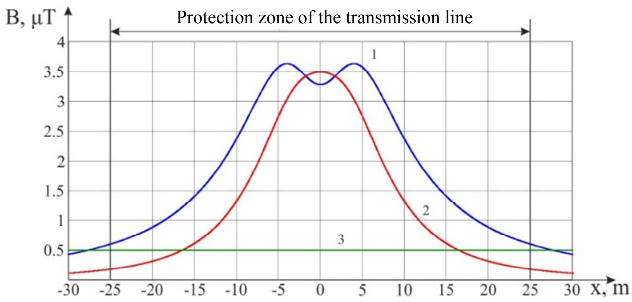
From the above we can conclude that it is necessary to limit the time of single-circuit mode of operation of this transmission line, as it is characterized by a significantly increased level of the magnetic field from the circuit that operates.



1 – at the effective value of the current in the phases of both circuits of 195 A;
2 – at disconnection of one circuit (effective value of the current of the second circuit is 390 A);
3 – line of the normative level of magnetic flux density of 0.5 μT

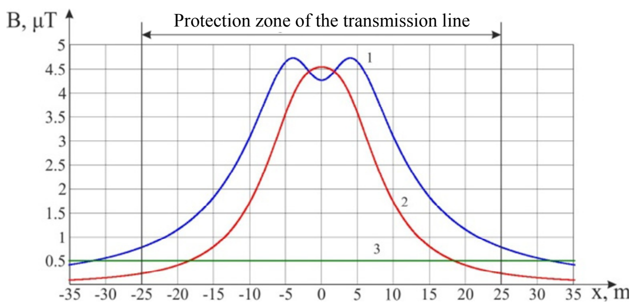
Fig. 7. Distribution of the magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» for the section made on the U110-2 type supports at the predicted increase in electrical loads

As mentioned above, one of the options to reduce the magnetic flux density of the transmission line may be the use of vector compensation due to the mirror arrangement of the phases of two circuits, the results of the corresponding calculations are shown in Fig. 8, 9 (compared to the traditional arrangement of phases).



1 – for the typical arrangement of the phases of two circuits;
2 – for the mirror arrangement of the phases of two circles;
3 – line of the normative level of magnetic flux density of 0.5 μT

Fig. 8. Distribution of the magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» at the level of 1.8 m from the earth's surface along the «*x*» coordinate for the section made on supports type U110-2, with typical and the mirror arrangement of the phases of the circuits (effective value of the current in the phases of both circuits is 150 A)



1 – for the typical arrangement of the phases of two circuits;
2 – for the mirror arrangement of the phases of two circles;
3 – line of the normative level of magnetic flux density of 0.5 μT

Fig. 9. Distribution of the magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» at the level of 1.8 m from the earth's surface along the «*x*» coordinate for the section made on supports type U110-2, with typical and the mirror arrangement of the phases of the circuits (effective value of the current in the phases of both circuits is 195 A)

It is obvious that the safe value of magnetic flux density of 0.5 μT at the mirror arrangement of the phases of two circuits and the phase current of one circuit of 150 A is achieved at a distance of 16.5 m from the centerline of the transmission line, i.e. within its protection zone.

Thus, even with the predicted increase in electrical loads, vector compensation will effectively reduce the level of the magnetic field of a two-circuit 110 kV transmission line «ChTPP – Chernihiv-330» (a point with a safe level of the magnetic flux density for humans is within the protection zone at a distance of 18.3 m from the axis of the power line).

In the area of passage of this transmission line at a distance of 20 m from its axis of symmetry is a residential multi-storey building with a height of about 20 m. Figure 10 shows the location of the building, as well as the location of the coordinate system for calculating the magnetic flux density on the facade of the building along the coordinate «*y*».

