Research of effects exerted by industrial frequency electromagnetic fields on city areas located near power lines

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Abstract. This paper presents the results of full scale research of electromagnetic fields of power transmission lines of various voltage classes at various distances from residential buildings along the full height from ground surface. The empirical correlation graphs of electric and magnetic field intensities versus distances from electric power lines at 1, 1.8, 3 m heights have been developed for the voltage classes of 110; 220; 500 kV, including empirical correlation graphs of electric and magnetic fields intensity versus height from ground at the sanitary protection zone lines and in uptown areas. A nomographic chart has been proposed, which is necessary to improve the electromagnetic safety of construction sites near power lines.

1. Introduction
The issue of enhancement of electromagnetic safety during construction of residential buildings near power lines has not been sufficiently studied yet. In particular, there is no research studying characteristics of electromagnetic fields generated by power transmission lines of various voltages at the heights above 1.8 m from ground surface. Electromagnetic field measurements were made taking into account road turns [1] near power lines, but no research has been performed for the heights above 1.8 m, which are very important during construction of multistoried buildings. It is well known [2] that significant 50 Hz electromagnetic fields can be observed near power transmission lines in the cottage and private households areas. Sanitary Regulations and Standards (SanPiN) 2.1.2.1002-00 provides a limitation of the electric field intensity (E), kV/m, which should not exceed 1kV/m within the range of 0.5 to 1.8 meters [2-3]. The magnetic field intensity (H), Amps/m is limited in Russia based on Sanitary Standards 2.1.8 / 2.2.4.2262-07 [4] and shall not exceed 8 Amps/m. Table. 1 provides research results of shielding characteristics of main construction materials used in residential buildings of Ukraine [5].

| Material                        | Shielding index (S) |
|---------------------------------|---------------------|
| White and red silica brick      | 1                   |
| Concrete                        | 1-1,02              |
| Reinforced concrete             | 1-1,02              |

Table 1. Research results of shielding characteristics of construction materials.
Research results (Table 1) indicate that the main construction materials covered by research essentially do not shield from 50 Hz electromagnetic field. Studies were also carried out in typical housing blocks of Kharkov of various heights constructed of panel concrete walls [5]. The results of field studies conducted in panel housing blocks near power lines have shown that the panel houses essentially do not shield from 50 Hz magnetic field [5]. Currently there are no computational correlation graphs of electromagnetic field intensity versus height of building facades ranging by distance from power lines (above 1.8 m) of various voltages at various distances from residential buildings. Nevertheless, the above research results show importance of taking into account the electromagnetic field characteristics over the entire height of the buildings’ facades [6-9].

2. Formulation of the problem

The objective of this research is to enhance electromagnetic safety in city areas located near the power transmission lines (as exemplified by Tyumen), taking into account changes in effects exerted by electromagnetic fields relative to the height above ground.

Targets:
1. To plot empirical correlation graphs of electromagnetic field characteristics versus distance from power transmission lines of various voltages at 1; 1.8; 3 m.
2. To plot empirical correlation graphs of electromagnetic field characteristics versus height above ground for various voltage power transmission lines found in the sanitary protection zone’s dividing lines and in residential areas.
3. To plot nomographic chart of electric field intensity for 500 kV power transmission lines above 1.8 m and provide recommendations for construction of buildings taking into account changes of electromagnetic field characteristics versus building heights.

This research has been planned and conducted in Tyumen within the timeframe of three years, from 2016 to 2018. A total of 30 observation sites were chosen. A total of 20 measurements were made at each observation site during field trips.

In accordance with the generally accepted method, measurements of electromagnetic field intensity emitted by power transmission lines are made within the range of 0.5 m to 1.8 m heights above ground [9-10]. The maximum values measured at these heights are then compared with maximum permissible levels, without due account of electric and magnetic fields intensity along entire extent of buildings heights. Thus, it was decided to conduct studies above 1.8 meters along the buildings facades involved in the study (on open balconies), which are very important for multistoried buildings.

The objects of study were buildings located near power transmission lines of various voltage classes (110 kV, 220 kV, 500 kV with similar electrical cables height) within the territory of Tyumen [9-10].

The measuring instrument was PZ-50, designed to measure magnetic and electric fields intensity of industrial frequency, including the ones generated by power lines. Based on research results, a nomographic chart was plotted for the highest voltage class transmission lines to determine the electric field’s intensity at various distances and at various heights of buildings above ground [11-15].

3. Solution of the problem

Empirical correlation graphs have been plotted using the field studies results, which made it possible to provide specific data on the magnitude of the intensity of electromagnetic field of various voltage class power lines at various distances. Also, correlation graphs are needed to justify the placement of residential buildings near power lines.

