INDUSTRIAL SAFETY AT THE ENERGY SITES OF ELECTRIFIED LINES

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ABSTRACT

Situation with labour safety and fire risk at railway transport facilities is studied and assessed at the example of railway electrified lines of JSC Russian Railways.

The industrial safety system at JSC Russian Railways has been developing for decades. In the new economic conditions, many of its basic principles have been preserved, but new factors have emerged that require scientific analysis, experimental verification, and modern technological tools.

In the course of the research, an assessment was made of labour safety situation at the energy sites of electrified lines of railways with particular regard to the use of a removable insulating tower for catenary repairs, assessment of high voltage hazards for employees, peculiarities of construction of fire protection compartments, fire risk calculations. It is concluded that the calculation of an individual fire risk cannot be used as a necessary and sufficiently autonomous basis for substantiating the size of fire compartments. The removable insulating tower carriage and shunt rod developed at Russian University of Transport are presented. Many conclusions have general character and are of universal interest.

Keywords: *railway, energy site, risk zones, occupational safety, contact network, removable insulating tower carriage, shunting rod, fire compartment.*

Background. *In the Russian Federation, about 50 % of the railways are electrified, the operators transport more than 80 % of cargo, and the share of passenger turnover on them is more than 41 % of total rail passenger turnover [1, p. 3].*

In recent years, the railways have been expanding operation of long heavy-weight trains, commissioning new electric rolling stock, increasing the speed of passenger trains and cargo density of electrified lines, followed by growing requirements for quality and reliability of traction power supply devices, especially the contact network.

The overhead contact system of JSC Russian Railways is a complex technical facility of electrified transport. The task of the service personnel is to constantly maintain the devices of catenary and overhead lines in a technically sound condition. To do this, it is necessary to know and carefully observe the safety regulations, quickly manage a difficult train situation, carry out preventive measures in a timely manner, and be able to perform maintenance work in a short time [1, 2].

Prediction of innovations to ensure safe working conditions at railway facilities and the use of new progressive initiatives as a condition for successful functioning of any enterprise are formulated in [3].

During the operation of network devices, various deviations from the standard state of individual elements and nodes appear. Checking the technical condition of overhead lines is a responsible work for the personnel of the contact network divisions.

Objective. *The objective of the authors is to consider selected industrial safety issues at the energy sites of electrified railways.*

Methods. *The authors use general scientific and engineering methods, comparative analysis, mathematical methods, methods of electrical engineering and of safety management.*

Results.

Risks under voltage

In the area of the overhead line, a considerable place belongs to works with a removable insulating tower, which are performed, as a rule, under voltage. In [2, 4], the order of conducting works and relevant regulations are studied.

In Russian University of Transport a new carriage and new own version of a shunt bar have been developed for an insulating tower.

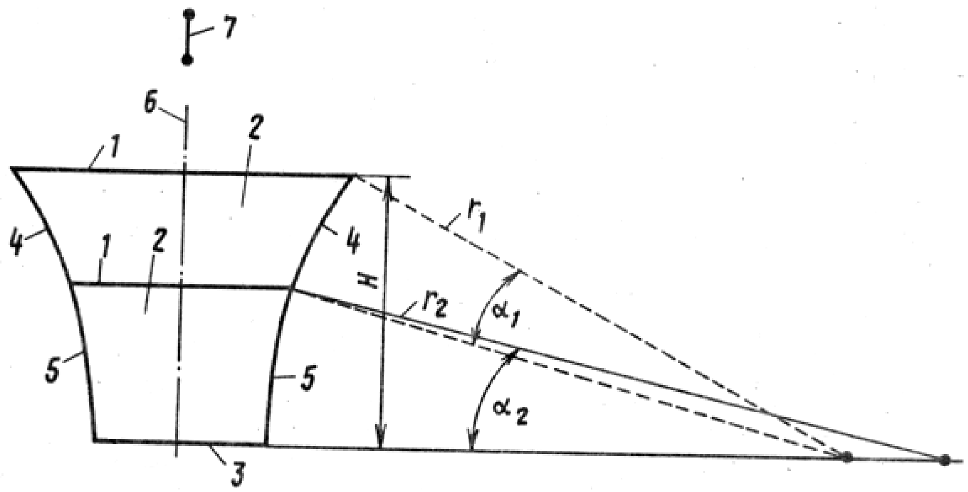
It was established experimentally [5, p. 3] that a carriage of an isolating removable tower for overhead line (Pic. 1) should consist of a metal frame 1 with a mesh fence 2 galvanically connected with a metal base 3. Each side wall of the metal frame 1 is made in the form of two conjugated cylindrical surfaces (4 and 5), which are caved-in regarding the carriage, and that have generatrix, parallel to the axis 6 of the contact network 7. The upper cylindrical surface 5 has a radius less than that of the bottom.

