International Journal of Engineering & Technology, 7 (4.3) (2018) 201-205

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Diagnostics of the 3 Kv DC Traction Power Network

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Abstract

The railway traction network line is one of the technical elements ensuring proper operation of railway traffic. Due to its technical function and specificity, it is an essential element of the railway infrastructure. That is, why diagnostics of traction networks is a very important issue. In the article, the authors presented issues related to the diagnostics of 3kVDC traction networks. An analysis of traction network faults for a group of power supply areas was also presented. Additionally, calculations of damage indicators in a selected, representative power supply area are presented. On the basis of made an analysis authors proposed solutions aimed at minimizing breakdowns in traction networks.

Keywords: *assessment indicators, traction diagnostics, traction network.*

1. Introduction

More and more freight on rail routes along with a growing speed of vehicles are requirements that the traction network need to comply with. High demands concerning its quality and reliability are of a strategic importance because the traction network does not have reserve. Early detection of changes in the traction power network is the main task in inspection activities. A condition for efficient planning of repairs and replacements is precise and the most up-to-date possible knowledge concerning the condition of rail traction devices. [1,2,3,4] A properly operating traction network enables traction vehicles to be operated in an optimal and safe way. It also gives the possibility of using modern solutions in the field of traction power engineering, and in particular in the field of energy efficiency. These solutions contain, first of all, the recuperation of electricity and the use of energy storage tanks [5,6,7]. These methods are currently the basis in the field of energy consumption of rail vehicle traffic.

2. Diagnostics of Power Traction Network 3kv DC

The 3 kV DC railway overhead wires constitute extensive structures of interconnected elements. Such a large technical complex is exposed to frequent failures and damage. Disturbances in the proper functioning of the network are caused by: breaking of electric wires, lack of electro-electronic power supply, operation of unauthorized persons. Due to the wide range of causes of failure and damage, they are divided into three main groups: Group I - damages dependent on traction network devices, Group II - damages dependent on electric traction vehicles and their service, Group III - other. Due to the subject matter of the article, the authors further present issues related mainly to the damage of Group I.

2.1. DC Traction Network Failure

To illustrate the scale, the problem was analyzed for damage and faults occurring in the 3kV DC traction network. The results presented below relate to the selected representative supply area of the 3kV DC railway traction and apply to a three-year period.
Figure 1 shows the percentage share of Group I damage in comparison with the damage of Group II and Group III.

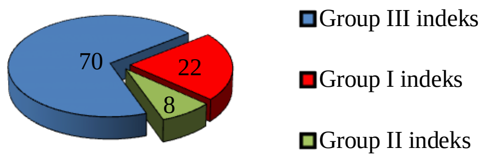

Fig. 1: Percentage share of Group I damage compared to Group II and Group III damages in the first year of the analysis

The index of share of Group I in the first year of the analysis was 22%, and in the remaining years - 19% and 15%, respectively. Figure 2 shows the number of Group I failures in the analyzed power circuits.

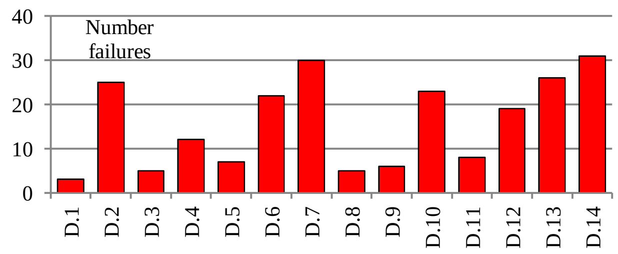

Fig. 2: Number of failures from Group I in the analyzed districts of the 3 kV DC power supply network (D.1-District 1, etc.)

In the case of traction, there is a systematic reduction in the number of failures and network failures. This is the result of proper diagnostics, maintenance and modernization of the network and the use of more and more modern construction solutions.

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The improvement of the overhead contact network is caused by adequate financing. It followed after a period, when the policy of local governments, as well as ministry of infrastructure, led to a slow disappearance of railway traffic, by cutting off the sources of financing. The occurring damages are quickly localized and removed in relation to previous years. Sporadically failures do not affect train delays as much as they used to. Appropriate network sectioning and the use of supernumerary elements leads to increased reliability of the traction network. On the basis of damage data for the selected power supply section, failure rates for individual groups were calculated in the next three analyzed years.

