CALCULATION AND REDUCTION OF POWER AND ENERGY WASTE IN ELECTRICAL NETWORKS

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Abstract

Electrical networks are the main element of the network that delivers the generated electricity to consumers. In this section, several methods are used to calculate the generated wastage. They differ from each other in the accuracy and simplicity of calculation. Power and energy losses of electrical networks are studied in detail in the article.

Key words: electrical networks, resistance, full power, current, voltage, reactive power, active power, exact and probabilistic statistical methods.

INTRODUCTION.

Power outages are very common in electrical networks, and there are reasons for this. Losses in electrical networks are the differences in energy consumption of the total energy consumption of transmitted electricity.

The planned indicator of electricity in the networks is defined as a percentage of the electricity received in the network of this energy system. The absolute loss of electricity in networks is significant (about 10% of the electricity consumed in the power supply systems of enterprises corresponds to losses in the network), it should be noted that here the term "loss" does not specify technical specifications. the meaning of the pointer.

ARTICLE BODY

During the transmission of electric energy from stations to consumers, a part of power and energy is wasted due to heating of conductors, generation of electromagnetic field and other effects. Such losses occur in overhead and cable lines, transformers and autotransformers of amplifying and reducing substations.

Active power loss in a section of a three-phase electrical network with resistance R is determined as follows:

$$\Delta P = 3I^2 R.$$

Here I - the load current.

The value of this current is determined by the following full power transfer:

$$S = \sqrt{P^2 + Q^2}\ . \qquad (10.2)$$

Here P - the active power converted into mechanical, thermal or light energy in consumers; Q - reactive power is used to generate electromagnetic fields in electric motors, transformers and lines.

If instead of the current in the power consumption formula, we put the expression $I = \frac{S}{\sqrt{3}U}$ through power and voltage, the following formula is formed:

$$\Delta P = 3\left(\frac{S}{\sqrt{3}U}\right)^2 R = \frac{S^2}{U^2} R = \frac{P^2 + Q^2}{U^2} R.$$

Here: U-voltage

According to the above formula, the line reactive power loss formula can be written:

$$\Delta Q = \frac{P^2 + Q^2}{U^2} X$$

In any element of the electrical network, including the line, ΔP the loss of active electrical energy depends on the nature of the load and changes over time. The energy dissipated during time t in an active power loss line operating with a constant load is defined as:

$$\Delta W = \Delta P t.$$

If the load varies throughout the year, then the energy loss in the line can be calculated using several methods. All existing methods can be divided into two large groups depending on the mathematical model used. These are exact and probabilistic statistical methods.

The most accurate way to calculate the energy loss is to determine it according to the load graphs of the sockets. In this case, the calculation involves determining the power losses for each level of the load graph and finding their sum. This method is sometimes called the graphical interpolation method.

Load graphs are divided into daily and annual load graphs. Daily graphs show the change in carrying capacity during the day and annual graphs show the change over the course of the year. The annual chart is based on the typical daily charts for the spring-summer and autumn-winter periods. Duration load graphs are used to calculate annual energy consumption. Creating such a graph is done in the following order. The initial ordinate of the graph is considered equal to the maximum load. Taking into account the number of different types of days (Saturday, Sunday, Monday, weekday) according to daily graphs, the number of hours during the year is determined for each value of carrying capacity. First of all, the time corresponding to the maximum load is determined, then the time interval for other values of the load force is determined (in descending order).

It is possible to determine the annual energy consumption according to the annual load graph. For this, power and energy losses are determined for each case. Then, by adding these wastes, the annual electricity waste is determined.

As an example, we take a three-step loading graph. For the load condition, the power dissipation in the line in Figure 1 is calculated as follows:

$$\Delta P_1 = \frac{S_1^2}{U_1^2} R .$$

We find the power consumption by multiplying the power consumption for this state by the duration of this state:

$$\Delta W_1 = \Delta P_1 \Delta t_1$$

In other cases, waste of electricity is found in the same way. For the case where the load is P2

$$\Delta P_2 = \frac{S_2^2}{U_2^2} R \ ;$$

$$\Delta W_2 = \Delta P_2 \Delta t_2 \ ,$$

For the case where the load is P3

$$\Delta P_3 = \frac{S_3^2}{U_3^2} R .$$

$$\Delta W_3 = \Delta P_3 \Delta t_3 .$$

Peak capacity and annual capacity for the i -stage of an N-stage multi-stage load schedule are calculated by the following formulas:

$$\Delta P_i = \frac{S_i^2}{U_i^2} R, \quad i = 1,...N \ ,$$

$$\Delta W = \sum_{i=1}^{N} \Delta P_i \Delta t_i \ .$$

Here: Δt_i - the duration of the i- step of the bootstrap graph.