The time spent by staff in an electric field significantly depends on the field strength in the working area, where an insulating removable tower carriage is used, and the metal frame 1 is connected to the overhead line by shunting rods. Reducing the electric field in this case can be achieved by changing the design of the carriage. Moreover, the intensity in the working area is defined as the geometric (vector) sum of the strength of the contact network ($E_{c.n.}$) and the field strength created by the carriage ($E_{car.}$), as well as of the intensity of the overhead lines ($E_{o.l.}$) at the intersections.

In the working area, each of the vector sums of the electric field strength of the overhead line and the carriage (Pic. 2) will be directed relative to each other at an angle significantly exceeding 90º.

In the considered variant, the total strength decreases if the carriage surfaces 4 and 5, parallel to the axis of the contact network (Pic. 1), are made in the form of two cylindrical surfaces connected between each other and caved-in regarding the carriage. The centers of the radii of the surfaces are located in a plane passing through the base of the carriage.

When modeling the electric fields of a carriage of an insulating removable tower for an overhead line on electrically conductive paper, it was found that the following ratios of the geometric dimensions of the carriage are optimal: α_1/α_2 *= 0,85–0,95;* r_1/H *= 1,9–2,0;* r_2/H *= 2,0–2,6. If we take H = 95 cm, then* r_1 *= 1800–1900 mm;* r_2 *= 2370–2470 mm;* α_1 *= 13–15º;*



Pic. 1. The carriage of the isolating removable tower contact network:
1 – metal frame; 2 – mesh fencing; 3 – metal base;
4 – cylindrical surface; 5 – generatrix, parallel to the axis of the contact network;
6 – axis parallel to the contact network; 7 – contact network.

α_2 = 12–13º, where H is the height of the carriage, α_1 is the central angle of the arc of the surface 4, α_2 is the central angle of the arc of the surface 5, r_1 is the radius of the concave surface 4, r_2 is the radius of the concave surface 5.

It is in the presence of these characteristics that the total intensity of the electric field of the carriage and the electric field of the overhead line decreases to 40º or more.

To a lesser extent, the total electric field strength at the intersection of high voltage lines decreases, because the carriage must be galvanically connected to the overhead line, which is unacceptable to significantly reduce the modulus of the vector $E_{car.} + E_{c.n.} + E_{o.l.}$.

While omitting the testing, we note that shunting rods have an undoubted benefit for the staff, one of the variants of such a rod developed at the University of Transport is shown in Pic. 3.

Fire compartments

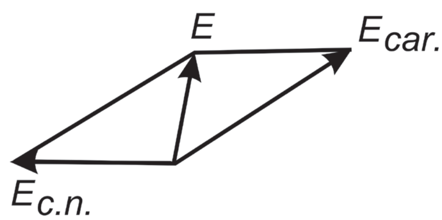
For the construction of buildings of the power supply facilities or of sections of the overhead line, the most important requirement is the need to divide them into fire compartments [6, pp. 8–33; 7, pp. 77–84]. Here an individual approach is needed, which leads to development and use of proper calculation methodology.

The division of the above mentioned buildings into fire compartments helps to limit the spread of fire beyond its seat. Most importantly, with fragmentation of working areas, formation of a fire protection system begins, and this task is realized in conjunction with planning, design and engineering design solutions.

