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ANALYSIS OF THE VALUES OF ACTIVE AND REACTIVE POWER IN DETERMINING LOSSES ENERGY IN ELECTRIC NETWORKS

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***Abstract**. The solution of the problem of energy distribution is more laborious in comparison with the calculation of the flow distribution in the electrical network . At the same time, the consumption of electric energy for the calculation period in each of the nodes of the calculation model of the network is considered to be known for both active and reactive power. The calculation of the balance of active energy in the network based on the solution of the equations of the steady state mode of the network gives the value of load losses, while other types of electrical energy losses should be included in the nodal values of consumption (generation) of energy (active and reactive). The article discusses the method of recovering losses of active and reactive power on the basis of statistical data on the operation of power equipment. The calculation method consists in calculating the average power losses in the electrical network for the billing period. The calculation consists in solving the system when representing the node load powers by random variables.*

***Keywords** - loss of electrical energy, time interval, active power, reactive power*

In [1] it is shown that the calculations of electrical energy losses can be performed on the basis of solving the problem of energy distribution in electrical networks. At the same time, the consumption of electric energy for the calculation period in each of the nodes of the calculation model of the network is considered to be known for both active and reactive power. The calculation of the balance of active energy in the network based on the solution of the equations of the steady state mode of the network gives the value of load losses, while other types of electrical energy losses should be included in the nodal values of consumption (generation) of energy (active and reactive) [2]. The solution of the problem of energy distribution is carried out by determining the average losses of active power in the network for the calculated period T. To do this, the expression for calculating the power losses in the element of the electrical network is linearized and then, taking into account the voltage, according to the numerical characteristics of the active and reactive power transmitted through the network element, is mathematical expectation of power losses in the calculated interval.

There are two approaches to calculating the energy distribution.

In the first approach, the calculated time interval is divided into intervals for which it is possible to determine the consumption of active and reactive power in the network nodes. For each interval, the distribution of the flow and the average values of the calculated losses and power flows are found [3].

In the second approach, for active and reactive powers at the network nodes, the distribution functions of their values are found over the entire calculated time interval T. On their basis, the mathematical expectations and covariances (correlation moments) of the powers at the nodes are found. Further, according to the equations of the steady state, the numerical characteristics of the voltages at the nodes, flows and power losses in the network branches are calculated. The determination of the numerical characteristics of the mode is carried out by two methods:

- statistical test method (Monte Carlo method);
- direct calculation of numerical characteristics according to linear and quadratic dependences (method of statistical linearization).

The first method requires hourly measurements of all consumption and generation capacities in the network nodes, which is not always possible at present.

The second method uses generalized information about energy consumption:

- interval of change of active and reactive powers in each network node;
- type (function) of the power distribution law in each network node;
- values of correlation coefficients between active and reactive powers for each node and for each pair of nodes.

This article discusses the application of the second method to determine the numerical characteristics of the network mode parameters and electrical energy losses.

The calculation method consists in calculating the average power losses in the electrical network for the billing period. The calculation consists in solving a system of equations with the representation of node load powers by random variables. Such a model assumes that all power changes, both regular and irregular, are described as random. The laws of power distribution reflect their ordered variation in the billing period, and the numerical characteristics are determined by averaging over the time of a single realization - the load schedule in the billing interval. A particular problem is being solved - the transformation of the numerical characteristics of systems of random variables.

Using the notation in Cartesian coordinates, which contains only multiplicative nonlinearity, one can obtain an exact equation relating mathematical expectations and covariances of powers and voltages in network nodes.

In general, the mathematical model of the steady state of the electrical network, consisting of n nodes, for the numerical characteristics of power (initial data) and voltages at the nodes (desired values) is written as [4]:

$$\sum_{j}^{n-1}(G_{ij}\left[m_{ui}m_{uj}+\operatorname{cov}(U_iU_j)\right]-B_{ij}\left[m_{ui}^{/}m_{uj}^{/}+\operatorname{cov}(U_iU_j^{/})\right]+B_{ij}\left[m_{ui}^{/}m_{uj}^{/}+\operatorname{cov}(U_i^{/}U_j)\right]+$$
$$+G_{ij}\left[m_{ui}^{/}m_{uj}^{/}+\operatorname{cov}(U_i^{/}U_j^{/})\right])=M(P_i)$$
$$\sum_{j}^{n-1}(-B_{ij}\left[m_{ui}m_{uj}+\operatorname{cov}(U_iU_j)\right]-G_{ij}\left[m_{ui}^{/}m_{uj}^{/}+\operatorname{cov}(U_iU_j^{/})\right]+B_{ij}\left[m_{ui}^{/}m_{uj}^{/}+\operatorname{cov}(U_i^{/}U_j)\right]-\quad(1)$$
$$-G_{ij}\left[m_{ui}^{/}m_{uj}^{/}+\operatorname{cov}(U_i^{/}U_j^{/})\right])=M(Q_i)$$

where $M(P_i)$ and $M(Q_i)$ mathematical expectations of powers in network nodes; G_{ui} and B_{ui} nodal conductance matrix elements (active and reactive components); m_{ui} , m_{ui} , m'_{ui} , m'_{ui} mathematical expectations of the real and imaginary components of stress complexes at nodes; $\operatorname{cov}(U_iU_j^{/})$ covariance between stress components at nodes i and j.

