

Modelling of a Double-Track Railway Contact System Electric Field Intensity

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Abstract. Working conditions of personnel that serves contact system (CS) are affected by factors including health and safety, security and working hours (danger of rolling stock accidents, danger of electric shock strokes, work at height, severity and tension of work, increased noise level, etc.) Low frequency electromagnetic fields as part of both electric and magnetic fields are among of the most dangerous and harmful factors. These factors can affect not only the working personnel, but also a lot of people, who do not work with the contact system itself, but could be influenced by electromagnetic field as the result of their professional activity. People, who use public transport or live not far from the electrified lines, are endangered by these factors as well. There are results of the theoretical researches in which low frequency electric fields of railway contact system were designed with the use of mathematical and computer modelling. Significant features of electric field distribution near double-track railway in presence or absence of human body were established. The studies showed the dependence of low frequency electric field parameters on the distance to the track axis, height, and presence or absence of human body. The obtained data were compared with permissible standards established in the Russian Federation and other countries with advanced electrified railway system. Evaluation of low frequency electric fields harmful effect on personnel is the main result of this work. It is also established, that location of personnel, voltage and current level, amount of tracks and other factors influence electric fields of contact systems.

1. Introduction

The working conditions of the personnel servicing the contact network (CS) include a complex of hazardous and harmful factors in the production environment and the work process (the danger of rolling stock rolling, the risk of electric shock, work at height, severity and tension, increased noise, etc.). A special place among hazardous and harmful production factors is occupied by low-frequency electromagnetic fields in the form of separate components of the electric field (EM) and magnetic field. These factors also have an impact on a large number of personnel who are not connected to the operation of the contact network, but who are exposed to ES during their labour activity, as well as the population using passenger transport and living near electrified lines.

Separate results of studies of the parameters of electric fields are presented in [1-5]. To predict the possible parameters of the EP and estimate Safety of their impact, the method of computer mathematical modeling was used.

2. Objectives and tasks of modelling assumptions

The aim of the simulation is to obtain the dependencies of the EP intensity in the workplaces of the personnel from distance, number of paths, voltage and other factors. Taking into account the tasks, the required solution, the computer program EFC-400 (developer Narda Safety Test Solutions, Germany) was used for mathematical modelling.



To perform mathematical modelling, the following assumptions were made:

- the contact suspension is replaced by one wire with a height equal to the height of the suspension of the trolley wire. This assumption has no significant effect on the induction values obtained, since the main contribution to the distribution of EPs is exerted by the voltage in the contact wire;
- in the zone of EP distribution there are no any metal elements and structures, including rolling stock. Such modeling conditions are valid for personnel located directly on or near the tracks, when there is no rolling stock, and the presence of metal objects may increase the intensity of the EP;
- practically all the current (95% of the current in the contact wire) flows along the rails. This assumption takes into account the cases when part of the reverse current flows on the ground, which slightly underestimates the induction values obtained.
- the human body is a block of conductive elements, a total height of 1.8 m, a width of 0.56 m and a thickness of 0.33 m (Figure 1).

Thus, the assumptions made do not have a significant effect on the results of mathematical computer simulation.

To simulate the intensity of ES for the CS in the EFC-400 program, a model of a two-track section was created, the source of EP, personnel was placed, the following initial data were entered: the standard voltage level of the compressor on the pantograph of the current collector is at least 25 kV; Height 0 - 6 m; Distance to the side of the track axis ± 15 m; Height of the contact wire - not less than 5.75 m; The length of the span is no more than 70 m.

