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MODELING THE COEFFICIENT OF ENERGY LOSSES IN A CONTACT LINE BASED ON THE MONTE-CARLO METHOD

Introduction

The volume of energy losses in electric grids is a main indicator of efficiency of their work, visual status indicator system of power registration, efficiency of power supply organizations. This indicator clearly shows the problems that require emergency solutions in development, reconstruction and modernization of power networks, improved methods and tools for their operation and management in improving the accuracy of electricity metering, fundraising efficiency for electricity consumed.

The main part of energy losses is losses in contact line. The average losses in contact line is 10,84 %. The structure of energy losses in percentage of the total number of consumption electricity is different in Ukrainian Railways. There are 16 % in Donetska railway, 15,07 % in Prydniprovska railway, 11,44 % in South railway, 17,26 % in Lvivska railway, 5,06 % in Odeska railway, 6,53 % in South-West railway.

A number of trends that affect the level of energy losses in a contact line were emerged. These trends are outdated equipment, physical and moral wear of metering of electricity, discrepancy installed equipment power transmissible. This situation connects with small investment in development and modernization of electric networks, improvement of their control regimes in accounting electricity.

After all the problem of reducing losses in the power grids not only lost its relevance, but rather has become one of the objectives of financial stability.

As mentioned in previous publications [1-6], it is better to determine energy losses in the contact network based on the indirect method. This method is based on using meter of losses. This method is based on the register values of per square ampere - hours on the feeders of traction substations. The meter is located on the feeder. It measures values of per square ampere – hours in the unit of time and scales them to the energy losses using the energy losses coefficient.

The literature review

The indirect method for determining the energy losses in contact line was described in the works of V. D. Bardushko, O. L. Bykadorov, V. T. Domanskiy, M. E. Krestyanov, A. N. Kuvychynskiy, K. G. Marquardt, V. T. Cheremysin [7-15].

The comparison of two ways of measuring of energy losses in the contact network was done in [10]. They are developed by South railway with Dnepropetrovsk National University of Railway Transport named after Academician Lazaryan (DIIT), and developed by Moscow State University of Railway Engineering (MIIT)

First way (DIIT) is based on using meter of volts-hours. Second way (MIIT) is based on using meter of ampere-hours.

Calculation formula of the second method of measurement [10]:

$$\Delta W = k_l \cdot I_f{}^2 t , \qquad (1)$$

where k_l – energy losses coefficient;

$I_f{}^2 t$ – sum of values of per square ampere-hours.

The South railway method has several disadvantages. They are measurement error is 10% and cannot be corrected by other coefficients; this method cannot be applied in areas of alternating current.

The most promising way to determine the energy losses in contact lines is using meter of losses which will register values of per square ampere-hours on the feeders of traction substations. These devices need individual settings for a particular feeder zone.

The value of the energy losses coefficient was defined in [11] by the next way:

$$k_l = \frac{r \cdot l}{1{,}94} \times \frac{\alpha \cdot \frac{N_0}{Nn} \sum_{p=1}^{v} \frac{W_{\text{PT}}^2 N}{N_{\text{p}}} + \frac{W_{\text{T}}^2 (n-1)(n^2 - n + 1)}{2{,}2 n^3}}{\alpha \cdot \frac{N_0}{Nn} \sum_{p=1}^{v} \frac{W_{\text{PT}}^2 N}{N_{\text{p}}} + \frac{W_{\text{T}}^2 (n-1{,}33)}{1{,}4 n}}, \qquad (2)$$

where r – resistance of contact line;

l – length of the section;

α – coefficient that depends on the time of current consumption by train;

N_0 – maximal throughput of the area;

N_n – maximal throughput of the area which are using;

v – the number of types of trains;

W_T – energy consumption for traction;

n – the maximum possible in this area number of trains.

Boundaries of changing of the energy losses coefficient depend on the values of its constituent were investigated in [14]. They are changing of numbers of trains, changing the time of current consumption by train and changing in different types of trains. If numbers of trains change in 10 %, the energy losses coefficient changes no more than 0,5 %. If the time of current consumption by train changes in 15 – 20 %, the energy losses coefficient changes in 1 %. If number of different types of trains change, the energy losses coefficient changes no more than 0,5 % too.

Other parameters are practically constant values for a particular area. So energy losses coefficient can be determined for any area.

In [8] were determined energy losses in contact line and currents of feeders of traction substations by using schedules of trains and locomotives current curves for a large number of instant schemes. The energy losses were determined by the next formula

$$k_{li} = \frac{\sum_{i=1}^{m} \Delta P_i}{\sum_{i=1}^{m} I_{fi}^2}, \qquad (3)$$

where i – number of instant scheme;

m – numerosity of instant schemes.

