https://doi.org/10.1051/e3sconf/202020907002

Simulation of Electromagnetic Fields Occurring at Intersection of Traction Networks and Multicircuit Power Lines

Natalia V. Buyakova[1,*], *Andrey V.* Kryukov[2, 3], *Dmitriy A.* Seredkin[3,*], and *Le Van* Thao[2].

[1]Angarsk State Tech-nical University, 665835, Angarsk, Russia
[2]Irkutsk State Transport University, 664074, Irkutsk, Russia
[3]Irkutsk National Research Technical University, 664074, Irkutsk, Russia

Abstract. Traction networks (TN) 25 kV generate higher electromagnetic fields (EMF) with frequency 50 Hz, whose strengths at a standardized height of 1.8 m, as a rule, do not exceed the permissible norms for electrical personnel. In places where railroads routes intersect with high voltage overhead power supply lines (OPL), interference of fields, generated by the traction network and OPL, occurs. This can lead to an increase in strengths and a complication of the EMF spatial structures. The article presents simulation results performed for a complex intersection, while 25 or 2 x 25 kV TN is crossed by a three-circuit 110-220 kV overhead power line at 90 degrees angle. Fazonord software application was used for simulating EMF strengths in points of traction networks and OPL intersection. Based on modeling results the following conclusions have been made: at intersection points of 1x25 kV traction network with a three-chain 110 - 220 kV power transmission line, the electrical field strength does not exceed the value acceptable for electrical personnel and reaches 4.2 kV/m; at the intersection with 2 x 25 kV traction network, this parameter decreases to 2.7 kV/m; the maximum amplitude of the magnetic field at the intersection points increases slightly.

1 Introduction

High-voltage overhead power lines (OPL) and electrified AC 25 kV railroads are sources of industrial frequency electro-magnetic field (EMF). Electromagnetic fields with high strength levels can generate interference causing disturbances of electrical and electronic devices' normal functioning [1–4] and result in serious accidents when operations are conducted on disconnected power supply lines or communication lines when personnel is subject to induced voltage.

25 kV traction networks (TN) generate higher electromagnetic fields (EMF) with frequency 50 Hz, whose strengths at a standardized height of 1.8 m, as a rule, do not exceed the permissible norms for electrical personnel. In places where rail-roads routes intersect with high voltage overhead power supply lines (OPL), interference of fields, generated by the traction network and OPL, occurs. This can lead to an increase in strengths and a complication of the EMF spatial structures [4].

In works [2, 15-20], a method was proposed for determining the fields of multi-wire systems, including traction net-works and power lines, based on preliminary calculation of the electrical network operating mode, which may contain mul-ti-wire lines, single-phase and three-phase transformers of various types, traction AC networks and moving traction loads. Fazonord software application [15] designed in Irkutsk State Transport university, combines possibilities for modes simulation in phase coordinates and simultaneous calculations of EMF strengths.

This article is a further development of ideas represented in work [16], which performs a detailed analysis of electro-magnetic field structure at a point of overhead power line and a railroad perpendicular intersection.

2 Simulation methods

Fazonord software application was used for simulating EMF strengths in points of traction networks and OPL intersection which was conducted in four stages:

1. The calculation of OPL traction networks in phase coordinates, the results of which were used to determine potentials and currents of all wires [15];
2. Calculation of vertical and horizontal components of electrical and magnetic fields of traction networks and OPL in their own coordinates.
3. Calculation of total EMF voltages components.
4. Calculation of strengths amplitude values $E_{\max}, H_{\max}$ with provision for possible fields elliptical polarization [2, 16].