- The Group I damage indicator (per 100 t/km) was calculated as follows:

W1= number of failures in group I / numbers of the traction network operated in t/km * 100
W1 (year 1)=6/ 1464.11*100=0.41
W1 (year 2)=3/ 1460.21*100=0.21
W1 (year 3)=6/ 1457.70*100=0.21

- The Group II damage indicator (per 100 t/km) was calculated as follows:

W2= number of damages in group II / numbers of the traction network in service in t / km * 100
W2 (year 1)=7/ 1464.11*100=0.48
W2 (year 2)=7/ 1460.21*100=0.48
W2 (year 3)=1/ 1457.70*100=0.07

- The Group III damage indicator (per 100 t/km) was calculated as follows:

W2= number of damages in group III / figures of the exploited traction network in t/km * 100
W3 (year 1)=25/ 1464.11*100=1.71
W3 (year 2)=27/ 1460.21*100=1.71
W3 (year 3)=31/ 1457.70*100=2.54

The higher the value of the coefficient for a particular group is, the greater the network failure rate is. A comparison of the above-calculated coefficients is presented in Table 1.

Table 1. Breakdown of the failure rate for individual damage groups

Group damage indicator I i E (at 100 t/km)	0.41	0.21	0.21
Damage indicator - Group II	0.48	0.48	0.07
Damage indicator - Group III	1.71	1.71	2.54
Total damage indicator (Groups I+II+III)	2.60	2.53	2.81

2.2. The Concept of Traction Network Diagnostics

The basic principles of diagnosing the technical condition of the traction network are governed by the internal guidelines of the PKP company - IEN-2-5520-31/00. These guidelines specify technical criteria on the basis of which the following conditions are defined: the status of the traction network, the method of diagnosing individual elements of the traction network and the equipment of organizational units dealing with the diagnosis of the traction network. Technical requirements and dimensional tolerances apply to the full range of lines with a maximum speed of 140km/h, while on lines with higher speeds, they are valid if strict requirements are not specified. Figure 3 presents activities included in the diagnostics of traction networks.

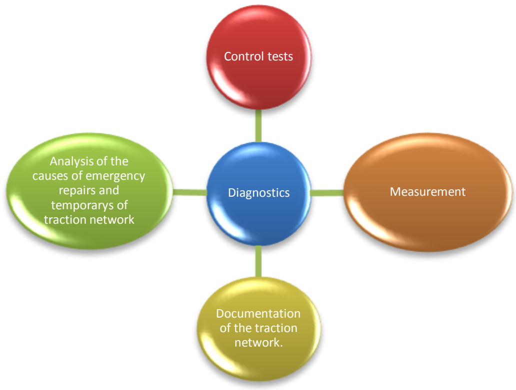

Fig. 3: Components of the diagnostic catenary 3 kV DC [8]

The diagnostic process of the 3kV DC traction network includes the following elements: control tests, measurements, review of technical documentation, analysis of the causes of traction network breakdowns. Control tests are based on an inspection of the overhead line equipment, including: supporting structures, lashings, foundations, foundation heads, contact wire, support cable and other. Guidelines define measurements as actions aimed at: detection of threats to the safe operation of 3 kV DC traction network, checking compliance with technical requirements and tolerances, including measuring the consumption of contact wires, suspension height and the distance of the contact wires, insulation distances from earthed structures, height of suspending tension weights, the gauge of the traction network support structures. Measurements are made using direct and indirect methods using specialized devices.

2.3. Diagnostics Methods for Traction Networks

The diagnostics of the traction power network include the upper and bottom network. The upper network of the electrical traction is diagnosed using a diagnostic car and contact (DST 2000 [9]) and contactless methods.