According to schedules of values of energy losses coefficient was determined that:

1. We had constant value of energy losses coefficient;
2. The period of time during which the value is set 2.5 - 3 hours.

So it is possible to determine the energy losses coefficient in the contact line by measuring the square of feeder's current.

The energy losses coefficient determined in simulations. Results of traction calculations, parameters of power supply system and number of trains in the area were used like output data.

Opportunities of standing and overtaking freight and passenger trains in probabilistic schedule models were taken into account.

However, as shown by experiments, the rate of loss depends on the egalitarian current number of trains in the area and so on. As defined noticeable error (7.5%) in this way. The error can be reduced in laying mechanism meter range previously estimated the energy losses coefficient. In [13] evaluated the impact on the value of equalized current of energy losses, which allowed make the following conclusions. There are equalizing currents have stronger influence on power loss than the less load on trains; depending on the ratio of traction load and equalized current power losses could grow by 1.5 – 12 times.

Error in determining the energy losses is significantly reduced by calculating the energy losses coefficient in real time. The solution of this problem is possible in the operation of the automatic control system of electricity.

Factor analysis of the energy losses coefficient was done in [10]. The energy losses coefficient was calculated on the simulation model only once for a particular feeder zone and after the entering to the meter isn't changed. Old electronic components were not allowed to adjust the energy losses coefficient by automated.

This way indirect method can be improved by taking into account factors that affect the energy losses in the contact line. These factors are the scheme of electric power supply of railway section, the wear (reduction of the area) of contact line, the number of trains on railway section, the environment temperature, speed and current of trains.

Formulation of the experiment on the railway is complex task. Therefore the research was carried out by simulation based on the Monte-Carlo method.

Formulation of the problem

Monte-Carlo method and simulation with using it is described in [16, 17]. Modeling for determining the character of changing of energy losses coefficient was done by using Crystal Ball program by the next way (fig. 1).

We have to set the output parameters and laws of distribution of variables for formation the model. Next experiments were done for these reasons.

The experiment area is described on the fig. 2.

Executed schedules of experimental area are studied for determining patterns of change speed and number of trains on areas between traction substations.

The average speed on the areas between traction substations was calculated on the base of these schedules (table 1).

The histogram of speed trains distribution on areas between traction substations of Odessa railway is shown in fig. 3. The calculations are made in the program Crystal Ball.

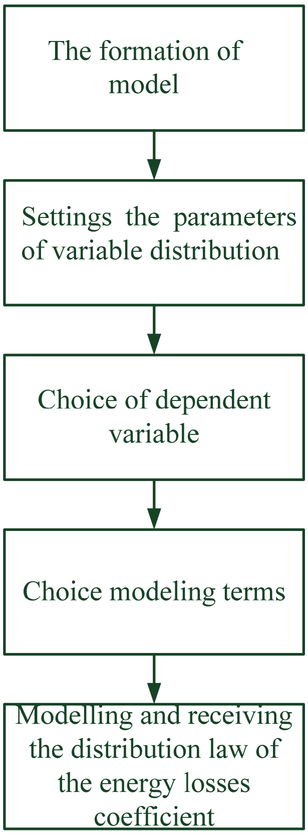


Fig. 1. Algorithm of simulation using Monte Carlo method in the Crystal Ball environment

According to the results of statistical studies found that the speed of trains on areas between traction substations obeys to lognormal distribution. The following characteristics of random variables the speed distribution of trains on areas between traction substations were received (table 2).

Let us analyze the executed schedules and calculate the number of trains on areas between traction substations A–K of Odessa railway (table 3) for a week in increments 1 hour.

The histogram of distribution numbers of trains on area between traction substations A K-of Odessa railway is shown in fig 4.

According to the results of statistical studies found that the numbers of trains on areas between traction substations obeys to binomial distribution. The following characteristics of numbers of trains on areas between traction substations were received (tab. 4).

Journals of contact line state for areas of Odessa railway were analyzed. The residual height of contact line was calculated. The average wear of contact line was determined by using tables [18] (fig. 5).

The histogram of wear of contact line distribution on areas between traction substations of Odessa railway is shown in fig. 6. The calculations are made in the program Crystal Ball.