After the joint solution of the system of equations (1), the mathematical expectation of power losses is determined

$$M(\Delta P_{\Sigma})=\sum_{k=1}^{m}G_k(\left[m_{ui}-m_{uj}\right]^2+D_{ui}+D_{uj}-2\operatorname{cov}(U_iU_j)+$$
$$+\left[m^{/}_{ui}-m^{/}_{uj}\right]^2+D^{/}_{ui}+D^{/}_{uj}-2\operatorname{cov}(U_i^{/}U_j^{/}))\quad(2)$$

where i and j are the numbers of nodes adjacent to branch k.

Losses of electrical energy are the average value of losses multiplied by the calculated time interval T_p

$$\Delta W=M(\Delta P_{\Sigma})T_p\quad(3)$$

The considered method for calculating electrical energy losses has the following features:

1) it is required to build a special mathematical model of node loads - mathematical expectations and covariance matrix of powers in nodes (see below);

2) the calculation is associated with the solution of a rather large system of equations;

3) it is necessary to take into account the correlation between the capacities of all loads of the electrical network;

4) the calculation is possible for any calculation interval - from several minutes to a year - and takes into account the reversibility of power flows in the network branches.

In the absence of regular real-time power measurements, one has to use integral measurements - energy, which leads to the loss of the intrinsic and mutual dependences of the consumed powers over time. In this case, a statistical energy consumption model (CM) can be used.

The main idea of constructing the CM is to estimate the mathematical expectations of the powers in the nodes according to the measurements of active and reactive energy.

Power dispersions should be determined by the length of the load power change interval. This requires extreme power values in this interval - the minimum and maximum values. In addition, at least approximate data on the form of the load power distribution law are needed. Then, for example, for active power with a symmetrical distribution law, the standard deviation (RMS) can be calculated by the formula

$$\sigma_p = \frac{P_{\max} - P_{\min}}{2t} \quad (4)$$

where P_{max} and P_{min} - maximum and minimum active power in the calculated interval; t - coefficient that determines the length of the interval.

To estimate the value of t values were calculated for daily, monthly and annual graphs of the total active load of one of the power systems. For daily and monthly charts, the average estimate of t turned out to be equal to 1.95, and for the year 2.3.

An analysis of a number of typical graphs of different types of loads and data from real measurements of the consumption of active and reactive powers of several consumers allows us to note some general properties of the loads of distribution electrical networks on a daily interval:

1) for most loads, the minimum value of the load power is quite different from zero;

2) power distribution is close to a symmetrical law with respect to the distribution center;

3) the correlation between the powers of one load and between different loads can be quite large, the calculated values of the power correlation coefficient on the daily interval vary from 0.36 to 0.98. Negative correlation or no correlation is not typical for all load curves.

For a predominantly household load with a small share of industrial consumers, the correlation coefficients of active and reactive powers of several nodes were calculated for a daily load schedule. The highest correlation is observed between the active powers of the feeders 0.88-0.96, the correlation between the active and reactive powers of one load varies within 0.62-0.92, the lowest correlation was between the reactive powers of the nodes - 0.33-0.73.

Conclusions.

Along with the known methods for calculating the losses of electrical energy for the tasks of analyzing and improving the efficiency of the operation of existing, as well as designed electrical networks, it is possible to use a method based on a probabilistic-statistical model of the energy consumption mode and an apparatus for converting the numerical characteristics of random variables. With the correct representation of the power consumption mode of electrical loads, this method gives the most accurate results for calculating power losses.

References

1. Qawaqzeh M., Miroshnyk O., Iegorov O. Development of algorithm for the operation of a combined power supply system with renewable sources // 2022 IEEE 3rd KhPI Week on Advanced Technology (KhPIWeek) 3-7 Oct. 2022.

2. Al Issa H., Miroshnyk O., Iegorov O. Analysis Ways of Improving the Accuracy of Identification of Non-sinusoidal Voltages and Currents Distortion by Means of Wavelet Analysis // 2022 IEEE 3rd KhPI Week on Advanced Technology (KhPIWeek) 3-7 Oct. 2022

3. Pazderin A.V. Calculation of technical losses of electricity based on the

solution of the problem of energy distribution // Electric Stations, 2004. No. 12. P. 44-49.

4. Murthy, KVS Ramachandra, and M. Ramalinga Raju. Electrical energy loss in rural distribution feeders-a case study // Power 12.12.31 (2007): 14-1.