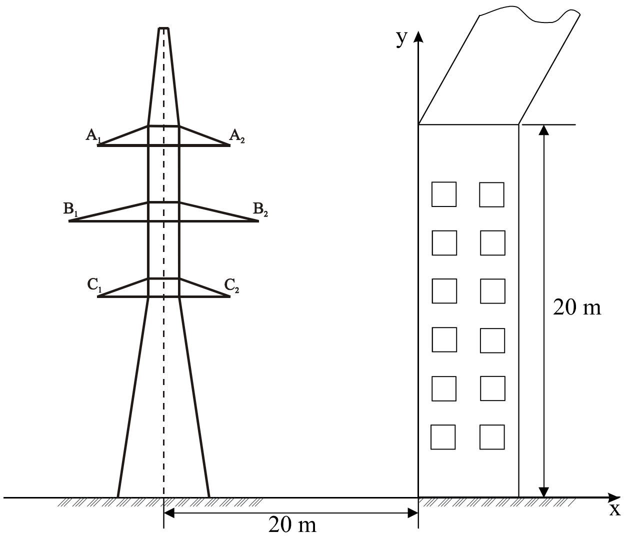
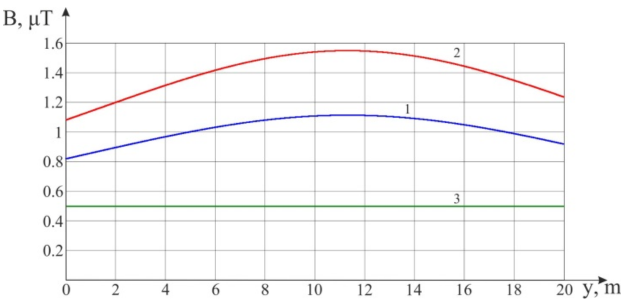


Fig. 10. Location of a multi-storey residential building in the protection zone of the two-circuit 110 kV transmission line «ChTPP – Chernihiv-330»

The results of the calculation of the distribution of the magnetic flux density on the facade of a residential building along the coordinate «*y*» are shown in Fig. 11.



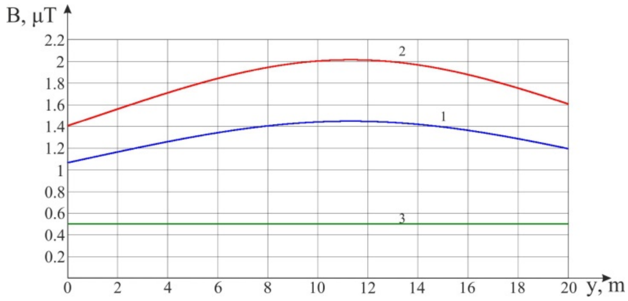
1 – at the effective value of the current in the phases of both circuits of 150 A;
2 – at disconnection of one circuit (effective value of the current of the second circuit is 300 A);
3 – line of the normative level of magnetic flux density of 0.5 μT

Fig. 11. Magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» on the facade of a multi-storey building

As can be seen from Fig. 11, on the facade of a multi-storey building, the normative value of the magnetic flux density of 0.5 μT is significantly exceeded more than 2 times with a uniform load of both circuits, and more than 3 times if one of the circuits is switched off. In [15, 16] and in a number of other investigations it is noted that the magnetic field penetrates into apartment houses practically without weakening.

Similar graphs are constructed for promising electrical loads (see Fig. 12).

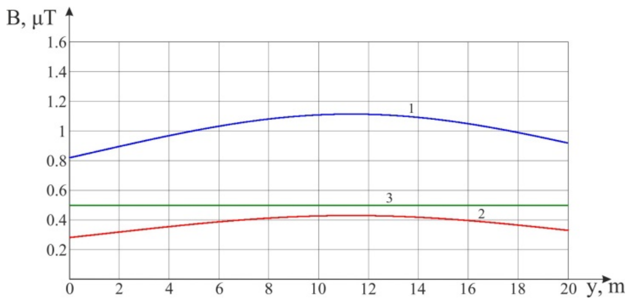
From curve 2 in Fig. 12, which corresponds to the single-circuit mode of operation, it is seen that at y = 11 m there is an excess of the magnetic flux density by 4 times. Obviously, it is necessary to use magnetic field reduction techniques here.



