DEVELOPMENT OF A PROBABILISTIC AND STATISTICAL MODEL FOR DETERMINING ELECTRICITY LOSSES IN DISTRIBUTION ELECTRIC NETWORKS

D.A.Badalova, J.R.Boboyev, A.Z. Yoqubaliyev.
Tashkent State Technical University named after Islam Karimov

Annotation. *Control over losses of electricity in the networks of supply and return of electricity and comparison of actual losses with technically justified values. At present, large-scale work has been launched in the distribution networks of Uzbekistan to introduce an automated system for monitoring and accounting for the consumption of energy resources, covering all consumers. At the same time, high accuracy and efficiency of obtaining information about energy flows was achieved.*

Introduction. The accuracy of information on accounting for electricity consumption does not yet solve the problem of loss control. It is necessary to develop a methodology for the rapid determination of technically justified losses of electricity in networks and analysis of the imbalance in energy consumption. At the current stage, this problem can be solved using the probabilistic-statistical method for determining losses in power networks. This method consists in using a regression relationship between power losses, on the one hand, and network parameters, on the other. The probabilistic-statistical method is not a new development. Its essence is described in the literature [1], but in the course of an extensive review of the literature on this topic, the authors did not find a method for obtaining the regression dependence itself, including the procedure for selecting influencing factors, finding empirical ones, which provides for a reliable account of the coefficients and verification of the adequacy of the obtained dependence.

A feature of the networks for which this technique is being developed is a large proportion of cable lines and low load of all network elements (transformers and power lines). The initial set of considered influencing factors and their functional dependence can be identified based on the analysis of the method for calculating electricity losses in voltage power networks (10/6/0.4 kV).

In the application package Statgrapfics Plus 5.0, the initial regression dependence was obtained in the traditional form [1].

$$\Delta W_a = 3{,}532 + 0{,}11 W_a^{\;0{,}499}\, L^{0{,}19} \left(\frac{Lkab}{L}\right) * N_u^{\;0{,}116}\, N_v^{\;-0{,}022}\, S_{\Sigma H}^{\;0{,}341}\, N_T^{\;0{,}114}; \qquad (1)$$

Checking the adequacy of the obtained regression dependence of electricity losses in networks on influencing factors is carried out by means of correlation analysis. Based on the test results, we can conclude that the resulting expression is adequate, since its coefficient of determination is 0.996, and the reduced coefficient of determination is 0.995.

By the method of stepwise regression analysis, expression (1) is reduced to a simpler form:

$$\Delta W_a = 3{,}532 + 0{,}11 \frac{11 W a\ 0{,}497\ Lkab0{,}20\ S\Sigma H0{,}35\ NT0{,}114}{Nu0{,}152}; \qquad (2)$$

The coefficient of determination of the final expression is 0.996, and the reduced coefficient of determination is 0.996, i.e., simultaneously with the simplification, the best agreement between the regression expression and the initial data was achieved.

Based on the results of multivariate regression analysis and step-by-step direct and inverse regression analysis carried out in the same Statgrapfics Plus 5.0 package, another expression was obtained for the dependence of electricity losses in power grids on various factors:

$$\Delta W_a = 0{,}024 W_a + 2{,}585\ L_{kab} + 0{,}014\ S_{\Sigma H} + 10617\ N_T - 1{,}333 N_u; \qquad (3)$$

The coefficient of determination of expression (3) is 0.998, and the reduced coefficient of determination is 0.998.

Next, the relative errors of the results of determining the losses of electricity by the regression expression (3) are calculated, since it has a simpler form with almost the same coefficients of determination with the expression (2). For a visual representation of the errors, they are plotted as a graphical dependence on the number of operating transformers in the power grid (Figure 1).

Research methods.The maximum error of the calculation results according to the regression expression (2) is 133% and is observed with a small number of operating transformers in the network, therefore, based on the results of clustering, separate regression dependencies were developed for the area up to and over 5 transformers.

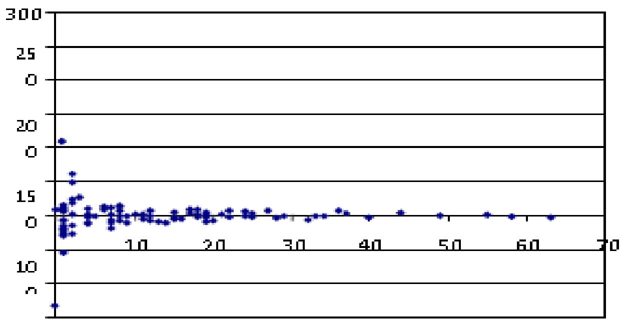


Fig. 1 Dependence of the error in determining energy losses in the network by expression (3) on the number of transformers operating in this network.

