

CALCULATION OF ELECTRICAL ENERGY LOSSES IN DISTRIBUTION NETWORKS

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Abstract

The article presents the causes of electrical energy losses in distribution networks and defines criteria for determining and evaluating these losses across different voltage levels.

Keywords

electrical networks; electrical energy losses; modeling; conditional constant losses; substation.

Аннотация

В статье представлены причины потерь электроэнергии в распределительных электрических сетях и определены критерии и оценки потерь электроэнергии на участках напряжения.

Ключевые слова

электрические сети; потеря электроэнергии; моделирование; условные постоянные потери; подстанция

At present, accurate calculation of electrical energy losses and the development of methods to reduce them are among the main challenges in power systems. According to international experts, the relative total losses in electricity transmission and distribution networks are considered acceptable if they do not exceed 4-5%. In Russia, this value reaches 11-13%, while in Japan and Western Europe it does not exceed 6-7%. According to official data, in the Republic of Uzbekistan these losses average 16-18% [3]. Therefore, research on electrical energy losses is a pressing issue in our country.

The high level of electrical energy losses in distribution networks is mainly associated with the following factors: technical parameters of network elements; non-optimal operating modes, lack of regulation tools, absence or insufficient compensation of reactive power, high unevenness of electrical loads, inefficiency of electricity metering systems, increase in installed capacity of nonlinear and asymmetric loads.

In addition, actual imbalances in distribution networks often exceed permissible values. Their dynamics are characterized by randomness and a tendency to increase both at substations and across the entire network. As a result, inaccuracies in electricity metering lead to unreliable initial data for calculating, analyzing, and forecasting energy losses [1].

In this article, we consider the calculation of electrical energy losses in low-voltage (0.4, 6, and 10 kV) networks.

The actual value of standard electrical energy losses over a certain period is calculated using the following formula:

$$\Delta W_{\text{norm}} = \Delta W_{\text{shd}} + \Delta W_k + \Delta W_{\text{yuk}} + \Delta W_{\text{rx}} + W_{\text{uz}} + \Delta W_{\text{mav}}$$

Where ΔW_{shd} - conditional constant electrical energy losses; ΔW_k - climate-dependent losses; ΔW_{yuk} - load-dependent losses; ΔW_{rx} - losses caused by permissible errors in metering systems; W_{uz} - electricity consumption for substation auxiliary needs during the reporting period; ΔW_{mav} - seasonal component of standard losses for the reporting period.

The actual value of standard electrical energy losses as a percentage is calculated as follows:

$$\Delta W_{\text{norm}} \% = \frac{\Delta W_{\text{norm}}}{W_{\text{xq}}} * 100\%$$

Where:

W_{xq} - the actual amount of electrical energy transmitted through the network.

The actual values of energy loss standards and their components are calculated from the beginning of the year on a monthly, quarterly, and calculated basis [6].

Methods for Calculating Electrical Energy Losses

The following methods are used:

1. In the energy system of Uzbekistan and its subdivisions, energy losses are calculated based on data obtained from electricity metering systems.

2. In 35–750 kV networks, loss standards are determined using main network parameters, active and reactive power graphs, and data recorded by digital devices.

3. In 0.38–10 kV networks, loss standards are determined using network parameters, power graphs, data recorded at 6–10 kV inputs of 35–750 kV substations, and actual or typical consumer load graphs.

If active and reactive power graphs for 35–750 kV network elements are unavailable or incomplete, they are modeled using seasonal measurements. Based on this, general patterns of power node fluctuations are identified [2].

The total technical losses of electrical energy in networks during a reporting period are equal to the sum of losses recorded in individual network elements.

Conditional Constant Electrical Energy Losses. Conditional constant losses depend on:

- losses in electrical equipment operating under no-load conditions (independent of climate);
- losses in devices not directly dependent on network load;
- losses in devices with constant parameters regardless of load level;
- losses that are actually load-dependent but are determined by established standards due to calculation difficulties.

Conditional constant losses are calculated using the following formula [6]:

$$\Delta W_{shd} = \Delta W_{shd}^{220-750} + \Delta W_{shd}^{35-110} + \Delta W_{shd}^{0.38-10}$$

Where:

$\Delta W_{shd}^{220-750}$, ΔW_{shd}^{35-110} , $\Delta W_{shd}^{0.38-10}$ – conditional constant losses for 220–750 kV, 35–110 kV, and 0.38–10 kV networks.

For 220–750 kV networks, $\Delta W_{shd}^{220-750}$ – conditional constant losses are determined by:

$$\Delta W_{shd}^{220-750} = \Delta W_{klx} + \Delta W_{Trx} + \Delta W_{shr} + \Delta W_{sk} + \Delta W_{rsk} + \Delta W_{vr} + \Delta W_{okch} + \Delta W_{kt} + \Delta W_{yuchk} + \Delta W_{p.u.l}$$

Where:

ΔW_{klx} – losses in cable line insulation; ΔW_{Trx} – no-load losses in power transformers; ΔW_{shr} – losses in shunt reactors; ΔW_{sk} – losses in synchronous compensators; ΔW_{rsk} – generator losses in compensator mode; ΔW_{vr} – losses in surge arresters; ΔW_{okch} – losses in overvoltage limiters; ΔW_{kt} – losses in voltage transformers; ΔW_{yuchk} – losses in high-frequency communication devices; $\Delta W_{p.u.l}$ – losses in substation busbars and connection wires.

For 35–110 kV networks:

$$\Delta W_{shd}^{35-110} = \Delta W_{klx} + \Delta W_{Trx} + \Delta W_{kq} + \Delta W_{sk} + \Delta W_{rsk} + \Delta W_{vr} + \Delta W_{okch} + \Delta W_{kt} + \Delta W_{yuchk} + \Delta W_{p.u.l}$$

For 0.38–10 kV networks:

$$\Delta W_{shd}^{0.38-10} = \Delta W_{klx} + \Delta W_{Trx} + \Delta W_{kq} + \Delta W_{sk} + \Delta W_{vr} + \Delta W_{orkch} + \Delta W_{kt} + \Delta W_{his} + \Delta W_{p.u.l}$$

Where:

ΔW_{his} – losses in electricity meters directly connected to the network.

Conclusion

Based on the analysis, it can be concluded that electrical energy losses in networks are calculated separately for each voltage level, and the total energy loss in the network is equal to the sum of losses across all voltage levels.

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