Below are empirical graphs of the electric field intensity versus distance from power transmission lines of various voltage classes at 1; 1.8; 3 m above ground (Figure 1, Figure 2).
For the 110 kV transmission line (Figure 1), an exceedance of electric field from the regulatory limit at a height of 3 meters by a factor of 1.5-2 at a distance of up to 25 meters from the source has been observed. For the 500 kV transmission line (Figure 2), a two-to-fourfold exceedance of electric field from the limit at a distance of up to 45 meters has been observed, particularly at the height of 3 m above ground. The magnetic field intensity (Figure 3) does not exceed the regulation limits in residential areas at the height range of 0.5 to 3 m.
To compare characteristics of electromagnetic fields of various voltage class power lines, measurements were taken below 3 m above ground at similar heights of power transmission lines. Figure 4 shows that for the 110 kV power transmission line the electric field intensity \( E \) along the full extent of the height above ground \( h \) does not exceed the norm in residential areas, which is not applicable to power lines of 220 kV and above. The regulation limit of electric field intensity is significantly exceeded: for the 220 kV power lines at an altitude of 3 meters by 2.4 times, for the 550 kV power lines - by 4 times. Thus, it has been concluded that depending on the height above ground the electric field intensity increases, the higher the power line’s voltage class the higher the deviation of the height above ground compared to the regulatory limit of the electric field intensity.

Therefore, it was decided to study the electric field intensity \( E \), \( \text{kV/m} \) at heights greater than 3 meters above ground level up to the height of 500 kV and 110 kV transmission lines. For the 500 kV transmission line (Figure 5), the electric field intensity increases at the sanitary protection zone’s...
dividing line above 3 meters, and the 1 kV/m limitation is exceeded by 2-7.5 times. These data are very important for construction of multistoried buildings. Correlation graphs have also been generated at distances of 40 meters from power lines in residential areas (Figure 6).

For the 500 kV transmission line located in the residential areas at the height of 3 meters and above, the correlation graph (Figure 6) of the electric field intensity versus height above ground shows that the electric field intensity increases, and the regulatory limitation of 1 kV/m is exceeded by a factor of 1.5-6.

For the 500 kV transmission line located in the residential areas at the height of 4 meters and above the graph shows that the electric field intensity increases, and the regulatory limitation of 1 kV/m is exceeded by a factor of 1.5-4.5. The magnetic field intensity does not exceed the normative limits along the whole building height.

Based on results of field studies a nomographic chart (Figure 7) was plotted to determine the electric field intensity at various distances from 500 kV transmission line of the highest voltage class.
Figure 7. Nomographic chart of determining electric field intensity (E, kV/m) at various distances R (m) from 500 kV power line at various heights above ground – h, m.

The plotted nomographic chart (Figure 7) makes it possible to make predictions of the electric field levels (E) in relation to height from ground (h) for 500 kV transmission lines, which is important for designing buildings of various number of storeys located near power lines. If in some areas where the electric field intensity outside the sanitary protection zones is higher than 1 kV/m, measures should be taken to reduce the electric field intensity [16-18] in residential areas (people’s dwelling areas).

The best roofing material for covering building roofs is sheet steel and metal shingles, which has been proven by the authors' research results [18-20]. The method for decreasing electromagnetic field levels during construction can be improved by earthing the screen at several points on the roof [20]. In other places of people's stay, the industrial frequency field intensity can be reduced by installing protective screens, for example, reinforced concrete, metal fences, metal rope screens [20]. For electromagnetic shielding, 0.01-0.05 mm thin-sheet and foil materials can effectively be used. To protect windows of residential buildings along the full extent of a building height from electromagnetic radiation, it is necessary to use metallized glass (tin, copper, nickel, silver and their oxides).

4. Conclusion
1. Field studies were conducted and empirical data were gathered allowing to analyze the effects of electromagnetic fields at the territory of Tyumen.
2. The empirical correlation graphs of electromagnetic field characteristics versus distance from power transmission lines of various voltage classes at 1; 1.8; 3 m heights have been plotted for the sanitary protection zone’s dividing line and for residential areas.
3. Empirical correlation graphs of electromagnetic field characteristics versus height above ground for 110 kV, 500 kV voltage class power transmission lines at the sanitary protection zone’s dividing line and for residential areas within height range of 0.5 to 30 meters above ground have been plotted.
4. Recommendations have been proposed to improve the electromagnetic safety of construction projects. A nomographic chart was plotted allowing to determine the electric field intensity with respect to the ground level at various distances from 500 kV transmission line, which can be used in
designing new buildings, taking into account the electromagnetic field characteristics along the building height above ground.

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