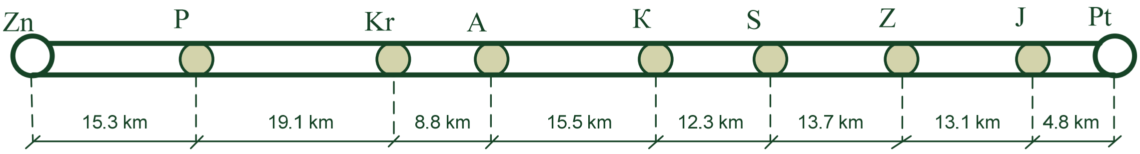


Fig. 2. Scheme of the region Zn – Pt of Odessa railway

Table 1

Fragment of average speed of trains on areas between traction substations of Odessa railway

№ train	Areas between traction substations							
	Zn-P	P-Kr	Kr-A	A-K	K-S	S-Z	Z-J	J-Pt
1	91.80	47.75	44.00	46.50	52.71	48.35	87.33	32.00
2	41.73	95.50	66.00	31.00	12.95	91.33	98.25	12.00
3	83.45	81.86	75.43	62.00	73.80	74.73	78.60	57.60
4	70.62	88.15	40.62	58.12	61.50	63.23	49.12	57.60
5	57.38	52.09	88.00	27.35	23.81	13.70	78.60	24.00
6	54.00	44.08	44.00	35.77	92.25	74.73	56.14	28.80
7	45.90	95.50	88.00	93.00	73.80	37.36	41.37	24.00
8	45.90	20.11	44.00	51.67	25.45	34.25	37.43	26.18
9	48.32	57.30	37.71	32.07	30.75	48.35	52.40	19.20
10	35.31	19.76	44.00	84.55	23.06	91.33	32.75	28.80
11	32.79	54.57	40.62	48.95	49.20	63.23	71.45	57.60
12	83.45	52.09	40.62	44.29	56.77	54.80	49.13	28.80
13	91.80	54.57	37.71	51.67	49.20	58.71	60.46	36.00

Table 2

Characteristics of random variables the speed distribution of trains on areas between traction substations, km/h

Mathematical expectation, μ	Median Me	Mode Mo	Average square expectations, σ	Dispersion, D	Asymmetry γ1	Excess γ2	Coefficient of variation, V
49,87	48,32	45,27	21,24	451,29	0,44	3,36	0,42

Table 3

Number of trains on area between traction substations A–K of Odessa railway

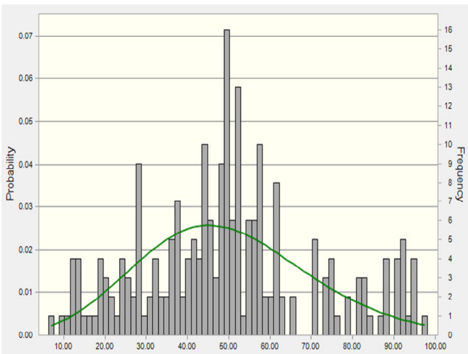
Date	Time																							
	0 5.00-6.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-24.00	24.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00
07	3	4	7	5	6	6	5	6	2	5	7	6	1	5	2	1	2	3	2	7	2	5	8	3
08	2	4	6	4	4	3	4	2	3	4	7	5	2	6	6	4	1	4	6	5	6	2	6	2
09	6	2	2	5	4	4	3	2	1	6	2	6	6	7	5	4	2	1	3	2	4	3	7	6
10	2	8	5	6	4	7	4	5	3	3	4	8	2	4	3	1	5	4	3	6	5	4	4	2
11	4	3	7	3	2	5	8	5	7	7	8	7	6	4	4	2	3	4	1	3	7	2	6	4
12	6	5	2	6	6	3	4	2	5	3	2	4	5	2	5	6	2	2	6	4	6	4	8	6
13	8	6	5	4	3	2	6	2	4	4	3	5	6	4	6	2	2	7	5	6	3	2	7	8

Table 4

Characteristics of numbers of trains on areas between traction substations

Mathematical expectation, μ	Median Me	Mode Mo	Average square expectations, σ	Dispersion, D	Asymmetry γ1	Excess γ2	Coefficient of variation, V
4,17	4,00	4,00	1,71	2,93	0,23	2,91	0,41

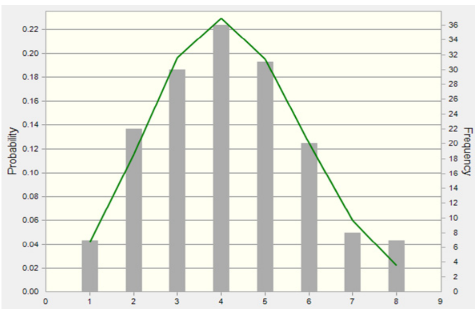
f(V)



V, km / h

Fig. 3. The histogram of speed trains distribution on areas between traction substations of Odessa railway

f(n)



n, pcs

Fig. 4. The histogram of distribution numbers of trains on areas between traction substations of Odessa railway

