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Development of a Model of Current Distribution in the Overhead Contact Lines for an Innovative de-Icing System

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Summary
Icing on the overhead contact line exclude the possibility of efficient current collection from the overhead contact line. The effects of icing can result in losses for carriers due to delay or cancellation of trains and also cases of damage to the traction infrastructure and pantographs. The existing methods of de-icing the traction network (mechanical, chemical and electrical) are currently ineffective. Therefore, it is necessary to develop a new electrical method that takes into account the detailed current flow in the overhead contact line. This article presents a model for calculating the current flow in the overhead contact line and the resistances of droppers, suspension elements, and distance holders measured on the basis of actual measurements.

Keywords: simulation model, de-icing of the contact line, current flow in the contact line

1. Introduction

Icing of the overhead contact line has many negative effects. Among them are, delays or total cancellations of train movements, overloading and winding of the overhead contact line, burning of the electric arc between the pantograph and the contact wire to the most costly, and dangerous collapse of the supporting structures for human life can be distinguished.

Existing de-icing methods can be divided into: mechanical, chemical, and electrical. The first one includes: de-icing with a special device (Fig. 1) or de-icing with an insulated rod (Fig. 2), Mechanical methods are extremely labor-intensive, dangerous for people

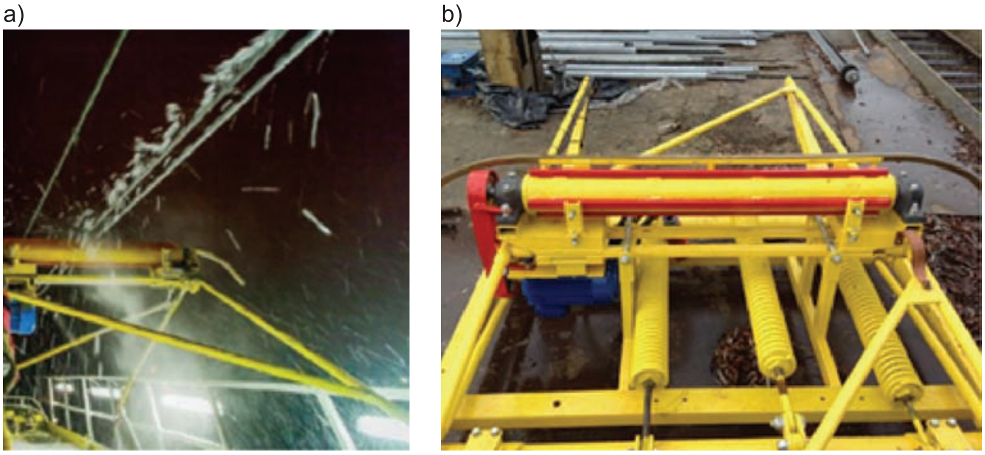

Fig. 1. De-icing device type USO-1A [1]: a) view of the device during operation, b) view of the dismantled device

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performing these activities. In addition, the geometry of the overhead contact line may be compromised.

Fig. 2. Mechanical de-icing of the catenary with an insulated rod [2]

Chemical de-icing methods consist the application of chemicals that significantly hinder the formation of icing on the contact line. The disadvantages of chemical methods are their short duration of operation and significant pollution of the environment. Existing electrical methods are either inefficient or have no heating current control or do not adjust the value of the heating current to the existing weather conditions.

In order to create a new and innovative system for de-icing the contact line, it is necessary to create a model of current distribution in catenary networks, taking into account such parameters as: suspension elements, catenary wire and contact wire, coupling handles, suspension elements (cantilever, push-off cantilever and steady arms), and other electrical and mechanical connections made of conductive materials.

The authors of the publication [3] have developed a model of current distribution with an indication of places where excessive temperature increases occur when freight trains pass.

The [4] authors of the article conducted tests and tests of the actual current capacity of the overhead contact line. Temperature increments were calculated for individual types of contact lines and catenary wires in different weather conditions.

The authors of the paper [5] created a mathematical model taking into account kinematic equations, railway traffic control issues, voltage in the overhead contact line, power demand, and its consumption based on actual measurements.