One of the most significant criteria when choosing the maximum allowable fire compartment area is to take into account the tactical and technical capabilities of the fire and rescue units serving the territory.

The decision making algorithm for dividing the building into fire compartments in accordance with the existing system of technical regulation is focused primarily on compliance with the requirements of regulatory documents.

Considering the practices, engineering solutions are substantiated mostly by calculations. However,



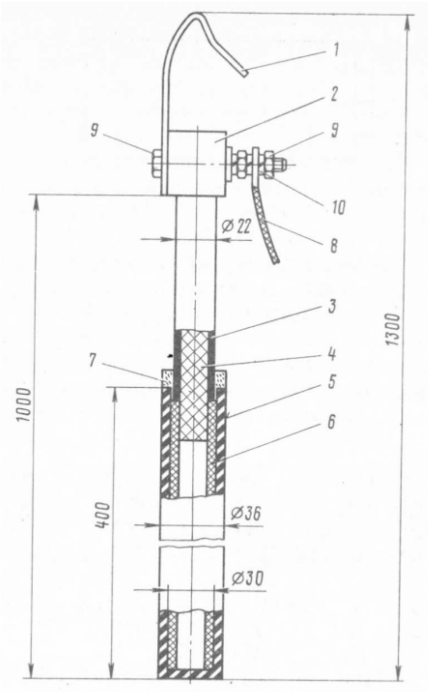
Pic. 2. Picture of the electric field strength in the area where the employees are located when working on the tower and being under the influence of the voltage:
$E_{c.n.}$ – vector of the electric field of the contact network; $E_{car.}$ – vector of the electric field of the carriage; E – the total vector of the electric field strength.

historically, for a number of reasons, fire-fighting solutions, including the design of fire compartments, are based primarily on regulations. This is natural because, as an integral part of the construction process, design requires minimal analysis and less time spent on preparing design solutions.

It is clear that the prescriptive rules may have their drawbacks. In particular, situations are possible when two buildings, designed according to the same standards and having the same class of functional fire hazard, will have different levels of safety for people and property in case of fire.

The designer often meets a challenge: on the one hand, one must obey the requirements of the standards, and on the other hand, the functional needs of the building customer must be met. Often questions arise regarding the binding of certain regulatory requirements to the specific features of the designed building. Prescriptive rules may be too conservative and therefore unreasonably expensive to be implemented. It is not by chance that sometimes they are «replaced» by generalized practices and compromise mutual agreements without serious engineering study [8–11].

For dividing the buildings of a power supply facility or of a catenary power feeding section into fire compartments, fire walls and ceilings of the 1st type



Pic. 3. Shunt shaft of a removable tower:
1 – copper hook; 2 – tip; 3 – PTFE tube; 4 – fiberglass rod; 5 – rubber coating; 6 – fiberglass tube; 7 – sealing ring; 8 – flexible copper wire; 9, 10 – fasteners.

are used. Fire resistance limits for them are set out in Table 23 of the Technical Regulations on Fire Safety Requirements [6] as no less than REI 150. The constructive fire hazard class of fire barriers is independent of the energy hazard class of a section of overhead line facility.

The fundamental difference between a building structure used as a fire barrier and a building structure with a standardized fire resistance is the requirement for appropriate filling of apertures in the barrier.

When dividing buildings and structures into compartments, one should comply with the regulations aimed at non-proliferation of fire, bypassing fire prevention obstacles.

Fire walls should be erected to the entire height of the building or up to fire ceilings of the 1st type and must ensure that fire does not enter the adjacent fire compartment, including during unilateral collapse of structures from the side of a source of fire.

The places of conjugation of fire-prevention walls, ceilings and partitions with other protecting structures of the fire compartment should have a fire resistance limit of no less than each other.

Fire safety of the object of protection is considered to be provided if the object fully complies with the regulations adopted in accordance with the Federal Law «On Technical Regulation» (dated 27.12.2002 No. 184-FZ), and the fire risk does not exceed permissible values. Proof of this is either compliance with regulatory documents on fire safety, or calculation of fire risks with the mandatory compliance in any case with the requirements of technical regulations.

