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SIMULATION OF CURRENT DISTRIBUTION THROUGH ELEMENTS OF THE OVERHEAD CONTACT LINE
Symulacja rozpływu prądu przez elementy sieci jezdnej

Abstract: *The compilation of unfavourable weather conditions, such as negative temperature and high humidity, leads to the formation of an ice layer and deposits on the elements of the overhead contact line, which leads to its degradation and prevents the supply of electricity to the traction vehicle. The traction line is located on a very large area and it is extremely difficult to effectively remove the remaining layers of ice. During planning the anti-icing measures it's very important to know the current distribution in wires. The authors of the article analysed the catenaries operated in Poland and in EU in terms of the current distributions in contact and catenary wires in through spans. The approach presented in this paper allows to take into account the wear of the contact wires during calculations of the current distributions.*
Keywords: traction network, de-icing, current distribution, simulation

Streszczenie: *Szereg niekorzystnych warunków atmosferycznych, takich jak ujemna temperatura i wysoka wilgotność, powoduje powstanie warstwy lodu i osadów na elementach sieci trakcyjnej, co prowadzi do jej degradacji i uniemożliwia dostarczanie energii elektrycznej do pojazdu trakcyjnego. Sieci trakcyjne znajdują się na rozległych obszarach i niezwykle trudno jest skutecznie usunąć warstwę lodu. Podczas planowania czynności mających na celu odlodzenie sieci jezdnych bardzo ważna jest znajomość rozpływu prądu w przewodach. Autorzy artykułu przeanalizowali sieci trakcyjne eksploatowane w Polsce i w UE pod kątem rozpływu prądów w przewodach jezdnych i linach nośnych w całym przęśle naprężenia. Przedstawione w niniejszej pracy podejście pozwala na uwzględnienie zużycia przewodów jezdnych podczas obliczeń rozpływu prądów*
Słowa kluczowe: sieć trakcyjna, odladzanie, rozpływ prądu, symulacja

1. Introduction

The problem of the occurrence of icing affects the proper functioning of all railway infrastructure managers with a traction network, including the largest manager in the country, i.e. PKP PLK S.A. It is therefore crucial to eliminate the impact of adverse weather conditions. The solution to the problem is to create an innovative power supply system for the overhead contact line elements, which will act as a current generator with appropriate parameters in order to increase the temperature of the contact wires, which in turn will prevent the formation of icing and frost for specific external conditions. An important stage in the creation of such a system is the simulation of current distribution in overhead contact lines, taking into account the wear of contact wires. There are various models of current distribution in contact networks [1]: a model of natural current distribution, linear analytical models, model with an infinite number of droppers, a model with a direct application of Kirchhoff's circuit laws in matrix form, and a finite element model [2]. In the existing publications, the wear of contact wires was not taken into account for the calculations of current fluxes [1-3]. This is a very important operating factor that affects the current flow. The work [4] discusses a model of the overhead contact line, the parameters of which were calculated on the basis of measurements in the laboratory of the Railway Institute. The article analyses all types of catenary operated on railway lines, in Poland and in Europe in terms of the number of contact wires and the number of catenary cables and stitch wires [5-8]. The distribution of current in contact lines was analysed in through spans, taking into account the wear of the contact wire.

2. Overhead contact line model for current distribution simulation

The analysis of current distribution in the overhead contact line was made on the basis of the overhead contact line model. In the proposed model, the elements of the overhead contact line are electrically connected to each other, constituting a system in which the contact wires and the catenary wire are the main carriers of electricity. The contact wires and the catenary wires work in parallel and are connected transversely through droppers, braces, suspension elements (cantilever, steady arms) and other electrical and mechanical connections made of conductive materials.

The simulation model of current distribution in the overhead contact line should take into account all these elements and connections. The input data for the construction of catenary models were catalogue data [5-8,15,16]. Network nodes are all points where at least two elements that make up a model are connected. Since the overhead contact line system operating in the DC system is considered, only resistive elements are present in the model. The fragment of the model of the span of contact line (screenshot of the "EasyEDA" simulation software window [9]) is shown in fig. 1.