The authors of the publication [6, 7] created a model for calculating asymmetrical reverse current for the AC power supply system.

Analysing the above literature, there is a need to create a simulation model for calculating the current distribution in the DC system overhead contact line.

2. Simulation model of the overhead contact line for calculation of current distribution

The elements of the overhead contact line are electrically connected to each other as a system in which the contact lines and the catenary wire are the main electrical energy carriers. The contact line and the catenary wire work in parallel and are connected transversely through droppers, coupling handle, suspension elements (cantilever, push-off cantilever and steady arms) and other electrical and mechanical connections made of conductive materials.

The model for simulation tests of current distribution in the upper overhead contact line should take into account all these elements and connections. It should also take into account the electrical parameters of the components and the connections between them. The overhead contact line consists of bays of equal normal length and design for the whole network of the specified type. Therefore, in order to limit the size of the model, it was decided to map one span. This model is to be used because of simulation tests of current distribution in network types with wires of 150 mm^2 and 120 mm^2. For this reason, a span of 62 m was adopted, which occurs in both types of the modelled network. In addition, the spacing between the droppers is the same for both types. Since the overhead contact line system operating in the DC system is considered, only resistive elements are present in the model. The arrangement of the developed model is shown in Figure 3.

The values of the model elements were determined using the calculation or measurement method. The resistances of the catenary wire sections (RL), the stich wire „Y" (RLy) and the contact line (Rpj) were calculated as the product of the resistance of 1 m of the wire or rope and the length of the wire or rope between the nodes. Due to the occurrence of mechanical connections, the measurement method was used to determine the resistance of droppers (Rw) in order to avoid complicated calculations. The resistance of the transition between the catenary wire and the dropper and the dropper and contact wire was measured, while the resistance of the dropper rope was calculated. Electrical connection resistance (Re) was determined in a similar way. All calculations were made taking the unit values of the resistance of the wires and cables presented in Table 1.

Resistance of other elements: suspension elements (Rs) and coupling handles (Rr) were determined on the basis of measurements in the laboratory of the Department of Electrical Power Engineering of the Railway Institute. All measurements were made on three samples for four current values, and the average value of all measurements was adopted as the final measurement result. The results of all measurements are presented in Tables 2–4, while the dropper resistance in Table 5.

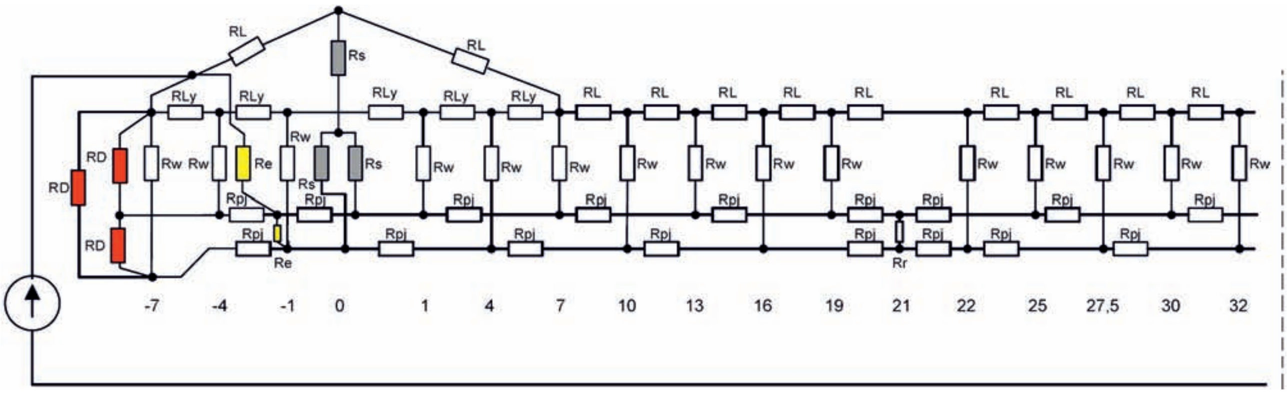

Fig. 3. A fragment of upper overhead contact line model diagram [authors' own work]

Table 1

Unit values of resistance of wires

Type of wire		Unit resistance [mW/m]
Symbol	**Name or function**	
DjpS150	Contact wire with a cross-section of 150 mm^2	0.1167
L10	Dropper rope with a cross-section of 10 mm^2	1.77
L35	Flexible rope "Y" with a cross-section of 35 mm^2	0.5159
L120	Support rope with a cross-section of 120 mm^2	1,540
L150	Support rope with a cross-section of 150 mm^2	1183
$L_2$185	Rope for electrical connections with a cross-section of 150 mm^2	1,015

[Authors' own work].