Hence the task is to consider the possibilities provided by the calculation of individual fire risk to justify the size of fire compartments.

Fire risk calculation

The calculation procedure is established by the order of the Emergency Situations Ministry of June 30, 2009 No. 382 «On approval of the methodology for determining the calculated values of fire risk in buildings, structures and structures of various classes of functional fire hazard» and by the Order of the Emergency Situations Ministry of July 10, 2009 No. 404 «On approval methods for determining the calculated values of fire risk at production facilities» [8, 12].

Calculations for fire risk assessment are carried out by comparing the presented data with standard values. The identification of the calculated risk values is carried out on the basis of:

a) analysis of the fire hazard of buildings;

b) frequency of fire situations;

c) construction of matrix of fire hazard factors for various scenarios of its development;

d) assessing the effects of fire hazards on people;

e) availability of fire safety systems for buildings.

The numerical expression of an individual fire risk is the frequency of exposure to fire hazards (FH) of a person in a building.

The frequency of exposure to FH is determined for a fire-hazardous situation, which is characterized by the greatest danger to life and health of people in the building.

An individual fire risk meets the required one, if:

$$Q_V \le Q_V^S, \quad (1)$$

where Q_V^S *– standard value of individual fire risk,*

$Q_V^S = 10^{-6}\, year^{-1}$;

Q_V *– calculated value of individual fire risk.*

Calculated value Q_v *in each task is calculated according to the formula:*

$Q_v = Q_f \cdot (1-R_{af}) \cdot P_{pr} \cdot (1-P_e) \cdot (1-P_{f.p.})$, (2)
where Q_f – frequency of fire in the building during the year, is determined using statistical data;

R_{af} – probability of effective response of automatic fire extinguishing installations (AFEI). The value of the parameter R_{af} is determined by the technical reliability of AFEI elements. If there are no automatic fire extinguishing systems in the building, R_{af} is assumed to be zero;

P_{pr} – probability of presence of people in the building, determined from the ratio $P_{pr} = t_{funct}/24$, where t_{funct} – time spent by people in the building in hours;

P_e – probability of evacuation of people;

$P_{f.p.}$ – probability of effective operation of the fire protection system, aimed at ensuring safe evacuation of people in case of fire.

The probability P_{fp} is calculated by the formula:

$$P_{FP} = 1-(1-R_{upd} \cdot R_{SOUE}) \cdot (1-R_{upd} \cdot R_{SP}) \quad , \qquad (3)$$

where R_{upd} – probability of effective response of the fire alarm system;

R_{SOUE} – conditional probability of an effective response of the fire alarm system and the evacuation control of people in the event of an effective fire alarm system;

R_{SP} – conditional probability of effective operation of the smoke protection system in the case of an effective fire alarm system.

As can be seen from the above formulas, the method for calculating fire risk does not contain indicators depending on the area of the fire compartment or its height. The safety of people is ensured by the proper arrangement of escape routes and technical fire protection systems. The dimensions of the fire compartments have only an indirect effect on security decisions.

And here there are two serious moments associated with the existing methods.

First: the calculation of fire risk, made in accordance with the methodology, cannot be a basis for justifying non-compliance with the provisions of regulatory documents.

The second point: the provisions of the Federal Law «Technical Regulations on Fire Safety Requirements» dated July 22, 2008 No. 123-FZ (as amended on 27.07.2017), in particular, Art. 87 that «the degree of fire resistance of buildings, structures and fire compartments should be set depending on their number of floors, functional fire hazard class, fire compartment area and fire hazard of the technological processes occurring in them» should be taken into account at the design stage. If the requirements of the regulatory documents for the fire compartment area are not fulfilled, naturally, the requirements of the federal law that the fire resistance level must correspond to the fire compartment area are not met.

Conclusions. *In the course of the research, an assessment was made of labour safety situation at the power supply and feeding facilities of electrified lines of railways, and besides:*

a) the removable insulating tower carriage and shunt rod developed at Russian University of Transport were presented;

b) it was established that the calculation of an individual fire risk cannot be used as a necessary and sufficient basis for substantiating the size of fire compartments.

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