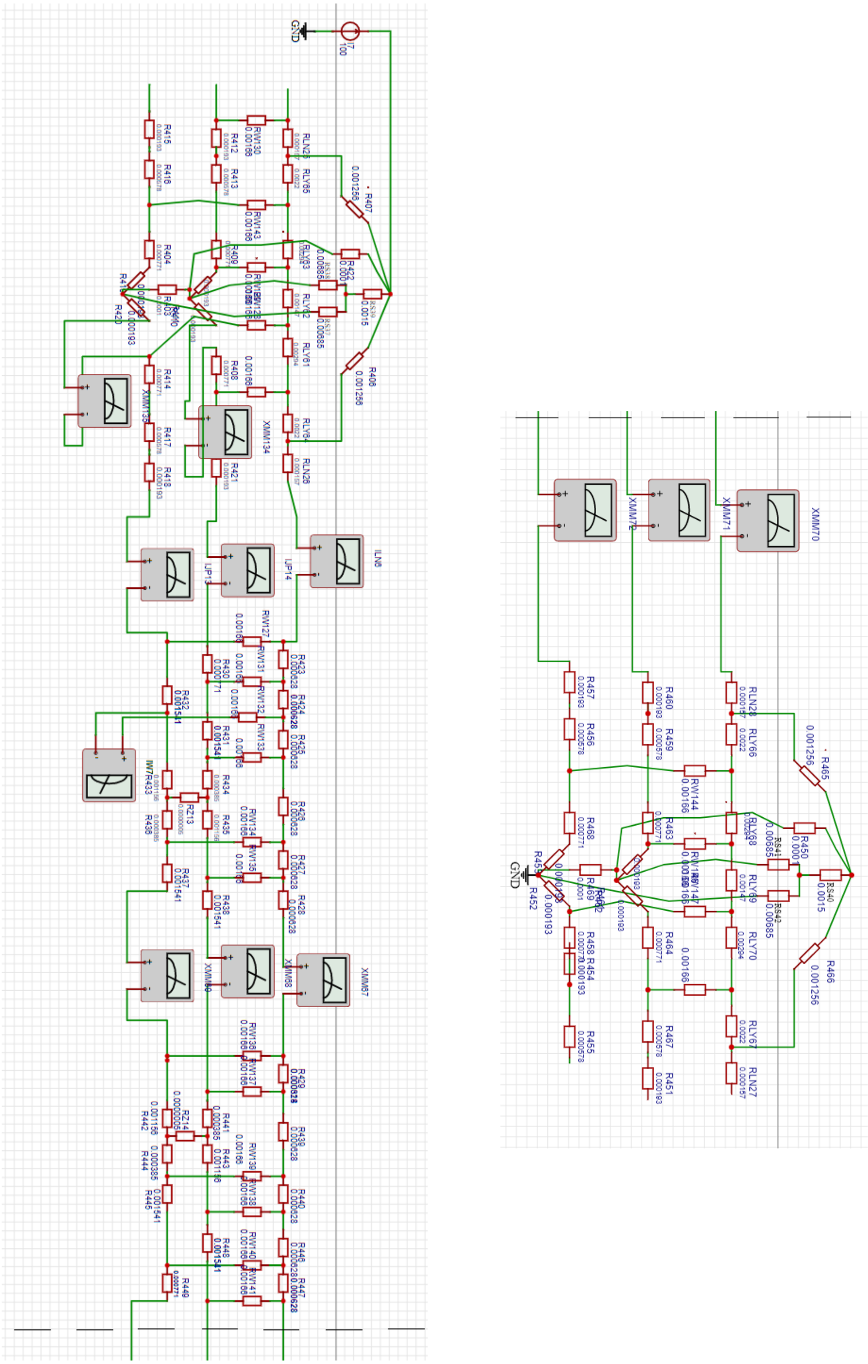

Fig. 1. Model of the contact line span in EasyEDA programme

The resistances of the model elements were calculated as follows: the suspension elements (Rs) and braces (Rr) were determined on the basis of measurements. 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 [4].