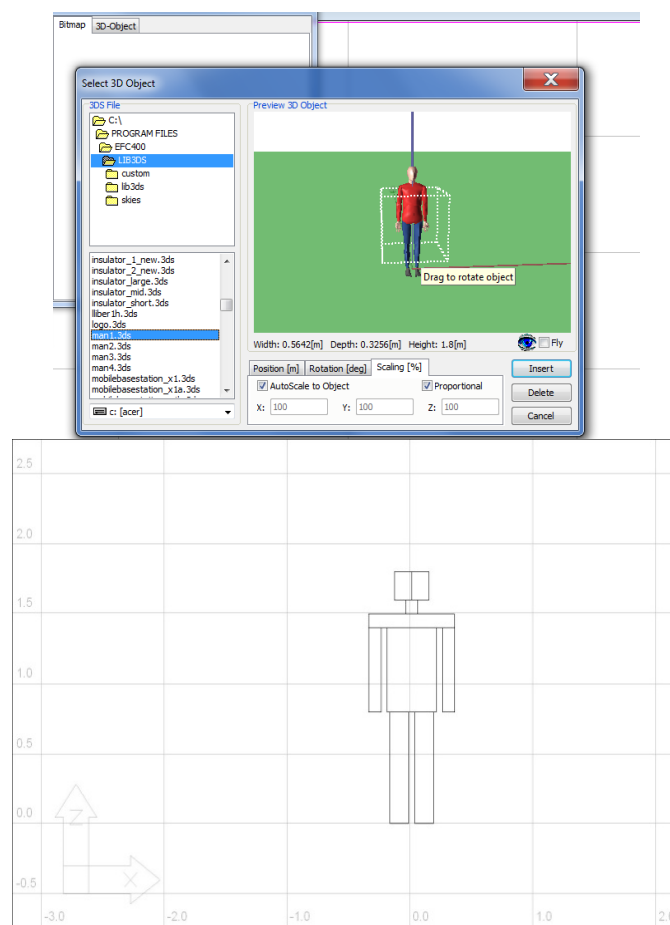


Figure 1. Model of the human body used in the program EFC-400

Table 1. Simulation results with voltage on both paths

№ n/n	Distance away from axis 1st way, [m]	EP Tension [kV/m]			
		At a height of 1.8 m		At the height of the contact wire	
		Without taking into account the human body	Given the influence of the human body when	Without taking into account the human body	Given the influence of the human body when
1	0	3.19	3.19	22.37	22.37
2	2	3.21	6.12	3.10	5.50
3	4	3.20	3.22	4.95	4.95
4	6	2.82	2.82	6.16	6.16
5	8	2.14	2.14	2.43	2.43
6	10	1.50	1.50	1.27	1.27
7	15	0.71	0.71	0.89	0.89

In accordance with the Rules [6], the distance between the axes of the tracks on the runways of double-track rail lines on straight sections should be not less than 4100 mm. On three-track and four-way lines, the distance between the axes of the second and third tracks, on straight sections should be at least 5000 mm. To simulate the distance between the axes of the tracks, 5 m is assumed.

3. Results of simulation for a two-way site under stress

The results of mathematical modeling of the distribution of the intensity of EP at a frequency of 50 Hz of the CS of the two-track section are presented in Table 1 and in Figure 2.

In order to evaluate the influence of the human model on the distribution of tension, modeling was performed when the human model was found in different zones of the two-track section: on the axis of the 1st and 2nd track, between the axes of the tracks, at a distance of 8 m away from the axis of the 2nd track. Figure 2 shows the distribution of EP stress in the presence of a human model between the track axes.

The presence of a model of the human body in different zones of the double track section distorts the intensity of the ES only in the immediate vicinity of the model: when the model is located within the axes of the tracks and between them, the tension at the level of the head and shoulders reaches values greater than 6 kV / m; When the model of the human body is located at a distance away from the axis of the 2nd path of 2 m, the tension at the level of the head and shoulders decreases to 5.3 kV / m, at a distance of 8 m - to 1.7 kV / m.

The presence of the human body model in different zones of the double track section will distort the tension at the height of the contact wire in certain zones: when the model is on the axis of the 1st or 2nd track, the maximum value of the tension does not change, while between the track axes the tension at the level of the head and shoulders increases from 3 to 13 kV / m; When the model of the human body is at a distance of 2 m away from the axis of the 2nd track, the tension increases from 3.3 to 10 kV / m, at a distance of 8 m - from 1 to 3.5 kV / m.