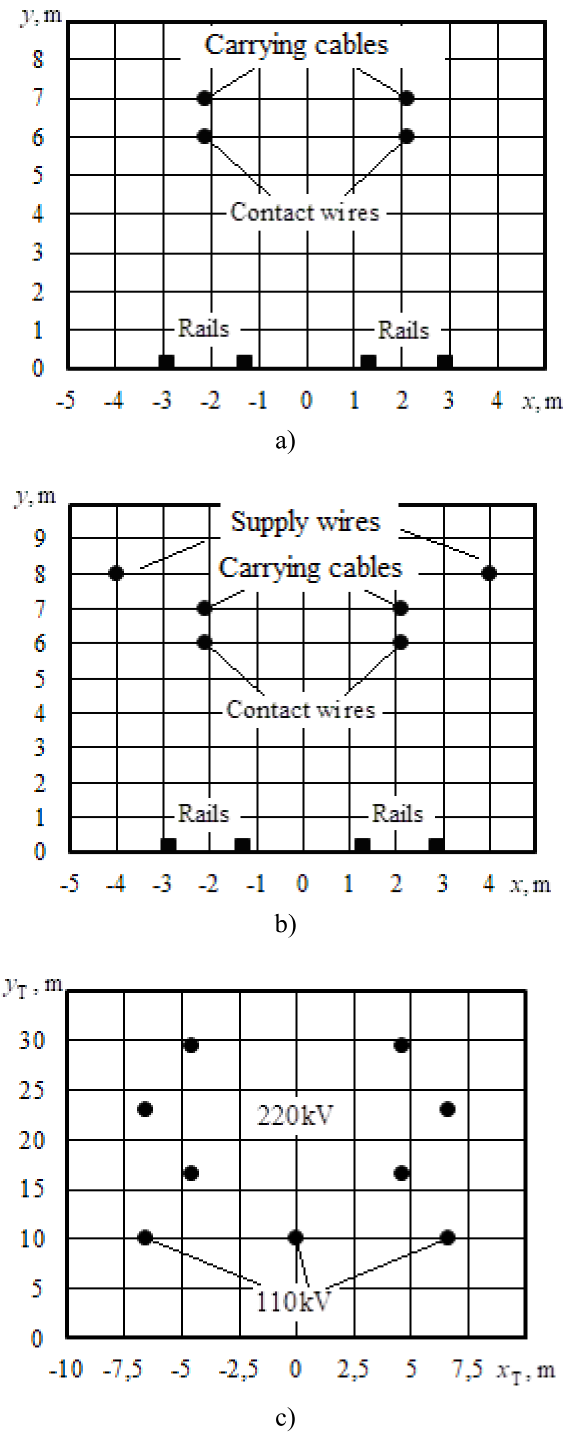
3 Simulation results

The simulation was performed for a case of intersection of 1x25 and 2x25 kV traction networks with three-circuit 110–220 kV OPL. Spatial location of the conductive parts is shown in fig. 1. It was assumed that AC-300

---

[*] Corresponding author: dmitriy987@mail.ru

wires are mounted on OPL pylons. The diagram of OPL wires transposition is shown in fig. 2. The length of the transposed OPL divided into three sections is assumed to equal to 100 km. Loads on 220 kV circuits receiving end were equal to 20 + *j*10 MVA, circuits 110 kV - 6 + j3 MVA per phase. A power transit of 8 + *j*8 MVA was transmitted via the overhead catenaries of each 2 km long traction network. The calculation was carried out for the intersection of the traction network with the first segment of the transposed OPL.



a)

b)

c)

Fig. 1. Wires arrangement: a – 25 kV TN; b – 2x25 kV TN; c – three-circuit OPL

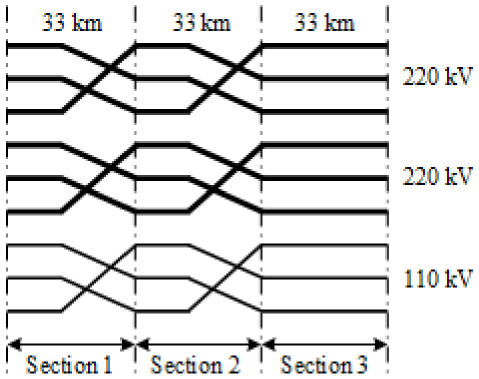


Fig. 2. OPL scheme of transposition

Table 1. Font styles for a reference to a journal article.