The resistances of the catenary wire sections (RL), the stitch wire "Y" (RLy) and the contact wires (Rpj) were calculated as the product of the resistance of 1 m of the wire and the length of the wire between the nodes. In order to simplify the calculations in the model, the average values of the droppers' length were adopted for the calculation of their resistance Rw. Electrical connection resistance (Re) was determined in a similar way. All calculations were made assuming the unit values of resistance of wires as in Table 1.

Table 1

Unit resistivity values [10-14]

Type of wire		Resistivity, Ω\m
Symbol	Name or function	
DjpS150	Contact wire with a cross-section of 150 mm^2	0.1167
L10	Dropper wire with a cross-section of 10 mm^2	1.77
L35	Stitch wire "Y" with a cross-section of 35 mm^2	0.5159
L120	Catenary wire with a cross-section of 120 mm^2	1.540
L150	Catenary wire with a cross-section of 150 mm^2	1.183
L185	Wire for electrical connections with a cross-section of 185 mm^2	1.015
Djp100	Contact wire with a cross-section of 100 mm^2	0.183

3. Calculated method

All calculations were carried out in the EasyEDA simulation software [9] based on the model of through spans. For pass-through spans was carried out an analysis of the impact of contact wire wear on the nature of current distribution in the contact line (for values of wearing 0, 5, 10, 15 and 20%). The analysis of current distribution for the tension spans was carried out for two types of the catenary lines 2C120-2C-3 and YC150-2CS150 (contact wire wearing 0%).

4. Results of current distribution analysis

Contact lines on railway network in Poland can be divided in terms of construction into:

- with one contact wire, e.g. C95-C,
- with two contact wires, e.g. YC120-2C,
- with one supporting rope, e.g. C95-C,
- with two supporting ropes, e.g. 2C120-2C-3,
- with stitch wire Y and without Y.

The tension of one contact wire varies between 637 daN and 1483 daN. For catenary wires, these forces are be between 953 daN and 2012 daN. In addition, the stitch wire of the 2C120-2C-1 contact line is tensioned with a force of 500 daN. The conducted analyses, field and laboratory tests of the overhead contact line show that:

• 28 types of contact lines were created at the PKP,

• currently, 9 types of catenary are used in new overhead contact line projects; these are contact line with numbers 3 (C120-2C), 4 (C95-2C), 10 (C95-C), 26 (YwsC120-2C), 30 (YwsC120-2C-M), 32 (2C120-2C-3), 35 (2C120-2C-4), 36 (YC150-2CS150), 37 (YC150-2CS150), according to the Catalog [8].

Table 4 and Fig. 2 - present the results of the analysis of current distribution in the analyzed traction line in spans.

The distribution of currents in the tension span for contact lines 2C120-2C3 and YC150-2CS150 for analyzed contact lines is presented in Tables 2-4.

Table 2

Current distribution in the overhead contact line 2C120-2C-3 tension span

Contact wire wear,%	Current share in catenary wire I_{LN}, %	Current share in the first contact wire, $I_{Djp\ 1}$,%	Current share in the second contact wire, $I_{Djp\ 2}$,%	Mean current share in contact wire, $I_{Djp\ sr}$, %	Total value of current share in contact wires, $I_{Djp\ sum}$, %
0	17.7	15.4	15.7	15-55	31.1