Analysis of the obtained dependences shows that the intensity of the EP 50 Hz at a height of 1.8 m reaches values above 3 kV / m above the track axes and 0.5 m away from the axis of each path. In this case, the presence of a human body in different areas can increase the tension at the level of the head and shoulders up to 6 kV / m, which exceeds the normalized value of the EP when exposed for the whole shift, equal to 5 kV / m [7]. The intensity of the EP decreases depending on the distance to the side of the path axis and varies according to the equation of the polynomial of degree 3 (the approximation coefficient $R^2 = 0.9976$). The presence of a human model in the EP spread zone distorts the lines of force, which increases the tension up to 1.9 times at the level of the head and shoulders.

At the height of the contact wire, the value of the voltage, regardless of the presence of a person standing on the axis of any path, does not change and is more than 22 kV / m. Tension of more than 20

kV / m is observed at a distance of up to 20 cm from the contact wire, which exceeds the standard value. In some areas at the height of the contact wire, the presence of the human body model increases the tension from 3.1 to 13 kV / m when located between the axes of the tracks; When finding a model of the human body at a distance of 2 m away from the axis of the 2nd track, the tension increases from 3.3 to 10 kV / m, at a distance of 8 m - from 1 to 3.5 kV / m. The values reach more than 15 kV / m at a distance from the contact wire to 40 cm, 10 kV / m to 60 cm, 5 kV / m to 1.2 m, then the intensity decreases sharply and at a distance of more than 6 m from the axis of each path The tension does not exceed 1 kV / m.

Table 2. The simulation results when there is voltage on one of the paths

№	Distance to the side of the path, [m]	EP Tension [kV/m]			
		At a height of 1.8 m		At a height of 1.8 m	
		Without taking into account the human body	Without taking into account the human body	Without taking into account the human body	Without taking into account the human body
1	0	2.26	4.12	26,50	26,50
2	2	1.83	1.83	3.40	3.40
3	4	1.20	1.46	2.70	2.70
4	6	0.68	0.68	0.75	0.75
5	8	0.42	0.42	0.38	0.38
6	10	0.33	0.33	0.32	0.32