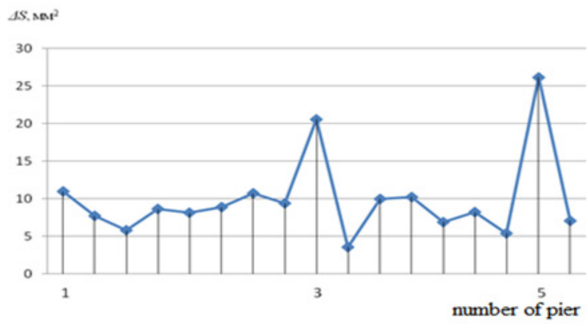
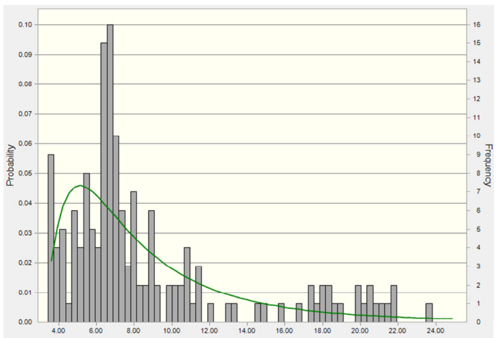


Fig. 5. The fragment of wear of contact line for Odessa railway area

f(ΔS)



ΔS, mm^2

Fig. 6. The histogram of distribution wear of contact line on areas between traction substations of Odessa railway

According to the results of statistical studies found that the wear of contact line on areas between traction substations obeys to lognormal distribution. The following characteristics of wear of contact line on areas between traction substations were received (table 5).

Diary forecast for each day of the year were studied for research change of temperature on the areas of Odessa railway. Monthly average temperatures were calculated.

The histogram of temperature changes on areas of Odessa railway is shown in fig 7.

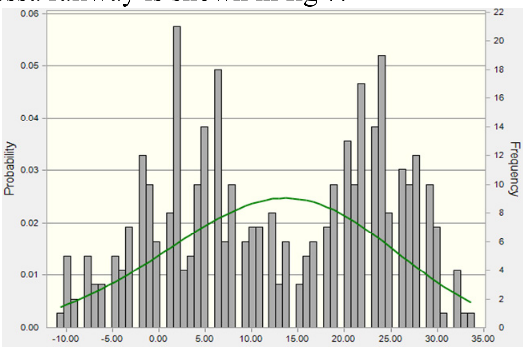


Fig. 7. The histogram of temperature changes on areas of Odessa railway

According to the results of statistical studies found that the temperature changes on areas of Odessa railway obeys to Weibull distribution. The following characteristics of temperature changes on areas of Odessa railway were received (table 6).

Summarizing the above results, we write the input data for modeling (table 7). The law of current distribution was found and described in [19].

For modeling we use the regression equation [6] to determine the rate of loss to alternating current area

$$k_l = 9.022 + 0.056n^2 - 0.72n + \\ +0.024\Delta S\% + 0.033t_e^o. \quad (4)$$

The character of changing coefficient of losses for areas of alternating currents was identified by using the Monte Carlo method. There is the lognormal distribution (fig 8). Next characteristic of the energy losses coefficients distribution were gotten (table 8).

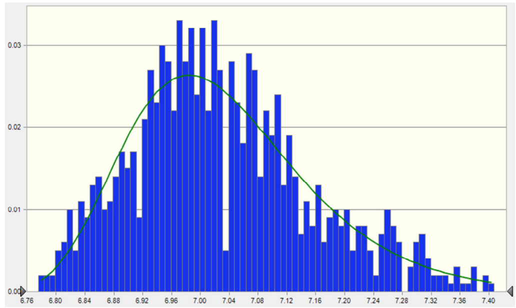


Fig. 8. Histogram of the energy losses coefficients distribution

Limits of changing the energy losses coefficient were identified. They are 6,56 to 7,79 for the area of alternating current.

To further provide recommendations for change of regulation loss factor will determine the degree of influence of each factor.

To area alternating current coefficient of correlation (fig. 9) between energy losses coefficient and temperature changes is 0.0129; ratio between between energy losses coefficient and wear of contact line is 0.0815; between energy losses coefficient and the number of trains areas between traction substations is -0.8562.

The main influence on energy losses coefficient is the number of trains on railway section. The correlation coefficients for areas of alternating currents is -0,8562. Since the correlation is negative, then with the number trains reduced energy losses coefficient. This is supported by previous studies.

Table 5

Characteristics of wear of contact line on areas between traction substations, mm^2

Mathematical expectation, μ	Median Me	Mode Mo	Average square expectations, σ	Dispersion, D	Asymmetry γ1	Excess γ2	Coefficient of variation, V
9,30	7,40	5,10	6,50	42,19	3,98	40,59	0,64

Table 6

Characteristics of random variables distribution changes of temperature, ^{0}C

Mathematical expectation, μ	Median Me	Mode Mo	Average square expectations, σ	Dispersion, D	Asymmetry γ1	Excess γ2	Coefficient of variation, V
12,51	12,80	13,65	11,56	133,59	-0.093	2,75	0,92