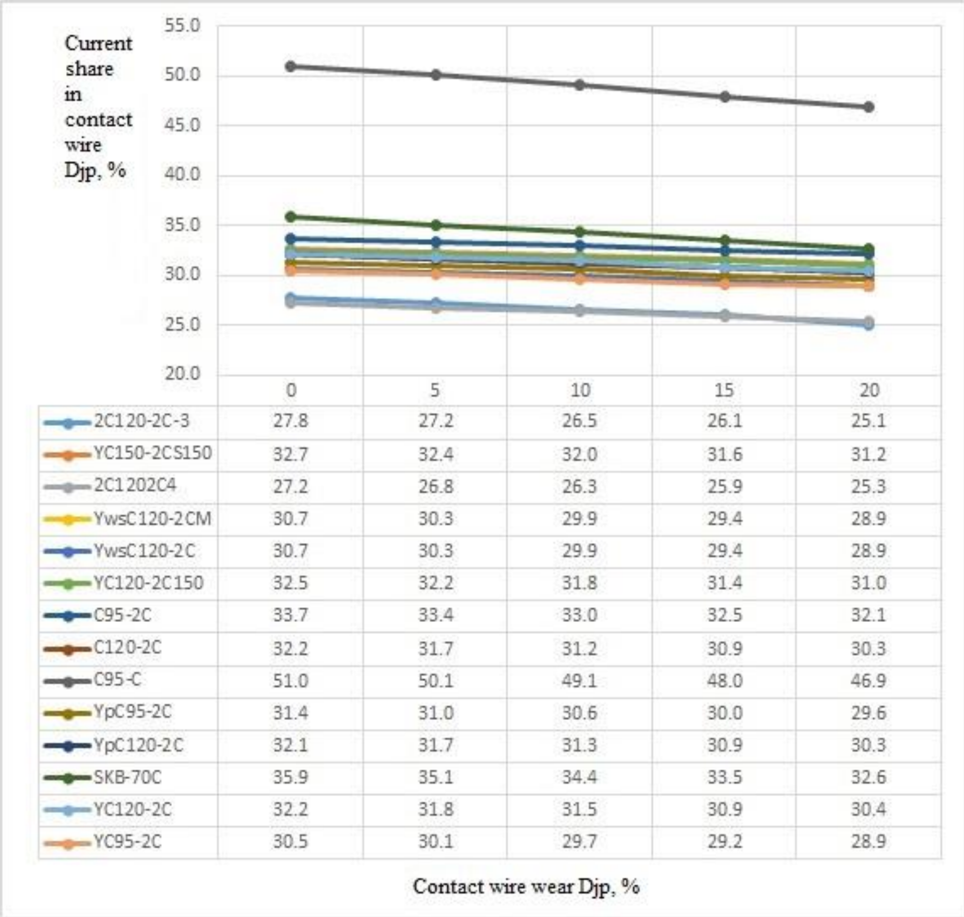

Fig. 2. Current in contact wire Djp for analyzed contact lines depending of wearing

Table 3

Current distribution in the overhead contact line YC150-2CS150 tension span

Contact wire wear, %	Current share in catenary wire ILN, %	Current share in the first contact wire, $I_{Djp\,1}$,%	Current share in the second contact wire, $I_{Djp\,2}$,%	Mean current share in contact wire, $I_{Djp\,sr}$, %	Total value of current share in contact wires, $I_{Djp\,sum}$, %
0	16.6	16.6	16.7	16.65	33