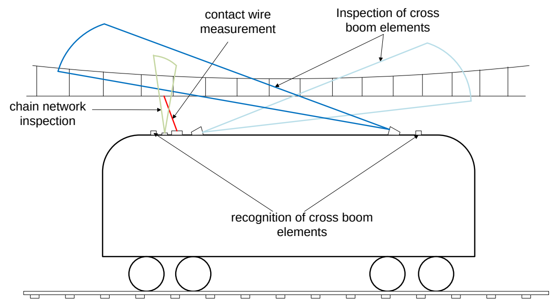

Fig. 4. Distribution of inspection systems in a diagnostic car

Diagnostics include the traction network and pantographs. One of the most important parameters influencing the quality of the cooperation of a pantograph and a catenary construction is the pressure of the pantograph on the overhead line. Too light pressure leads to interconnection breaks and too heavy pressure leads to excessive displacing of the catenary construction which, as a result, leads to mechanical damages and excessive wear and tear of carbon covers.

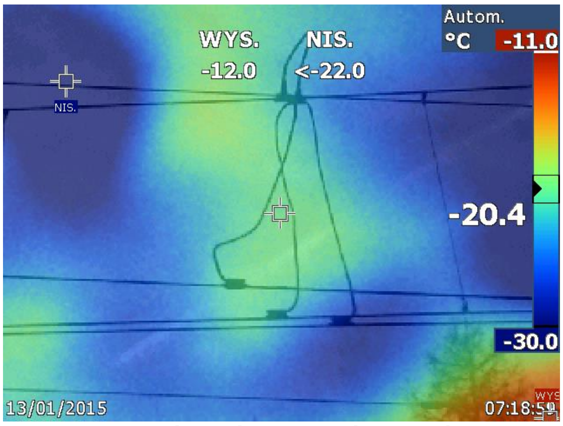

Fig. 5. Electrical connection thermograph

Rail network is characterized mostly by two parameters: rail grounding resistance rp [Ωkm] and longitudinal resistance of the tracks rs [Ω/km]. Two technical problems result in this situation: insufficient conductance of the tracks and earth-leakage current.

3. Assessment of the Current Status of the Traction Network

The assessment of the traction network condition in the selected section was performed based on the indicators proposed by the Railway Institute of Poland. It is obvious, that before carrying out such an assessment, the necessary research material was first collected. For this purpose, in accordance with the provisions of the Iet-2 manual [10], the technical condition of the traction network was inspected on a selected section and the necessary documentation materials were obtained. The collected material allowed to assess the condition of the traction network using seven indicators. Indicators according to the applied algorithm can be divided into three groups:

- Indicator for assessing the condition of contact wires „Wdjp",

$$Wdjp = \left(\frac{(Gnom - Gmin) - (Gsr.measur. - Gmin)}{(Gnom - Gmin)} \right) = 0 \le Wdjp \le 1 \quad (1)$$

The algorithm used in this indicator allows to determine the condition of the conductor by comparing the thickness of the new contact wire *djp* and calculated average wear based on the last measurement.

- The indicator of assesment of supporting calbe „Wln", supporting structures „Wk", equipment „Wosp", insulation „Wizo" and the return network „Wpo".

$$Wln, Wk, Wosp, Wizo, Wpo = \left(\frac{STmax - STocen}{STmax - STmin} + \frac{Wu}{Wprz} \right) / 2 = 0 \le Wln \le 1 \quad (2)$$

Above indicators constitute the quotient of the current assessment status for the minimum assessment and the quotient of the current age of the devices to the expected exploitation time. This way of constructing the indicator allows to include, on the one hand, the age of devices, and on the other hand the objective assessment issued by the diagnostician on the basis of all available information.

- Traction network status indicator „Wst"

$$Wst = \left(\frac{Wdjp + Wln + Wk + Wizo + Wosp + Wpo}{6} \right) = 0 \le Wst \le 1 \quad (3)$$

It is the arithmetic average of all indicators, which allows for issue a general rating for each diagnosed section.

The value of individual indicators indicates their technical condition and it means:

- 0.00≤W≤0.25 – indicator for good status – devices after modernization, with a non-deteriorated degree of wear; their technical condition allows further safe operation without the need for ongoing repairs.
- 0.25<W≤ 0.83 – indicator for a sufficient condition / satisfactory - technical condition of the devices allowing for further safe operation; the possibility of performing current repairs.
- 0.83<W≤ 0.99 – satisfactory status indicator – devices qualifying for renovation / modernization; the technical condition of the devices allows their further operation with suspended supervision.
- W=1 – indicator for insufficient status – devices that due to poor technical condition should be excluded from further use, e.g. they are eligible for reconstruction.