Table 7

Distribution laws of factors affecting to the coefficient of energy losses

Parameter	Distribution law	Law's parameter
The number of trains on railway section	Binomial	P=0,0822, n=43
The wear of contact line	Lognormal	m=17,2, σ=5,67
The environment temperature	Weibull	k=50,51, ν=4,6924
The speed of trains	Lognormal	m=47,52, σ=22,07

Table 8

Characteristics of the energy losses coefficient distribution

Mathematical expectation, μ	Median Me	Mode Mo	Average square expectations, σ	Dispersion, D	Asymmetry γ1	Excess γ2	Coefficient of variation, V
7,04	7,02	6,98	0,13	0,02	0,87	4,38	0,02

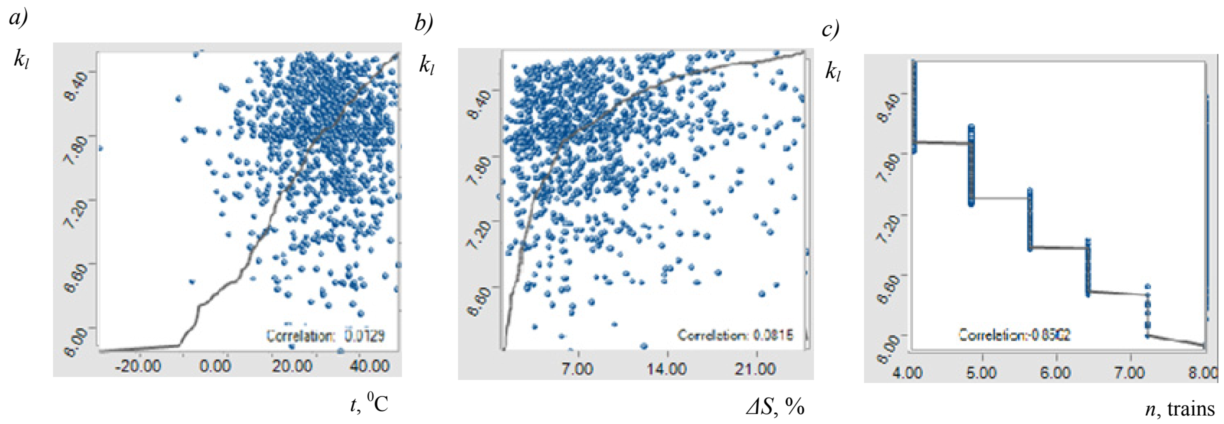


Fig. 9. The correlation of energy losses coefficient versus:
a – environment temperature; *b* – the wear of contact line; *c* – number of trains at the experimental area

Conclusion

1. Probabilistic nature of factors that affect the energy losses coefficient was determined. Limits of their changes and laws of distribution were identified. It was established that the number of trains at the experimental area obeys the binomial distribution. Speed of trains at the experimental area, the wear (reduction of the area) of contact line obey lognormal distribution. The environment temperature obeys Weibull distribution.

2. Based on the mathematical modeling for area of Odessa railway was found that the average losses at the studied area is 12.4%.

3. The energy losses coefficient for area of alternating current obeys the lognormal distribution. These facts were proved on the basis of statistical tests. Mean value of the energy losses coefficient is 7.04.

4. The biggest impact to the the energy losses coefficient has the number of trains at the experimental area. The correlation coefficients for areas of alternating currents is -0.8562.

REFERENCES

1. Kuznetsov W. G., Bosiy D. A., Kirilyuk T. I. Oblik vtrat elektrychnoi enerhii v tiahovii merezhi nepriamym sposobom [Accounting electricity losses in traction network by the indirect method]. *Visnyk Dnipropetrovskoho natsionalnoho universytetu zaliznychnoho transportu imeni akademika V. Lazariana* [Bulletin of Dnipropetrovsk National University of Railway Transport], 2012, issue 42, pp. 103-109.

2. Bosiy D. A., Kirilyuk T. I. Udoskonalennia nepriamoho metodu obliku vtrat elektrychnoi enerhii v kontaktnii merezhi. [Improvement indirect method of accounting electricity losses in the contact system] *Vostochno-Evropeiskyi zhurnal peredovykh tekhnolohyi* [Eastern-European Journal of enterprise technologies],

СПИСОК ВИКОРИСТАНИХ ДЖЕРЕЛ

1. Кузнецов В. Г. Облік втрат електричної енергії в тяговій мережі непрямим способом / В. Г. Кузнецов, Д. О. Босий, Т. І. Кирилюк // Вісн. Дніпропетр. нац. ун-ту залізн. трансп. ім. акад. В. Лазаряна. – 2012. – № 42. – С. 103-109.

2. Босий Д. О. Удосконалення непрямого методу обліку втрат електричної енергії в контактній мережі / Д. О. Босий, Т. І. Кирилюк // Восточно-Европейский журнал передовых технологий. – 2012. – № 5/8 (59). – С. 35-39.