Table 2

Result of transition resistance measurements – catenary wire – dropper and dropper – contact wire

Current [A]	Transition resistance of the catenary wire – dropper [mW]	Transition resistance contact wire – dropper [mW]	Total transition resistance [mW]
Sample 1			
5	0.46	0.48	0.94
10	0.42	0.45	0.87
15	0.39	0.45	0.84
50	0.40	0.50	0.90
Sample 2			
5	0.41	0.51	0.92
10	0.44	0.49	0.93
15	0.45	0.54	0.99
50	0.43	0.51	0.94
Sample 3			
5	0.44	0.47	0.91
10	0.45	0.45	0.90
15	0.42	0.51	0.93
50	0.47	0.48	0.95

[Authors' own work].

In the developed model, two sources were used to simulate the current distribution with one and two-sided power supply. The current is received from the network through the (Ro) resistor, the value of which regulates the total load current of the network. RD resistors are mapping adjacent spans.

Table 3

Resistance measurement results of suspension elements

Current [A]	Resistance of the steady arms together with the contact wire mounting [mW]	Resistance between the steady arm and the catenary wire [mW]
Sample 1		
5	6,94	1.54
10	6.85	1.60
15	6.86	1.55
50	6.89	1.45
Sample 2		
5	6.83	1.56
10	6.85	1.52
15	6.89	1.59
50	6.90	1.48
Sample 3		
5	6.77	1.51
10	6.86	1.48
15	6.88	1.50
50	6.89	1.51

[Authors' own work].

Table 4

Result of measurement of resistance of coupling handles

Current [A]	Sample 1 [mW]	Sample 2 [mW]	Sample 3 [mW]
5	0.061	0.048	0.051
10	0.048	0.049	0.056
15	0.052	0.051	0.049
50	0.048	0.053	0.050

[Authors' own work].

Table 5

Dropper resistance with connections [mW]

Location of the dropper – distance from the pole [m]	The net with a catenary wire with a cross-section of 150 mm^2	The net with a catenary wire with a cross-section of 120 mm^2
−7	2.513	2.325
−4	2.122	1.934
−1	1.933	1,745
1	1.933	1,745
4	2.122	1.934
7	2.513	2.325
10	2.678	2,473
13	2.458	2.227
16	2 273	2,019
19	2,121	1,849
22	2 003	1.716
25	1.917	1.620
27.5	1,872	1.569
30	1.850	1.544
32	1.850	1.544
34.5	1,872	1.569
37	1.917	1.620
40	2 003	1.716
43	2,121	1,849
46	2 273	2,019
49	2.458	2.227
52	2.678	2,473
55	2.513	2.325
58	2.122	1.934
61	1.933	1,745
63	1.933	1,745
66	2.122	1.934
69	2.513	2.325

[Authors' own work].

3. Conclusions

This article showed that the currently used methods of de-icing the overhead contact line are ineffective. Mechanical methods are time-consuming and dangerous for the crew who perform them. Chemical methods are harmful to the environment and are not 100% effective. Electrical methods do not have heating current regulation, do not take into account the degree of wear of the contact wire and do not take into account weather conditions. For this reason, it is necessary to create a new innovative method. For this purpose, a simulation model for current distribution was created. Above, the values of unit resistance of contact line and catenary wires, resistances of suspension elements, droppers and coupling handles, calculated and obtained as a result of actual measurements, are presented. The presented results are one of the stages of creating a new innovative method of de-icing the overhead contact line. In the following publication will be discussed the simulation of current distribution in catenary wires.

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