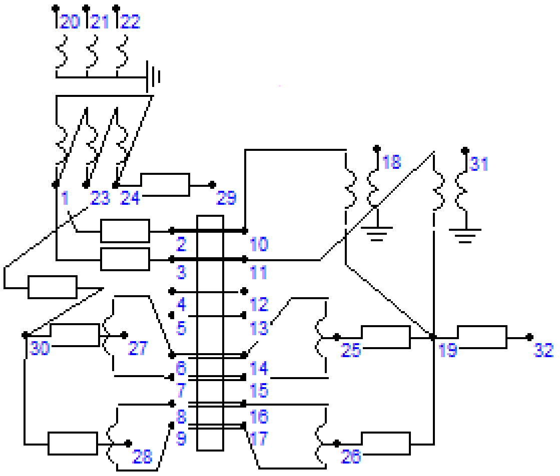
OPL	Phase	*U*, kV	*U*, degr.	*I*, A	*I*, degr.
Left 220 kV	A	133	0	160.6	–18.4
	B	133	–120	160.5	–138.3
	C	133	120	160.5	101.7
Right 220 kV	A	133	0	160.9	–18.6
	B	133	–120	160.9	–138.5
	C	133	120	160.9	101.5
110 kV	A	65	0	100.7	–21.1
	B	65	–120	100.6	–141
	C	65	120	100.6	99.2

Table 2. Voltages and currents of 1x25 kV traction network

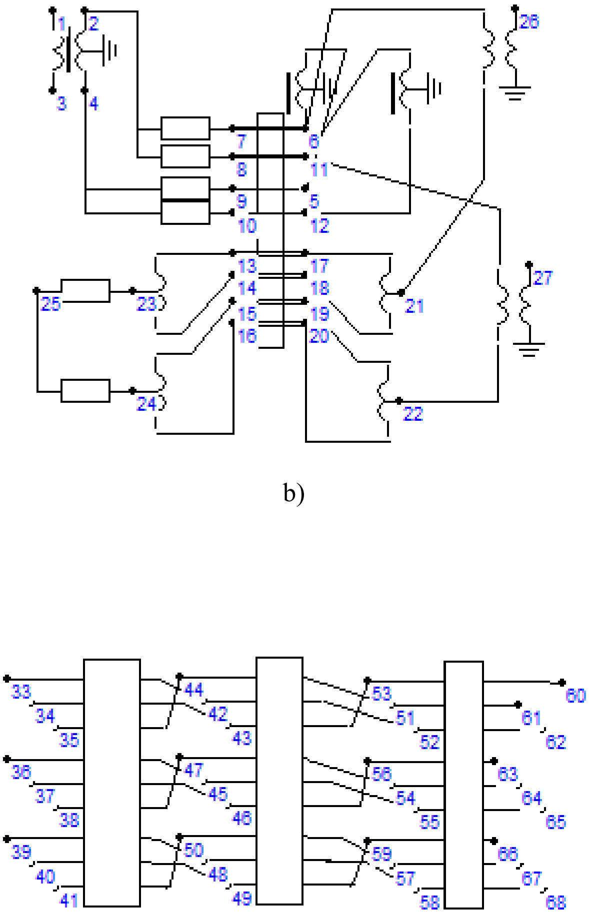
Path	*U*, kV	*U*, degr.	*I*, A	*I*, degr.
1	25.6	–5.6	450	–51
2	25.6	–5.6	450	–51

Table 3. Voltages and currents of 2x25 kV traction network

Path	Place of measuring	*U*, kV	*U*, degr.	*I*, A	*I*, degr.
1	Overhead catenary	25.8	26.2	246.2	–21.2
2		25.8	26.2	246.2	–21.2
1	Power cord	26.5	–153.3	198.7	164.2
2		26.5	–153.3	198.7	164.2



a)

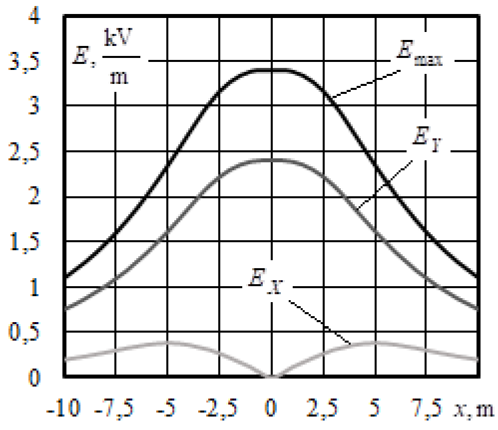


b)