1 – at the effective value of the current in the phases of both circuits of 195 A;
2 – at disconnection of one circuit (effective value of the current of the second circuit is 390 A);
3 – line of the normative level of magnetic flux density of 0.5 μT

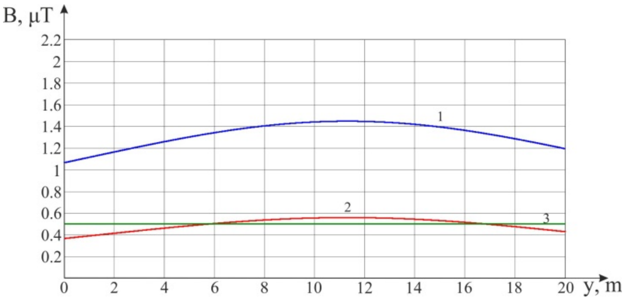
Fig. 12. Magnetic flux density of the 110 kV overhead transmission line ChTPP – Chernihiv-330» on the facade of a multi-storey building at the predicted increase in electrical loads

Figures 13, 14 show the results of the corresponding calculations under the condition of the mirror arrangement of the phases of the two circuits of the transmission line in comparison with the usual variant of their arrangement.



1 – for the typical arrangement of the phases of two circuits;
2 – for the mirror arrangement of the phases of two circles;
3 – line of the normative level of magnetic flux density of 0.5 μT

Fig. 13. Magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» on the facade of a multi-storey building with typical and the mirror arrangement of the phases of the circuits (effective value in the phases of both circuits is 150 A)

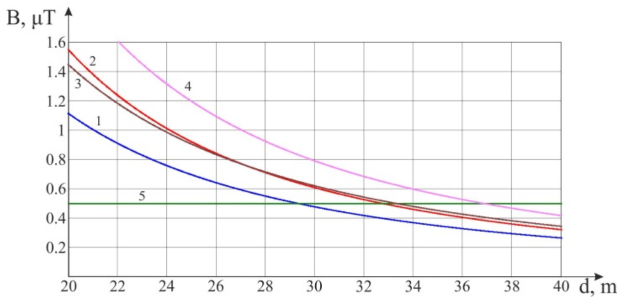


1 – for the typical arrangement of the phases of two circuits;
2 – for the mirror arrangement of the phases of two circles;
3 – line of the normative level of magnetic flux density of 0.5 μT

Fig. 14. Magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» on the facade of a multi-storey building with typical and the mirror arrangement of the phases of the circuits (effective value in the phases of both circuits is 195 A)

The location of the phases in the mirror symmetry allows to effectively reduce the magnetic field on the facade of a residential building. For phase currents of both circuits equal to 150 A, the excess of the normative value of the magnetic flux density is absent at all points, and for the perspective current of 195 A there will be a slight excess. Obviously, with a further increase in phase current (above 195 A), the vector compensation will no longer be sufficient and other methods of reducing magnetic flux density, such as shielding, will need to be used.

If we do not apply vector compensation, it is obvious that it is necessary to determine the safe distance from the axis of the transmission line to the facades of multi-storey residential buildings, which will be greater than 20 m. The results of the corresponding calculation are shown in Fig. 15. It is assumed that the facade of a multi-storey building can be located at a distance of 20 m to 40 m, and the value of the magnetic flux density is calculated for a point at a height of 11.3 m, as the graphs in Fig. 11, 12 show that it is at this height that the magnetic flux density reaches its maximum value.



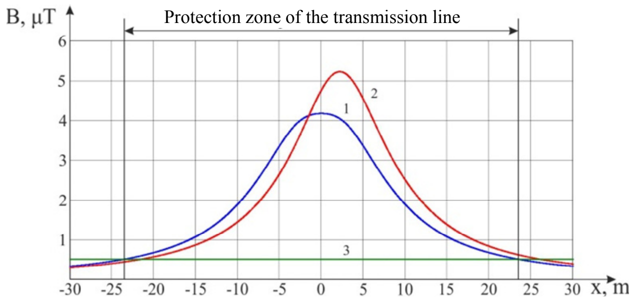
1 – at the effective value of the current in the phases of both circuits of 150 A;
2 – at disconnection of one circuit (effective value of the current of the second circuit is 300 A);
3 – at the effective value of the current in the phases of both circuits of 195 A;
4 – at disconnection of one circuit (effective value of the current of the second circuit is 390 A);
5 – line of the normative level of magnetic flux density of 0.5 μT