Table 4

Current distribution in the analysed overhead contact lines

Type of Overhead Contact line	Contact wire wear, %	Resistivity of overhead contact line, Ω/km	Current share in catenary wire I_{LN}, %	Mean current share in contact wire, $I_{Djp\ sr}$, %	Total value of current share in contact wires, $I_{Djp\ sum}$, %
2C120-2C-3	0	0.0418	46.051	27.847	55.694
	5	0.0428	46.478	27.588	55.176
	10	0.04378	46.297	26.52	53.04
	15	0.04486	47.653	26.0775	52.155
	20	0.046	48.401	25.055	50.11
YC150-2CS150	0	0.0385	34.631	32.6845	65.369
	5	0.0398	35.272	32.364	64.728
	10	0.04124	35.984	32.008	64.016
	15	0.0426	36.767	31.6165	63.233
	20	0.0443	37.612	31.194	62.388
2C120-2C-4	0	0.0418	45.608	27.196	54.392
	5	0.0428	46.439	26.781	53.562
	10	0.04378	47.326	26.337	52.674
	15	0.04486	48.28	25.86	51.72
	20	0.046	49.311	25.345	50.69
YwsC120-2C	0	0.05614	38.593	30.709	61.418
	5	0.057986	39.377	30.3115	60.623
	10	0.059754	40.21	29.8955	59.791
	15	0.061784	41.129	29.4355	58.871
	20	0.064034	42.132	28.934	57.868
YC120-2C150	0	0.0405	34.972	32.514	65.028
	5	0.042	35.673	32.1815	64.363
	10	0.04361	36.37	31.815	63.63
	15	0.0451	37.155	31.427	62.854
	20	0.047	38.034	30.983	61.966
C95-2C	0	0.0621	32.469	33.7655	67.531
	5	0.0644	33.25	33.3755	66.751
	10	0.0666	34.071	32.9645	65.929
	15	0.0692	34.918	32.509	65.018
	20	0.072	35.767	32.117	64.234
C120-2C	0	0.0574	35.604	32.1985	64.397
	5	0.0593	36.418	31.441	62.882
	10	0.0612	37.448	31.2765	62.553
	15	0.0633	38.241	30.88	61.76
	20	0.06567	39.268	30.366	60.732
C95-C	0	0.0941	48.962	51.038	51.038
	5	0.09675	49.895	50.105	50.105
	10	0.0992	50.883	49.117	49.117
	15	0.102	51.943	48.057	48.057
	20	0.105	53.075	46.925	46.925
YpC95-2C	0	0.061	37.31	31.345	62.69

	5	0.063	38.124	30.9385	61.877
	10	0.065	38.983	30.5085	61.017
	15	0.0674	39.926	30.037	60.074
	20	0.07	40.948	29.5255	59.051
YpC120-2C	0	0.05614	35.805	32.0975	64.195
	5	0.057986	36.633	31.6835	63.367
	10	0.059754	37.446	31.2775	62.555
	15	0.061784	38.373	30.8135	61.627
	20	0.064034	39.381	30.3095	60.619
SKB-70C	0	0.1095	64.111	35.889	35.889
	5	0.113	64.856	35.144	35.144
	10	0.1163	65.641	34.359	34.359
	15	0.12	66.48	33.519	33.519
	20	0.1243	67.38	32.62	32.62
YwsC120-2C-M	0	0.05614	38.547	30.7265	61.453
	5	0.057986	39.354	30.323	60.646
	10	0.059754	40.2	29.9005	59.801
	15	0.061784	41.132	29.434	58.868
	20	0.064034	42.148	28.926	57.852
YC120-2C	0	0.05614	35.6	32.2	64.4
	5	0.057986	36.403	31.7985	63.597
	10	0.059754	37.005	31.4975	62.995
	15	0.061784	38.187	30.9065	61.813
	20	0.064034	39.201	30.3995	60.799
YC95-2C	0	0.061	38.956	30.522	61.044
	5	0.063	39.975	30.1025	60.205
	10	0.065	40.678	29.671	59.342
	15	0.0674	41.646	29.1775	58.355
	20	0.07	42.693	28.6535	57.307

5. Conclusion

1. On the basis of the conducted analysis of current distribution in 14 traction lines in spans, the following was found:

- the distribution of currents is influenced by the design of the overhead contact line and the wear of contact wires. Wear of contact wires reduces the percentage of current in the contact wire. For the analyzed overhead contact lines with two contact wires, the average percentage of current in one contact wire varied from 35.9% to 25.1% of the overhead contact line current depending on the value of contact wire wearing,
- for the C95-C overhead contact line, the average percentage of current in the contact wire varied from 51% to 46.9%.

In the other analyzed traction lines listed in Table 1, the nature of current distribution in the spans is the same.

2. The current distribution in the spans of the contact lines 2C120-2C3 and YC150-2CS150 differs significantly from the current distribution in the spans.

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