3. Кирилюк Т. І. Способи підвищення ефективності електроспоживання на залізницях України / Т. І. Кирилюк // Энергосбережение. Энергетика. Энергоаудит. – 2012. – № 108 (102). – С. 15-25.

2012, issue 5/8 (59), pp. 35-39.

3. Kirilyuk T. I. Sposoby pidvyshchennia efektyvnosti elektrospozhyvannia na zaliznytsiakh Ukrainy [Ways to improve the efficiency of power consumption on the railways of Ukraine] *Enerhosberezhenye. Enerhetyka. Enerhoaudyt* [Energy saving. Power engineering. Energy audit], 2012, issue 108 (102), pp. 15-25.

4. Maksimczuk W. F., Kuzniecov W. G., Kalasznikov K. A., Kirilyuk T. I. Badania rezerw zasilania poprzez racjonalne rozmieszchenie pociagow na odcincu [Badania rezerw zasilania poprzez racjonalne rozmieszchenie pociagow na odcincu] *Infrastruktura transport (Poland).* [Infrastruktura transport (Poland)], 2013, issue 2, pp. 28–31

5. Kuznetsov W. G., Bosiy D. A., Kirilyuk T. I. Vyznachennia rehlamentu zminy koefitsiienta vtrat [Determination of regulation changes of the energy losses coefficient] *Visnyk natsionalnoho tekhnichnoho universytetu «KhPI»* [Bulletin of the National Technical University «KPU»], 2013, issue 56, pp. 193-198.

6. Kirilyuk T. I. Metod vyznachennia koefitsiienta vtrat na osnovi povnoho faktornoho eksperymentu [The method of determining the energy losses coefficient on the base of full factorial experiment] *Enerhosberezhenye. Enerhetyka. Enerhoaudyt* [Energy saving. Power engineering. Energy audit], 2013, issue 11 (117), pp. 24-29.

7. Domanskyy V. T., Blokhin V. F., Domanskaya G. A. Eksperementalnoe opredelenie poter energii v elektrotyagovykh setyakh postoyannogo toka [Experimental determination of the energy loss in Electrotraction DC networks] *Vesnik VNIIZhTa* [Bulletin of ASRIRT (Scientific Research Institute of Railway Transport)], 1990, issue 5, pp. 29-32.

8. Bykadorov A. L., Domanskyy V. T. Sravnitelnaya otsenka kosvennykh sposobov izmereniya poter energii v kontaktnoy seti peremennogo toka [Comparative evaluation of indirect methods of measuring the energy losses in the contact line of AC] *Trudy Rostovskogo instituta inzh.zh.d.transporta* [Works of the Rostov Institute of Engineers of Railway Transport], 1979, issue 153, pp. 20-27.

9. Bardushko V. D. *Analiz i parametricheskiy sintez sistem tyagovogo elektrosnabzheniya.* Avtoreferat Diss. [Analysis and parametric synthesis of the traction power supply systems]. Irkutsk, 2001, 42 p.

10. Krestyanov M. E. K opredeleniyu poter elektricheskoy energii v tyagovoy seti [By the definition of electric power losses in traction network] *Trudy MIITa* [Works of the Moscow State University of Railway Engineering (MIIT)], 1971, issue 380, pp. 3-12.

11. Marquardt K. G., Kuvichinsky A. N., Davydov E. N. Kosvennye sposoby opredeleniya poter elektricheskoy energii v tyagovoy seti [Indirect methods for determining losses of electric energy in the traction network] *Trudy MIITa* [Works of the Moscow State University of Railway Engineering (MIIT)], 1969, issue 302, pp. 102-108.

12. Bykadorov A. L., Domanskyy V. T. Sravnitelnaya otsenka kosvennykh sposobov izmereniya poter energii v kontaktnoy seti peremennogo toka [Comparative evaluation of indirect methods of measuring the energy losses in the contact line of AC] *Trudy Rostovskogo instituta*

4. Maksimczuk W.F. Badania rezerw zasilania poprzez racjonalne rozmieszchenie pociagow na odcincu / W.F. Maksimczuk, W.G. Kuzniecov, K.A. Kalasznikov, T.I. Kirilyuk // Infrastruktura transport (Poland).-2013. – №2 – p.28–31.

5. Кузнецов В. Г. Визначення регламенту зміни коефіцієнта втрат / В. Г. Кузнецов, Д. О. Босий, Т. І. Кирилюк // Вісник національного технічного університету «ХПІ» .-2013. – №56 – С. 193-198.

6. Кирилюк Т. І. Метод визначення коефіцієнта втрат на основі повного факторного експерименту / Т. І. Кирилюк // Энергосбережение. Энергетика. Энергоаудит – № 11 (117), 2013. – С. 24-29.