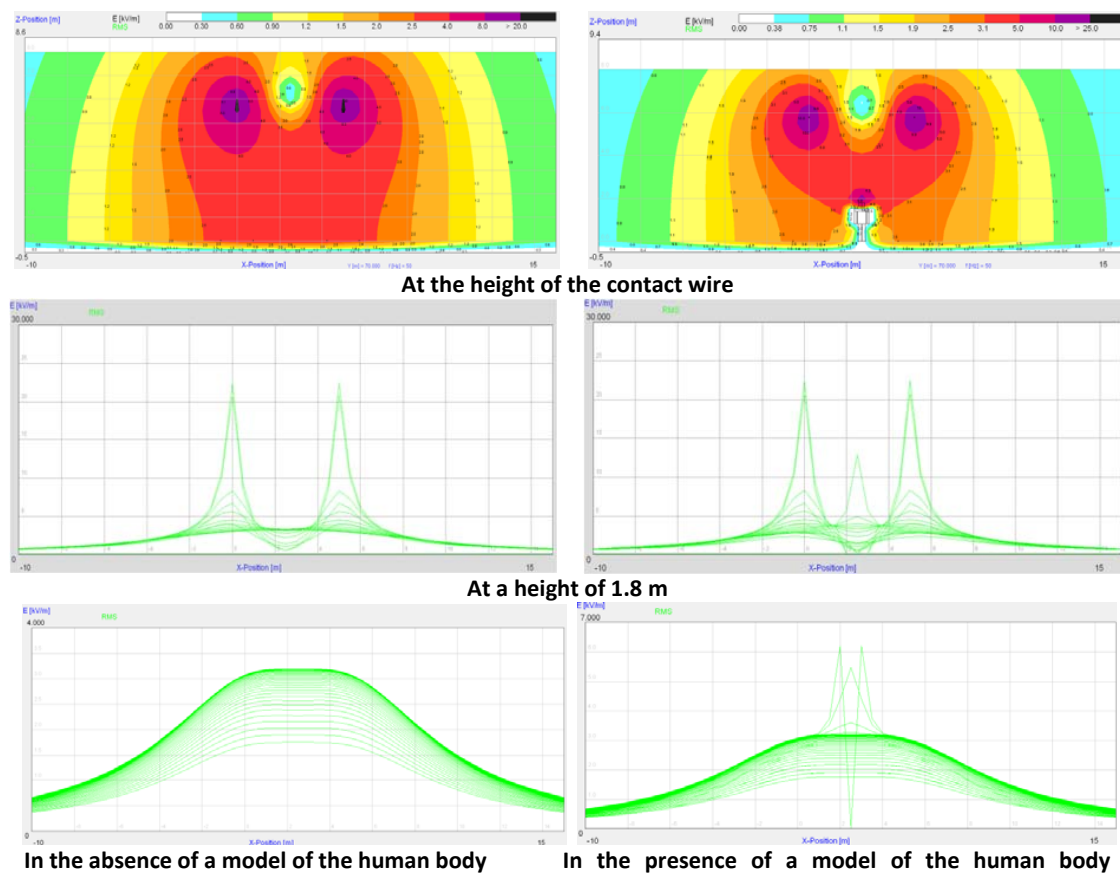


Figure 2. Dependences of the electromotive force intensity for a double-track section under voltage. From a distance away from the axis of the track and along the height

4. Results of modeling for a two-way site with one-way voltage availability

In the production of track works, maintenance of the compressor station and other infrastructure devices on double-track sections, there is often a situation where one of the paths is disconnected. Let us consider a two-track section in the absence and presence of a model of the human body in the absence of the stress of one path. The simulation results for such a case are shown in Table 2 and in Figure 3.

Analysis of the obtained dependences shows that the intensity of the EP 50 Hz at a height of 1.8 m reaches values of more than 2.2 kV / m above the axis of the path that is under tension. The intensity of the EP in Shoulder level and head of the human model increases to 6 kV / m only when located on the axis of the disabled path. When the personnel are at the level of the contact wire on the track axis with the voltage removed (on the support, in the insulating tower, on the site of the motor vehicle), the tension does not exceed 1 kV / m. In this case, the presence Railway transport depends on the location of personnel, the level of voltage, current, number of paths and other factors: (1), where x is the distance from the path axis, m; The human body in different areas can increase the tension at the level of the head and shoulders up to 4 kV / m (on the axis of the non-switched path) and up to 2 kV / m (on the axis of the disconnected path). The EP stress decreases rapidly depending on the distance away from the path axis.

At the height of the contact wire, the value of the voltage, regardless of the presence of a person standing on the axis of any path, is more than 25 kV / m (on the axis of the non-switched path) and more than 5 kV / m (on the axis of the disconnected path). Tension greater than 5 kV / m is observed at a distance of up to 20 cm from the contact wire. The presence of the human body model at the height of the contact wire (the disconnected path) increases the tension at the level of the head and shoulders up to 6 kV / m.