Structure, description and graphic interpretation of the contact wire indicator „Wdjp":

Table 2. Contact wire indicator „Wdjp" parameters

The scale of the indicator	The number of fixed assets for the indicator Wdjp
0.00≤Wdjp≤0.25	30
0.25<Wdjp≤0.83	90
0.83<Wdjp≤0.99	7
Wdjp=1	0

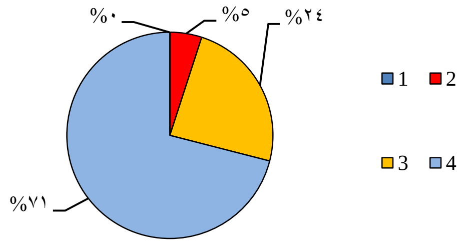

Fig. 6. Percentage of individual indicators of the condition of contact wires "Wdjp" in relation to the number of devices (1-Wdjp=1; 2-0.83≤Wdjp≤0.99; 3-0.00≤Wdjp≤0.25; 4-0.25≤Wdjp≤0.83)

Structure, description and graphic interpretation of the "Wln" carrier rope indicator:

Table 3. "Wln" carrier rope indicator parameters

The scale of the indicator	The number of fixed assets for the indicator Wln
0.00≤Wln≤0.25	5
0.25<Wln≤0.83	5
0.83<Wln≤0.99	74
Wln=1	0

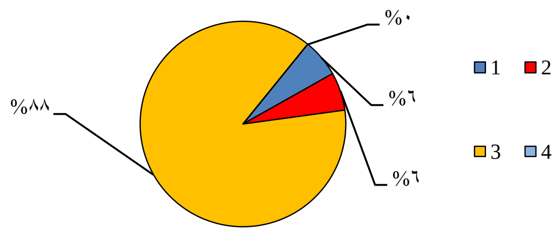

Fig. 7. Percentage . of individual indicators of the condition of contact wires "Wln" in relation to the number of devices (1-0.00≤Wln≤0.25; 2-0.25≤Wln≤0.83; 3-0.83≤Wln≤0.99; 4-Wln=1)

Structure, description and graphic interpretation of the carrier rope indicator „Wk":

Table 4. Carrier rope indicator „Wk" parameters

The scale of the indicator	The number of fixed assets for the indicator Wk
0.00≤Wk≤0.25	0
0.25<Wk≤0.83	81
0.83<Wk≤0.99	3
Wk=1	0

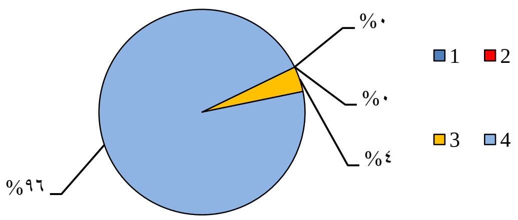

Fig. 8. Percentage of individual indicators of the condition of contact wires "Wk" in relation to the number of devices (1-0.00≤Wk≤0.25; 2- Wk=1; 3-0.25≤Wk≤0.83; 4-0.83≤Wk≤0.99)

Structure, description and graphic interpretation of the insulation indicator „Wizo":

Table 5. Insulation indicator „Wizo" parameters

The scale of the indicator	The number of fixed assets for the indicator Wizo
0.00≤Wizo≤0.25	0
0.25< Wizo ≤0.83	82
0.83< Wizo ≤0.99	2
Wizo =1	0

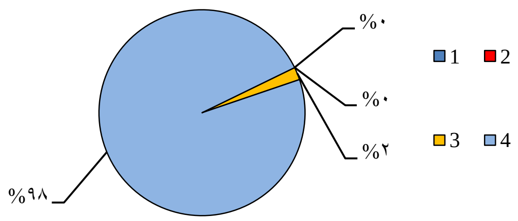

Fig. 9. Percentage of individual indicators of the condition of contact wires "Wizo" in relation to the number of devices (1- 0.00≤Wizo≤0.25; 2- Wizo=1; 3- 0.25≤Wizo≤0.83; 4- 0.83≤Wizo≤0.99)