7. Доманский В. Т. Эксперементальное определение потерь энергии в электротяговых сетях постоянного тока / В. Т. Доманский, В. Ф. Блохин, Г. А. Доманская // Весник ВНИИЖТа. – 1990. – № 5. – С. 29-32.

8. Быкадоров А. Л. Сравнительная оценка косвенных способов измерения потерь энергии в контактной сети переменного тока / А. Л. Быкадоров, В. Т. Доманский // Труды Ростовского института инж.ж.д.транспорта. – 1979. – Вып. 153. – С. 20-27.

9. Бардушко В. Д. Анализ и параметрический синтез систем тягового электроснабжения: Автореф. дис. д-ра. техн. наук: 05.13.01 / ИрГУПС –Иркутск, 2001. – 42 с.

10. Крестьянов М. Е. К определению потерь электрической энергии в тяговой сети / М. Е. Крестьянов // Труды МИИТа. – 1971. – Вып. 380. – С. 3-12.

11. Марквардт К. Г. Косвенные способы определения потерь электрической энергии в тяговой сети / К. Г. Марквардт, А. Н. Кувичинский, Е. Н. Давыдов // Труды МИИТа. – 1969. – Вып. 302. – С. 102-108.

12. Быкадоров А. Л. Сравнительная оценка косвенных способов измерения потерь энергии в контактной сети переменного тока / А. Л. Быкадоров, В. Т. Доманский // Труды Ростовского института инж.ж.д.транспорта. – 1979. – Вып. 153. – С. 20-27.

13. Доманский В. Т. Эксперементальное определение потерь энергии в электротяговых сетях постоянного тока / В. Т. Доманский, В. Ф. Блохин, Г. А. Доманская // Весник ВНИИЖТа. – 1990. – № 5. – С. 29-32.

14. Быкадоров А. Л. Исследование коэфициента настройки счётчиков потерь энергии на имитационной модэли / А. Л. Быкадоров, В. Т. Доманский, В. М. Ляшук // Сборник научных трудов ВЗИИТ. – 1984. – Вып. 121. – С. 62-68.

15. Быкадоров А. Л. Расчёт потерь энергии в тяговых сетях матричным методом / А. Л. Быквдоров, В. Т. Доманский // Труды МИИТа. – 1979. – Вып. 636. – С. 139-145.

16. Шрейдер Ю. А. Метод статистических испытаний (метод Монте-Карло) / Ю. А. Шрейдер – М. : Физматлит, 1962. – 334 с.

inzh.zh.d.transporta [Works of the Rostov Institute of Engineers of Railway Transport], 1979, issue 153, pp. 20-27.

13. Domanskyy V. T., Blokhin V. F., Domanskaya G. A. Eksperementalnoe opredelenie poter energii v elektrotyagovykh setyakh postoyannogo toka [Experimental determination of the energy losses in DC networks] *Vesnik VNIIZhTa* [Bulletin of ASRIRT (Scientific Research Institute of Railway Transport)], 1990, issue 5, pp. 29-32.

14. Bykadorov A. L., Domanskyy V. T., Lyashuk V. M. Issledovanie koefitsienta nastroyki schetchikov poter energii na imitatsionnoy modeli [Investigation of tuning coefficient for energy losses methers with the simulation model] *Sbornik nauchnykh trudov VZIIT* [Collection of Scientific Papers of ACIRE], 1984, issue 121, pp. 62-68.

15. Bykadorov A. L., Domanskyy V. T. Raschet poter energii v tyagovykh setyakh matrichnym metodom [Calculation of the energy losses in the traction network by the matrix method] *Trudy MIITa* [Works of the Moscow State University of Railway Engineering (MIIT)], 1979, issue 636, pp. 139-145.

16. Schrader Y. A. *Metod statisticheskikh ispytaniy (metod Monte-Karlo)* [Method of statistical tests (Monte Carlo)]. Moscow, Fizmatlit, 1962, 334 p.

17. Gmurman V. E. *Rukovodstvo k resheniyu zadach po teorii veroyatnostey i matematicheskoy statistike: Ucheb. posobie dlya studentov vtuzov. – 9-e izd., pererab. i dop.* [Guide to solving problems in the theory of probability and mathematical statistics: textbook manual for students of technical universities. - 9th Edition, Revised. and add.]. Moscow, High School, 2004, 404 p.

18. *Pravyla ulashtuvannia ta tekhnichnoho obsluhovuvannia kontaktnoi merezhi elektryfikovanykh zaliznyts. TsE-023* [Rules of Design and maintenance of a contact network of electrified railways. IS-023] Kyiv, Ukrzaliznytsia, 2008, 208 p.