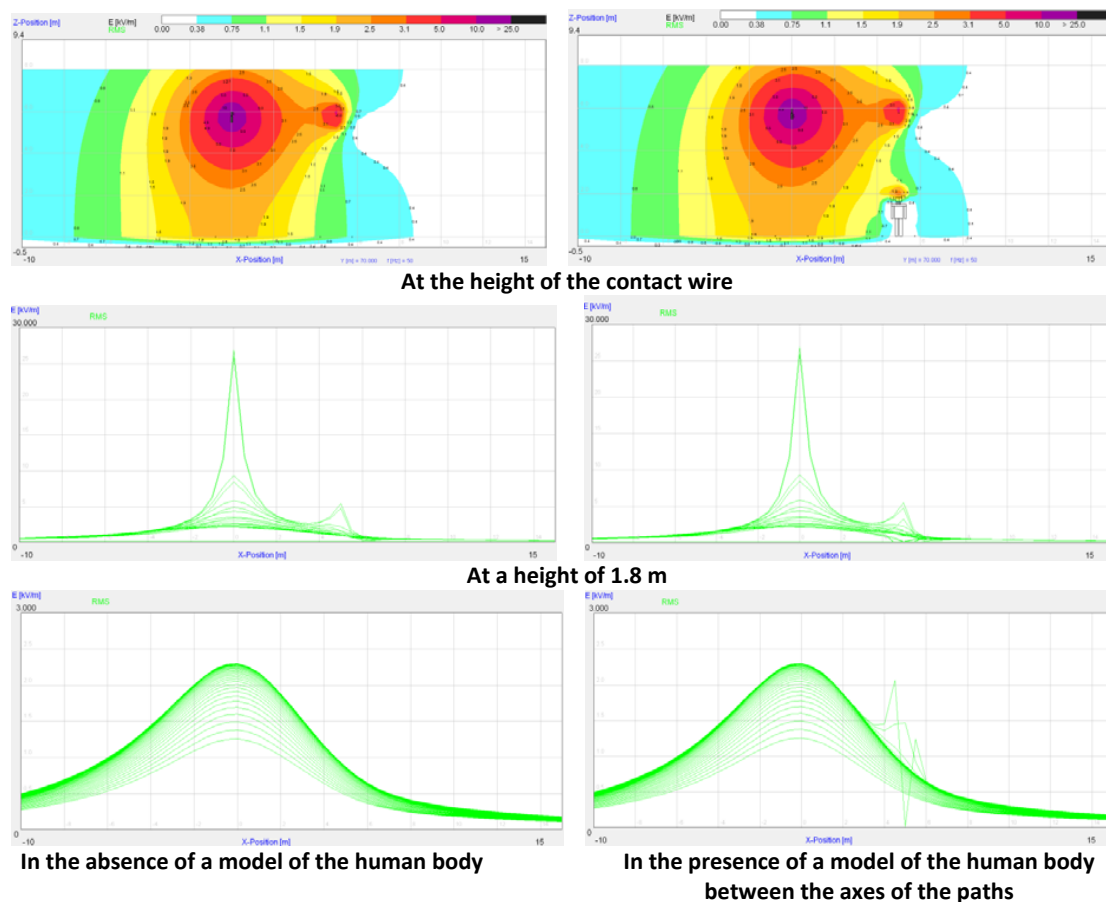


Figure 3. The distribution of the intensity of the ES of an alternating current of a two-path. Section in the presence of the voltage of one path and the model of the person on the axis of the path.

5. Conclusions

As a result of the conducted research using computer-aided mathematical modeling it was obtained that the parameters of the EP of the CS of railway transport depend on the location of the personnel, the voltage level, the current, the number of paths and other factors.

The following dependencies of the intensity of the ES in the workstations of the personnel from the indicated parameters were established:

1. At the AC of 25 kV single-path section, the voltage of 50 Hz EP at a height of 1.8 m reaches values of more than 2.4 kV / m, and at the height of the contact wire - more than 25 kV / m. The presence of a human model in the EP spread zone increases the tension at the head level by 1.67 times. On a double-track section, the voltage of 50 Hz EP at a height of 1.8 m reaches values above 3 kV / m above the track axes and 0.5 m away from the axis of each path, i.e. More in 1.32 times. The presence of a human model in the EP propagation zone distorts the lines of force, which increases the tension up to 1.9 times at the level of the head and shoulders. At the height of the contact wire, the tension value is more than 22 kV / m, which exceeds the standard values and requires the limitation of the operating time according to the sanitary norms and rules [6].
2. In the double-track section, in the absence of voltage in one of the tracks, the voltage of the EP 50 Hz at 1.8 m is more than 2.2 kV / m above the axis of the path that is under tension, which is 1.4 times less than the intensity If there is voltage in both ways. At the height of the contact wire, the value of the voltage is more than 25 kV / m on the axis of the unconnected path and more than 5 kV/m on the axis of the disconnected path, which exceeds the normalized values.
3. For a multi-path section (more than 2 paths), it was obtained that the EP voltage of 50 Hz at a height of 1.8 m reaches values above 3.5 kV / m above the 3-way axes in the center and more than 3 kV/m above the axes Extreme ways, i.e. More in 1.58 times in comparison with single-track section and in 1.19 times in comparison with two-track section. The presence of the human model increases tensions up to 1.7 times at the level of the head and shoulders. At the height of the contact wire, the value of the voltage is more than 20 kV / m and is observed at a distance of up to 20 cm from the contact wire of each path under voltage, which exceeds the normalized values.

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