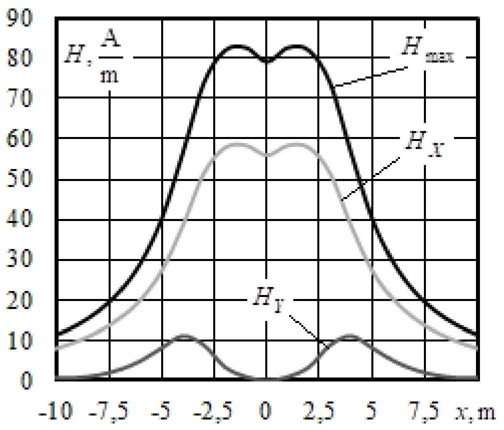
c)

Fig. 3. Fazonord PSW design models schemes: a – TC 1x25 kV; b – TC 2x25 kV; c – OPL 110-220 kV

Calculated electrical and magnetic fields strengths in their own coordinates of traction networks and OPL at a height of 1.8 m are provided in fig. 4–6.

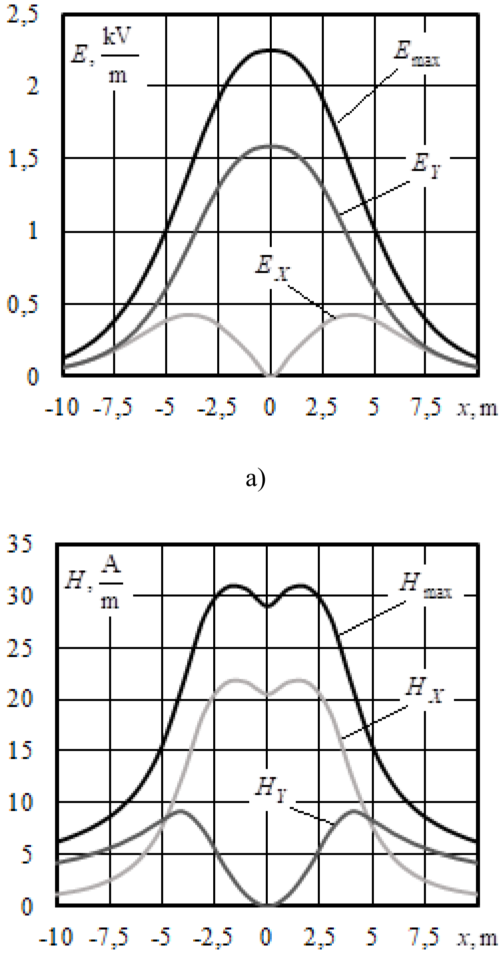


a)



b)

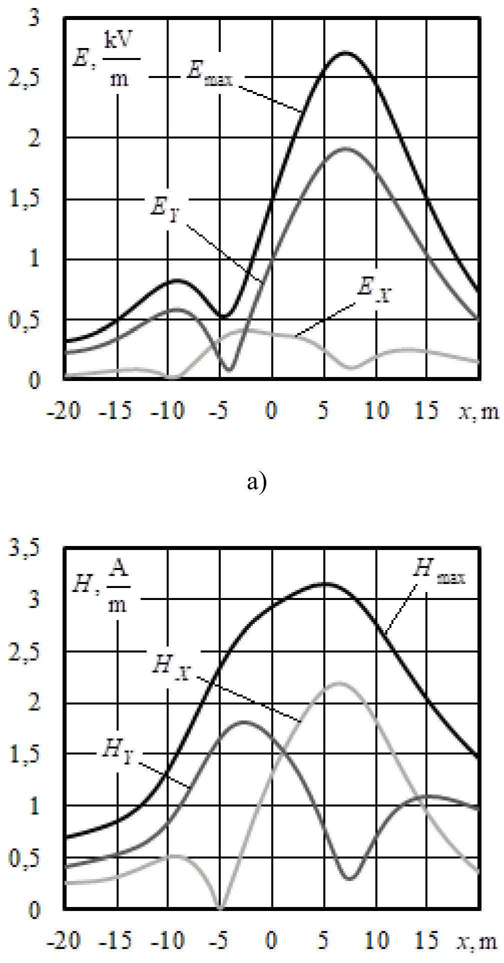
Fig. 4. Electrical (a) and magnetic field (b) strengths of 25 kV traction network at a height of 1,8 m.



a)

b)

Fig. 5. Electrical (a) and magnetic field (b) strengths of 2x25 kV traction network at a height of 1,8 m.