Fig. 15. Magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» at a height of 11.3 m when changing distance from the axis of the transmission line to the facade of a multi-storey building

Thus, without the use of vector compensation, the facade of a residential building must be located from the axis of the transmission line at a distance of 29 m at the same current in the phases of both circuits of 150 A. When single-circuit transmission lines operation with current of 300 A (or two-circuit operation with promising load of 195 A in the phases of both circuits), the safe distance should be 33 m, it is obvious that this distance is appropriate in the current situation. Provided that only one circuit with phase current of 195 A will operate, the corresponding distance should be 37 m.

The section of the transmission line «ChTPP – Chernihiv-330», built on supports of the PB110-2 type, runs mainly along the private sector of the city, and in some places the supports are actually located in the yards of private houses or close to the fence.

The results of the calculation of magnetic flux density in such a section at the level of 1.8 m in the direction perpendicular to the transmission line route are shown in Fig. 16.



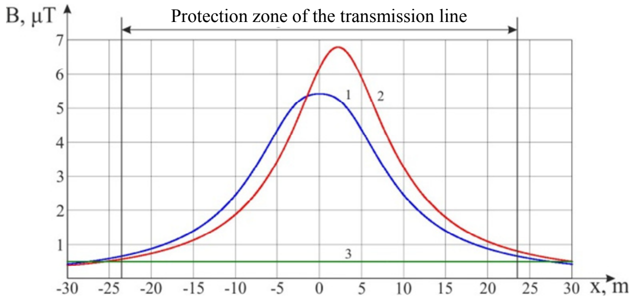
1 – at the effective value of the current in the phases of both circuits of 150 A;
2 – at disconnection of one circuit (effective value of the current of the second circuit is 300 A);
3 – line of the normative level of magnetic flux density of 0.5 μT

Fig. 16. Distribution of the magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» at the level of 1.8 m from the earth's surface for the section made on the PB110-2 type supports

Residential houses in this section of the transmission line are located at a distance of 6-10 m from its axis of symmetry, it is obvious that the field at such points can exceed the normative value by 6-8 times. At the boundary of the protection zone of the transmission line (±23.5 m from the beginning of the coordinate system in Fig. 16) under uniform load of both circuits, the magnetic flux density corresponds to the normative value, in single-circuit mode it is 0.6 μT, and the point with safe magnetic flux density value in this mode corresponds to the coordinate x = 26 m. It should also be noted that all houses have attics, and some of them are generally two-story, respectively, the magnetic flux density in such premises will be even greater. It is obvious that the location of buildings within the protection zone of this section of the transmission line is unacceptable.

Similar graphs for the current in phase of 195 A are shown in Fig. 17.

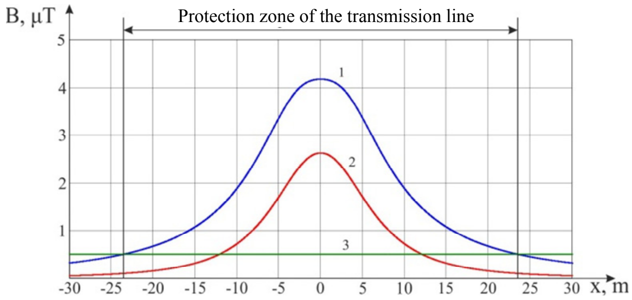
In the two-circuit mode of operation with uniform load on the border of the protection zone on the right side there will be magnetic flux density of 0.65 μT, and in the operation in the single-circuit mode – 0.8 μT. The safe value of the magnetic flux density is observed at a distance of 27 m and 30 m, respectively.