Ultimately, the probabilistic-statistical model of electricity losses in networks can be represented as follows:

$$\begin{cases} \Delta Wa = 0{,}019Wa + 1{,}856\ \mathrm{Lkab} + 0{,}007 S\Sigma H + 2{,}538\ \mathrm{NT} & NT < 5 \\ \Delta Wa = 0{,}024Wa + 2{,}567\ \mathrm{Lkab} + 0{,}014\ S\Sigma H + 1{,}54\ \mathrm{NT} - 1{,}361\mathrm{Nu} & NT < 5 \end{cases}$$

(4)

The dependence of the error in calculating power losses according to formulas (4) on the number of transformers in the network is shown in Figure 2. It can be seen from the presented dependence that the maximum error in calculating losses does not exceed 55%.

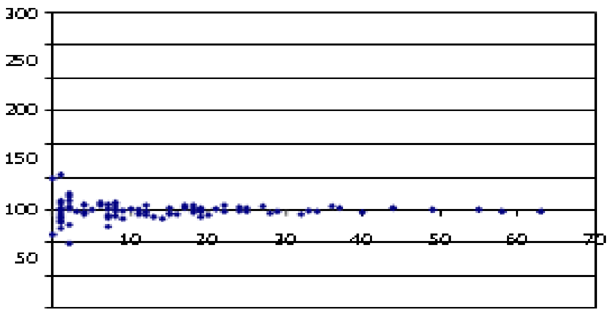


Fig.2 Dependence of the error in determining the energy losses in the network by expression (4) on the number of transformers operating in this network.

To evaluate the obtained error values of the probabilistic-statistical method and conclude on the feasibility of its application, it is necessary to compare the errors of this method and the method of instrumental determination of energy losses in networks. The traditional instrumental method for determining energy losses in the network provides for their calculation by the difference between the electricity received and released from the network, recorded by measuring complexes. The error of this method, under the assumption that commercial losses in the network are equal to zero, is due to the metrological characteristics of the measurement system.

In the literature [2], the errors of measuring complexes for electricity metering are studied in detail, which are divided into systematic and random. When comparing two methods for determining losses, the random error of the measuring complex, which is determined by the expression [2], is of interest.

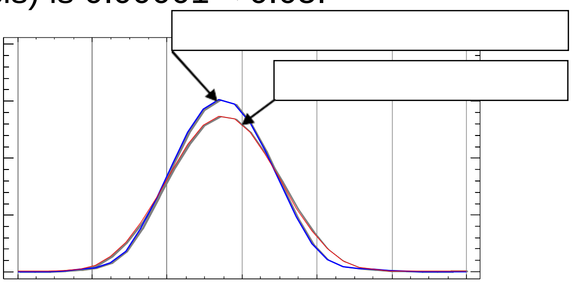
$$d = \pm 1{,}1\sqrt{(1+3{,}05\,\mathrm{tg}^2\,\varphi)\delta^2_{\text{тт}} + (1+1{,}35\,\mathrm{tg}^2\,\varphi)\delta^2_{\text{тн}} + \delta^2_{\text{сч}}} \quad (5)$$

We accept the number of measuring complexes at the points of electricity supply to the network equal to the number of input feeders, and at the outlet points - the number of transformers, then the random error of the entire measuring system is determined by the formula

$$\delta = +1{,}1\sqrt{0{,}95\left(\frac{\delta_{\text{пэ}}}{100}\frac{1}{N_v}\right)^2 N_v + 0{,}95\left(\frac{\delta_{\text{оэ}}}{100}\frac{1-\Delta W_a/W_a}{N_{\text{т}}}\right)^2 N_{\text{т}}} \quad (6)$$

The error of the instrumental method is defined as the ratio of the random error of the measuring system to the percentage of electricity losses in the network.

Results. When conducting the analysis of variance, the null hypothesis was the hypothesis that the two samples were equal, and the alternative hypothesis was the hypothesis that the standard deviation of the sample of the probabilistic method is less than the standard deviation of the sample of the instrumental method. The results of the analysis showed that the alternative hypothesis is correct, since the significance level of the criterion (the probability of rejecting the correct null hypothesis) is 0.00001 < 0.05.



probabilistic-statistical method
0,02
instrumental method
0,015

0,01

0,005

-110 -70 -30 10 50 90 130

Fig. 3 - functions of the density distribution of the errors of the methods for determining the losses of electricity in networks.

Conclusions. As a result of the research, it was proved that the developed probabilistic-statistical model for determining electricity losses in distribution networks is adequate, since its error is less than the error of the instrumental method, and is appropriate for practical use in operational calculations.

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