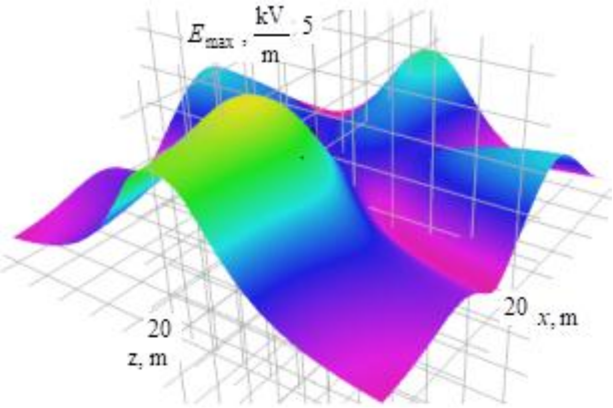


a)

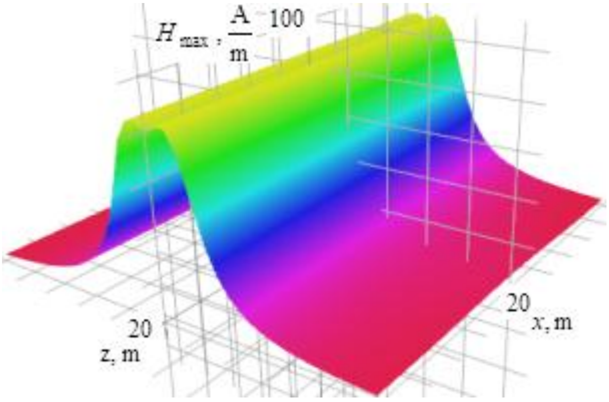
b)

Fig. 6. Electrical (a) and magnetic field (b) strengths of OPL at a height of 1,8 m.

Volumetric diagrams of the resultant strengths of electric and magnetic fields at the intersection of traction networks and OPL at a height of 1.8 m are shown in Fig. 7, 8. Figure 9 shows the hodographs of the resultant strengths vectors. Table 4 represents maximal values of electrical and magnetic fields strengths at intersection points.

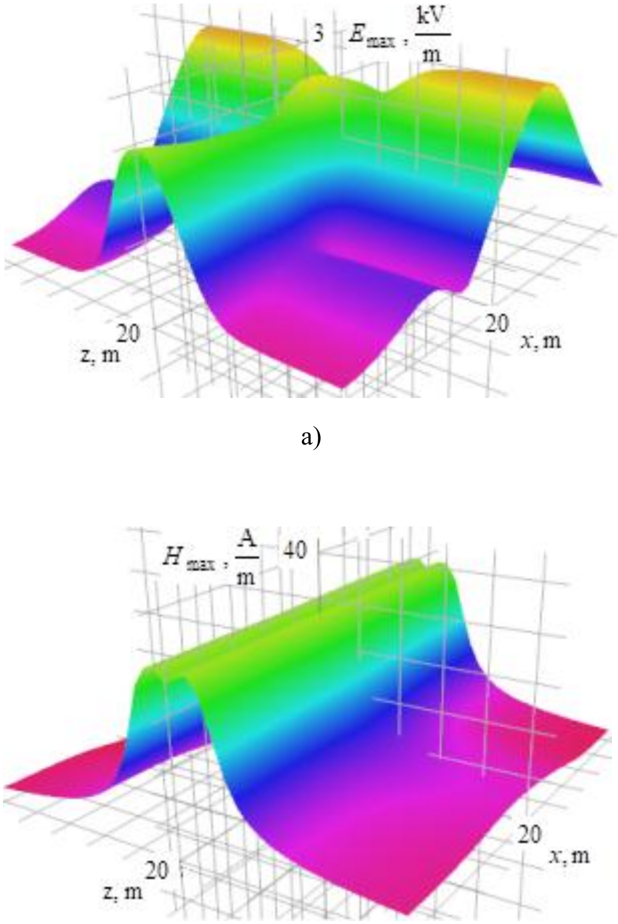


a)



b)