Structure, description and graphic interpretation of the devices indicator „Wosp":

Table 6. Devices indicator „Wosp" parameters

The scale of the indicator	The number of fixed assets for the indicator Wosp
0.00≤ Wosp ≤0.25	0
0.25< Wosp ≤0.83	82
0.83< Wosp ≤0.99	2
Wosp =1	0

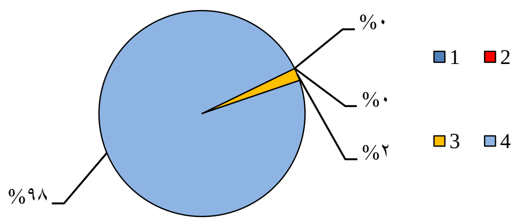

Fig. 10. Percentage of individual indicators of the condition of contact wires "Wosp" in relation to the number of devices (1-0.00≤Wosp≤0.25; 2-Wosp=1; 3-0.25≤Wosp≤0.83; 4-0.83≤Wosp≤0.99)

Structure, description and graphic interpretation of the return network indicator „Wpo" :

Table 7. Return network indicator „Wpo" parameters

The scale of the indicator	The number of fixed assets for the indicator Wpo
0.00≤ Wpo ≤0.25	0
0.25< Wpo ≤0.83	82
0.83< Wpo ≤0.99	2
Wpo =1	0

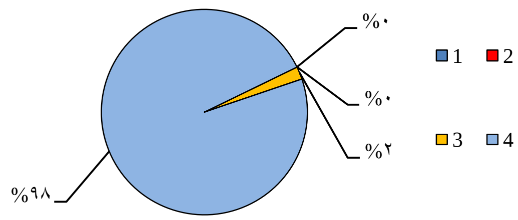

Fig. 11. Percentage of individual indicators of the condition of contact wires "Wpo" in relation to the number of devices (1-0.00≤Wpo≤0.25; 2-Wpo=1; 3-0.25≤Wpo≤0.83; 4-0.83≤Wpo≤0.99)

Structure, description and graphic interpretation of the traction network status indicator „Wst":

Table 8. Traction network status indicator „Wst" parameters

The scale of the indicator	The number of fixed assets for the indicator Wst
0,00≤ Wst ≤0,25	0
0,25< Wst ≤0,83	79
0,83< Wst ≤0,99	5
Wst =1	0

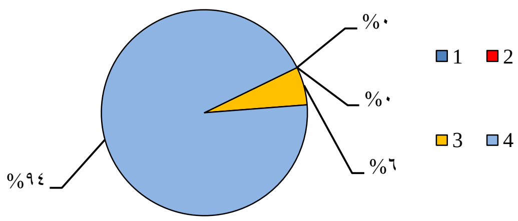

Fig. 12. Network status indicator "Wst" for the analyzed section of the railway line (1- 0.00≤Wst≤0.,25; 2- Wst=1; 3- 0.25≤Wst≤0,83; 4- 0.83≤Wst≤0.99)

Analysis of the research material leads to the following conclusions:

- Indicator „Wdjp" shows, more than 95% of contact wires have a good or satisfactory condition, however the remaining 5% qualifies for renovation due to approaching the maximum permissible values of average and local wear of the djp cable cross-section.
- The "Wln" indicator indicates that nearly 90% of lifting ropes are eligible for replacement due to unsatisfactory condition.
- Indicators "Wk", "Wosp", "Wizo" show unambiguously that 98% of supporting structures, accessories and insulators are eligible for renovation.
- The "Wpo" indicator informs that 98% of the return network in the examined section is eligible for renovation.
- The "Wst" indicator, which is the arithmetic average of the remaining indicators, indicates that 95% of the traction network on the tested section has a sufficient condition, however 5% of devices are eligible for renovation / modernization.