1 – at the effective value of the current in the phases of both circuits of 195 A;
2 – at disconnection of one circuit (effective value of the current of the second circuit is 390 A);
3 – line of the normative level of magnetic flux density of 0.5 μT

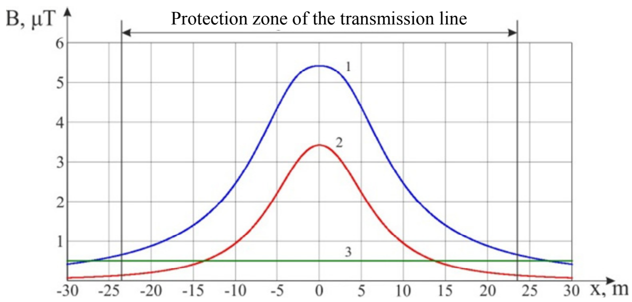
Fig. 17. Distribution of the magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» for the section made on the PB110-2 type supports at the predicted increase in electrical loads

The use of vector compensation in this case will also achieve a significant improvement in the situation, as seen in Fig. 18, 19.



1 – for the typical arrangement of the phases of two circuits;
2 – for the mirror arrangement of the phases of two circles;
3 – line of the normative level of magnetic flux density of 0.5 μT

Fig. 18. Distribution of the magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» at the level of 1.8 m from the earth's surface along the «x» coordinate for the section made on supports type PB110-2, with typical and the mirror arrangement of the phases of the circuits (effective value of the current in the phases of both circuits is 150 A)



1 – for the typical arrangement of the phases of two circuits;
2 – for the mirror arrangement of the phases of two circles;
3 – line of the normative level of magnetic flux density of 0.5 μT

Fig. 19. Distribution of the magnetic flux density of the 110 kV overhead transmission line «ChTPP – Chernihiv-330» at the level of 1.8 m from the earth's surface along the «x» coordinate for the section made on supports type PB110-2, with typical and the mirror arrangement of the phases of the circuits (effective value of the current in the phases of both circuits is 195 A)

For the case shown in Fig. 15, the safe value of the magnetic flux density of 0.5 μT is already at a distance of 12 m from the centerline of the transmission line route, at the boundary of the protection zone the magnetic flux density is 0.1 μT. It should also be noted that for the section made on the supports PB110-2, the mirror arrangement of the phases of the circuits allows to significantly reduce the magnetic flux density at all points in space at the level of 1.8 m, including directly below the transmission line route.

Figure 19 shows that at currents in the phases of each circuit of 195 A changing the location of the phases of different circuits in mirror symmetry (vector compensation) also allows to effectively reduce the magnetic field of the transmission line, the magnetic flux density reaches a safe value at a distance of 13.8 m from the center the transmission line rote, and at the boundary of the protection zone is 0.13 μT.

The results of the calculation of the magnetic flux density at the currents obtained in JSC «Chernihivoblenergo» were checked using the device TM-192 of the TENMARS Company, which is designed to measure the magnetic flux density of power frequency in the range of 0.01-200 μT. The measurement results confirm the correctness of the calculations.

Conclusions.

In this work the magnetic field of the two-circuit 110 kV overhead transmission line «ChTPP – Chernihiv-330» passing through the residential area in different modes of its operation (single-circuit and two-circuit) under current and perspective load is considered and the ways of its reduction to the safe level are investigated.

It is shown that the level of the magnetic flux density of the two-circuit 110 kV transmission line «ChTPP – Chernihiv-330» at existing and prospective loads (current of one phase of each circuit of 150 A and 195 A, respectively, or of 300 A and 390 A when operating in single-circuit mode) can exceed the normative level of 0.5 μT at the boundary of the protection zone up to twice, and a particularly significant level of the magnetic flux density will be observed during the operation of the transmission line in single-circuit mode at prospective load.

It is determined that safe living of the population along the route of this two-circuit transmission line is achieved if the facades of residential buildings are at least 33 m away from the axis of the transmission line for multi-storey buildings and at least 27 m for single-storey buildings.

When working in two-circuit mode in case of exceeding the normative level of the magnetic flux density, it is recommended to use the method of vector compensation [10], which is realized by the mirror location of the wires of different circuits of the transmission line. It is shown that this method allows to effectively reduce the level of the magnetic field of the given transmission line outside its route and, in particular, at the boundary of the protection zone.

Further reduction of the negative impact of the magnetic field on the population in the conditions of increasing electric loads can be achieved by limiting the operating time of two-circuit transmission lines in single-circuit mode, characterized by increased magnetic field from the operating circuit, and the use of magnetic field shielding.

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