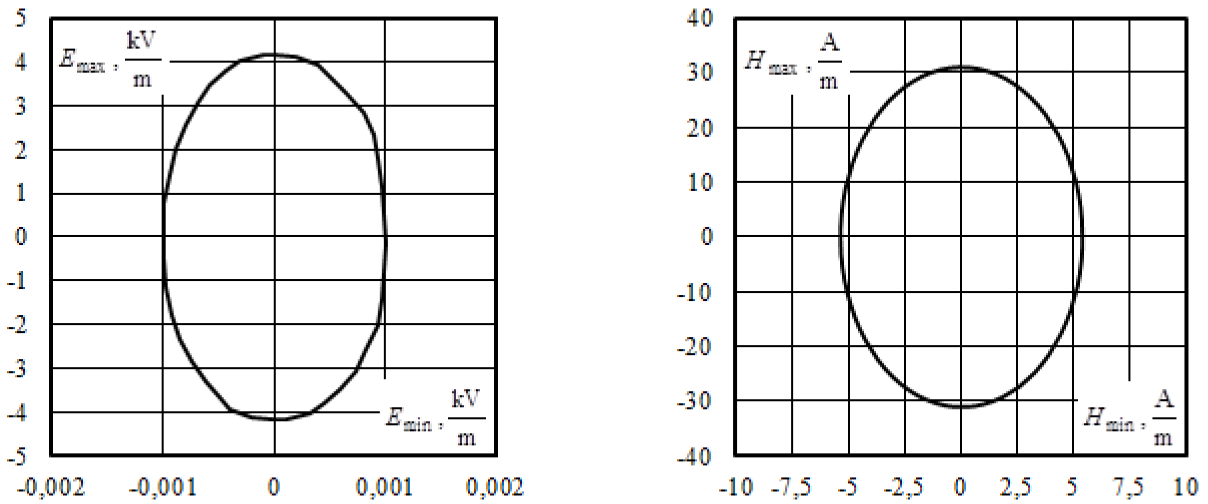
Fig. 7. Amplitude values of EMF strengths at the point of 2x25 kV traction network OPL intersection: a – electrical field; b – magnetic field



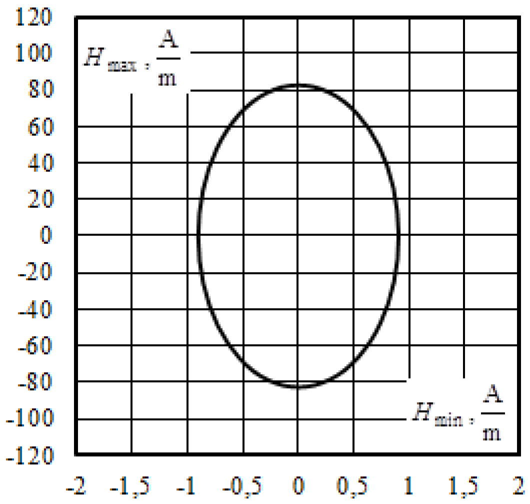
a)

b)

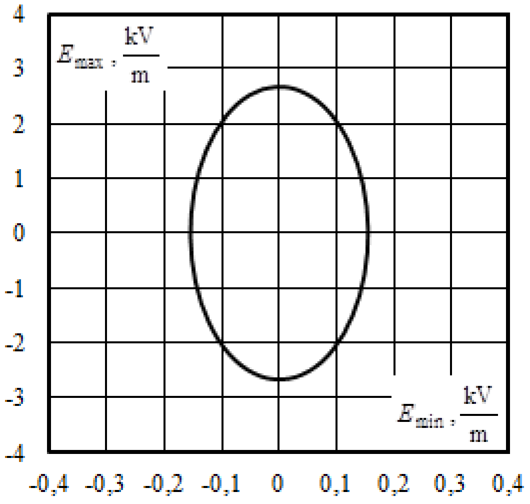
Fig. 8. Amplitude values of magnetic field strengths at the point of 2x25 kV traction network and 220 kV OPL intersection: a – electrical field; b – magnetic field



a) d)



b)



c)

Fig. 9. Hodographs of resultant vectors at points with maximal values of electrical (a, c) and magnetic (b, d) fields strengths for crossing TN 25 kV (a, b) and 2x25 kV (c, d) with OPL: a – point $x = 0$ m, $z = 9$ m; b – point $x = 1$ m, $z = 0$ m; c – point $x = -18$ m, z = –7 m;d – point $x = 2$ m, z = 3 m