19. Marquardt K. G. *Elektrosnabzhenie elektrifitsirovannykh zheleznykh dorog* [Power supply of electrified railways]. Moscow, Transport, 1982, 528 p.

17. Гмурман В. Е. Руководство к решению задач по теории вероятностей и математической статистике: Учеб. пособие для студентов втузов. – 9-е изд., перераб. и доп. / В. Е. Гмурман – М. : Высш. школа, 2004. – 404 с.

18. Правила улаштування та технічного обслуговування контактної мережі електрифікованих залізниць. ЦЕ-023: Затв. Наказ Укрзалізниці 20.11.2007 № 546-Ц – К. : Укрзалізниця, 2008. – 208 с.

19. Марквардт К. Г.Электроснабжение электрифицированных железных дорог / К. Г. Марквардт – М. : Транспорт, 1982. – 528 с.

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Reduction in energy losses is a national objective. It corresponds to the state target economic program of energy efficiency and the development of the sphere of energy production from renewable energy sources and alternative fuels in 2012 - 2015 years.

Formulation of the experiment on the railway is complex task. Therefore the research was carried out by simulation based on the Monte-Carlo method.

The purpose and tasks of the research are establishment of the probabilistic nature of the coefficient of energy losses, determining its average value and finding the factor that has the greatest impact on the coefficient of energy losses.

Distribution laws and the basic characteristics of the factors influencing the coefficient of energy losses were identified during the study. These factors are the wear (reduction of the area) of contact line, the number of trains on railway section, the environment temperature, speed and current of trains.

The law of statistical distribution of the loss coefficient was established for the first time. This makes it possible to evaluate its borders and make recommendations on regulations change it. The average value the loss coefficient is determined by which it will be possible to adjust meter.

Keywords: energy losses, coefficient of energy losses, meter of losses, alternating current, distribution law, modeling, Monte-Carlo method.

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МОДЕЛЮВАННЯ КОЕФІЦІЄНТУ ВТРАТ ЕЛЕКТРИЧНОЇ ЕНЕРГІЇ В КОНТАКТНІЙ МЕРЕЖІ НА ОСНОВІ МЕТОДУ МОНТЕ-КАРЛО

Зменшення втрат електроенергії – державне завдання, що відповідає державній цільовій економічній програмі енергоефективності й розвитку сфери виробництва енергоресурсів з відновлюваних джерел енергії та альтернативних видів палива на 2012 – 2015 роки.

Так як постановка експерименту на залізниці складна задача, то дослідження проведено за допомогою моделювання на основі методу Монте Карло.

Метою роботи є встановлення ймовірнісної природи коефіцієнту втрат, визначення його середнього значення та виділення фактору який має найбільший вплив на коефіцієнт втрат.

В ході роботи встановлені закони розподілу та основні характеристики факторів, що впливають на коефіцієнт втрат, а саме зносу контактних проводів, кількості поїздів на розрахунковій зоні, температури навколишнього середовища, швидкості руху, значення споживаного струму.

Вперше встановлено закон статистичного розподілу коефіцієнта втрат, що дає можливість оцінити його межі та надати рекомендації щодо регламенту його зміни. Визначено середнє значення коефіцієнта втрат, за яким можна буде налаштовувати лічильник

Ключові слова: втрати електроенергії, коефіцієнт втрат, лічильник втрат, змінний струм, закон розподілу, моделювання, метод Монте-Карло.

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МОДЕЛИРОВАНИЕ КОЭФФИЦИЕНТ ПОТЕРЬ ЭЛЕКТРИЧЕСКОЙ ЭНЕРГИИ В КОНТАКТНОЙ СЕТИ НА ОСНОВЕ МЕТОДА МОНТЕ-КАРЛО

Уменьшение потерь электроэнергии - государственная задача, которая соответствует государственной целевой экономической программе энергоэффективности и развития сферы производства энергоресурсов из возобновляемых источников энергии и альтернативных видов топлива на 2012 - 2015 годы.

Так как постановка эксперимента на железной дороге сложная задача, то исследование проведено с помощью моделирования на основе метода Монте-Карло.

Целью работы является установление вероятностной природы коэффициента потерь, определение его среднего значение и выделение фактора который имеет наибольшее влияние на коэффициент потерь.

В ходе работы установлены законы распределения и основные характеристики факторов, влияющих на коэффициент потерь, а именно износа контактных проводов, количества поездов на расчетной зоне, температуры окружающей среды, скорости движения, значение потребляемого тока.

Впервые установлен закон статистического распределения коэффициента потерь, что дает возможность оценить его границы и дать рекомендации по регламенту его изменения. Определено среднее значение коэффициента потерь, по которому можно будет настраивать счетчик.

Ключевые слова: потери электроэнергии, коэффициент потерь, счетчик потерь, переменный ток, закон распределения, моделирование, метод Монте-Карло.

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