4. Conclusion

The analysis allows to conclude, that the main reason for obtaining such poor results for the majority of indicators is the time of exploration of traction network devices in the analyzed section, which is 40 years (the expected period of service for traction net-

work is just 40 years). The second issue is the very small number of renovations carried out during the current period of operation.
The collected material and the analyzes performed in the course of the study show that the entire section of the traction network needs to be modernized quickly. Despite the first steps towards modernization, there is no doubt that work is needed to develop the project and then implement it. There are several options to consider, however, what is worth emphasizing, the replacement option and related expenditures can match or even exceed the construction of a new traction network. It should be emphasized, that despite the costs incurred, only the original state will be restored without a significant increase in speed. Therefore, the only correct solution is the complete disassembly of the existing traction network, and then the construction of a new one with the necessary infrastructure and a track system adapted to the speed of 120km/h. Until the implementation of modernization works, it was proposed the solutions, which improve the traction network indicators in locations where the lowest results were obtained and which require overhaul in the first place, i.e. exchange of lifting ropes at the six stretch sections, replacement of “djp” contact wires on two tension sections and replacement of 11 support structures. The proposed solutions have been adopted, while their implementation should be carried out with increased supervision. In the conclusion of the analysis, it should be emphasized once again that the diagnostic of the traction network consists in collecting information and assessing the current technical condition, and consequently presenting the technical condition of the traction network, based on which maintenance cycles can be determined and any damage that may occur.
The basic condition for successful planning of repairs and replacements is accurate and up-to-date knowledge about the condition of the devices. However, due to economic reasons, periods of periodic inspections and periods of inspection inspections performed by specialized diagnostic cars were extended. Considering the above facts and time of operation of traction network devices, it is mainly the diagnostician is responsible for the correct assessment of the traction network condition.
It should be strongly emphasized, that steps should be taken to carry out as many automatic inspections as possible by specialized diagnostic cars. This is mainly due to inspection time, but also to economic factors related to the lack of the need to block railway line, and above all, early detection of potential failures. It is equally important, that the inspection tours are carried out with modern diagnostic vehicles, which, in addition to measuring the basic parameters, will also allow the measurement of “djp” cable wear. At the time of increasing speed on railway lines it seems to be the only reasonable solution.

References

[1] Kiessling F. et al, *Contact Lines for Electrical Railways: Planning – Design – Implementation – Maintenance*, Wiley VCH, (2009).

[2] Heland J. et al., *Fahrdrahtlage und Kontaktkräfte – Messungen an ochgeschwindigkeitsstrecken in China*, EB 110, (2012).

[3] Judek S. & Jarzębowicz L., “Algorithm for Automatic Wear Estimation of Railway Contact Strips Based on 3D Scanning Results”, *Proceedings of the International Conference On Electrical and Power Engineering (EPE)*, Iasi (2014).

[4] M. Beznaritnyy, A & I. Gavrilyuk, V & O. Romantsyev, I & I. Shchyeka, V. “Electromagnetic compatibility research of return traction network with signaling devices, centralization and blocking”, *Science and Transport Progress. Bulletin of Dnipropetrovsk National University of Railway Transport*, (2014).

[5] Kawałkowski K., Młyńczak J., Olczykowski Z. & Wojciechowski J., “A Case Analysis of Electrical Energy Recovery in Public Transport”, *Advances in Intelligent Systems and Computing*, (2017), Vol. 631, pp. 133-143.

[6] Łukasik L., Ciszewski T & Wojciechowski J., “Power supply safety of railway Traffic control systems as a part of international transport safety”, *Proceedings of the 16th International Scientific Conference Globalization and Its Socio-Economic Consequences*, Slovakia, (2016), pp. 1212-1219.

[7] Nowakowski W., Olczykowski Z., & Wojciechowski J., “Supply railway traffic control devices in case of failure of the power system”, *Archives of Transport System Telematics*”, (2017).

[8] PKP, “Wytyczne diagnozowania sieci trakcyjnej”, Warszawa, (2000).

[9] “Instrukcja obsługi stacjonarnego stanowiska DST 2000 do przetwarzania danych z wagonu diagnostycznego sieci trakcyjnej“, Gdańsk, (2010).

[10] “Instrukcja utrzymania sieci trakcyjnej Iet-2” – Załącznik do Zarządzenia Nr 3/2014 Zarządu PKP Polskie Linie Kolejowe S.A., (2014).