Table 4. Maximum values of electrical and magnetic fields strengths

Parameter	TN 1x25 kV	TN 2x25 kV	Three-circuit 110-220 kV OPL	TN and OPL intersection		Difference, %	
				1x25 kV	2x25 kV	Between columns 2 and 5	Between columns 3 and 6
1	**2**	**3**	**4**	**5**	**6**	**8**	**9**
E_{max},. kV/m	3,4	2,3	2,7	4,2	2,7	19	15
H_{max}, A/m	83	31	3,1	83	31	0	0

4 Conclusion

Based on simulation results, the following conclusions can be made:

1. When separately modeling, the electric field strengths at a standard height of 1.8 m, do not exceed the permissible standards of 5 kV/m for electrical personnel both for traction networks and OPL. The magnetic field strength of 1x25 kV traction network exceeds the permissible value of 80 A/m. A similar parameter for the 2x25 kV traction network is reduced to 30 A/m, which is associated with the mutual compensation of the magnetic fields generated by overhead catenaries and power wires.

2. At the intersection points of 1x25 kV traction network with a 220 kV three-circuit OPL, the electrical field strength does not exceed the value permissible for electrical personnel and reaches 4.2 kV/m. When crossing a 2x25 kV traction network, this parameter is reduced to 2.7 kV/m.
3. The magnetic field strength at the intersection of power lines with 25 kV traction network reaches 83 A/m. For 2×25 kV TN, a similar parameter is reduced to 31 A/m.
4. At the intersection of 1x25 and 2x25 kV traction networks with OPL, the maximum amplitude of the magnetic field increases insignificantly.

References

1. A.I. Sidorov, I.S. Okrainnaya, *Electromagnetic fields near ultrahigh-voltage electrical installations* (Chelyabinsk, 2008)
2. N.V. Byakova, V.P. Zakaryukin, A.V. Kryukov, *Electromagnetic safety in railroads power supply systems: modeling and control* (Angarsk, 2018)
3. A.B. Kosarev, B.I. Kosarev, *Basics of electromagnetic safety of railroad transport power supply systems* (Moscow.,2008)
4. S.M. Apollonsky, T.V. Kalyada, B.E. Sindalovsky, *Human life safety in electromagnetic fields* (St. Petersburg, 2006)
5. S.M. Appolonsky, A.N. Gorsky, *Electromagnetic fields calculations* (Moscow, 2006)
6. A.A. Ustinov, Improving the efficiency of energy production and use in Siberia, 517 (2005).
7. N.B. Rubtsova, M.Sh. Misrikhanov, V.N. Sedunov, A.Yu. Tokarsky, Bulletin of Samara Research Center of RAN **5(3)**, 839 (2012)
8. R. Kircher, J. Klühspies, R. Palka et al, Transportation Systems and Technology **4(2)**, 152 (2018)
9. A. Ogunsola, A. Mariscotti, *Electromagnetic Compatibility in Railways* (London, 2013)
10. A. Ogunsola, U. Reggiani, L. Sandrolini, EMC'09, 567 (2009)
11. F. Sheilah, *Railway Electrification Systems & Engineering* (Delhi 2012)
12. A. Steimel, *Electric traction motive power and energy supply. Basics and practical experience* (Munchen, 2008)
13. A.R. Zakirova, Zh.M. Bukanov, Bulletin of the Ural State University for railroads communication **2**, 73 (2016)
14. A.R. Zakirova, *Protection of electrical personnel against harmful effect of electromagnetic fields* (Ekaterinburg, 2018)
15. V.P. Zakaryukin, A.V. Kryukov, *Complex asymmetrical modes of electrical systems* (Irkutsk, 2005)
16. V.P. Zakaryukin, A.V. Kryukov, Transport infrastructure of Siberian region, 641 (2018)
17. V.P. Zakaryukin, A.V. Kryukov, N.V. Buyakova, The power grid of the future, 39 (2013)
18. N. Buyakova, V. Zakarukin, A. Kryukov, Advances in Intelligent Systems Research **158**, 20 (2018)
19. N. Buyakova, V. Zakaryukin, A. Kryukov, Tu Nguyen, E3S, 1 (2018)
20. N.V. Buyakova, V.P. Zakaryukin, A.V. Kryukov, Advances in Engineering Research **158**, 219 (2018)