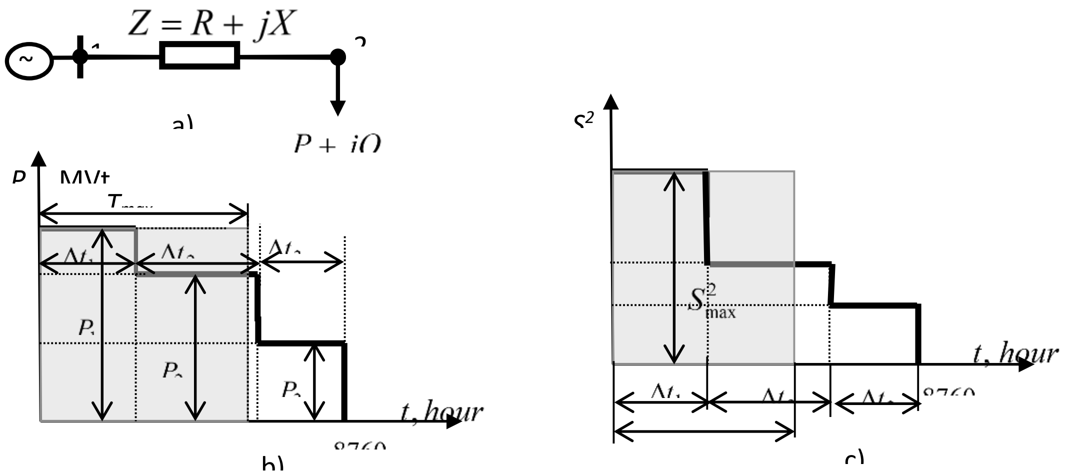

Figure 1. Finding the loss of electricity according to the load graph and the time of maximum loss:
a) line switching scheme; b) three-stage loading graph;
c) Three-line graph S^2.

The advantage of the method of determining wastage according to the load graph is high accuracy. But the lack of information about the loads of all sections limits the use of this method.

One of the simplest ways to determine the loss is based on finding the maximum loss time. Based on it, the case with the maximum power loss from all cases is determined. By calculating this condition, the maximum power consumption $\Delta P_{\max}$ is found. Energy consumption during the year is found by multiplying this energy consumption by the time of maximum consumption τ :

$$\Delta W = \Delta P_{\max} \tau .$$

The time of maximum loss is such a time, if during this time the energy consumed during operation with maximum load is equal to the energy consumed during operation according to the load schedule during the year, i.e.

$$\Delta W = \Delta P_1 \Delta t_1 + \Delta P_2 \Delta t_2 + ... + \Delta P_n \Delta t_n = \Delta P_{\max} \tau ,$$

Here: N - Number of graph loading steps.

The relationship between the loss of electricity and the electricity received by the consumer can be done in the following way.

Energy received by the consumer:

$$W = P_1 \Delta t_1 + P_2 \Delta t_2 + ... + P_n \Delta t_n = \sum_{i=1}^{N} P_i \Delta t_i = P_{\max} T_{\max} .$$

Here: $P_{\max}$ - the maximum power of the load receiver.

Maximum load time $\grave{O}_{m\grave{a}x}$ is such a time during which the energy received from the network by the consumer operating at maximum load is equal to the energy received by him from the network operating according to the load schedule for a year, i.e.

$$T_{\max} = \frac{\sum_{i=1}^{N} P_i \Delta t_i}{P_{\max}} = \frac{\sum_{i=1}^{N} S_i \cos\phi_{o'r} \Delta t_i}{S_{\max} \cos\phi_{o'r}} = \frac{\sum_{i=1}^{N} S_i \Delta t_i}{S_{\max}}.$$

$S^2 = f(t)$ make a graph (Fig. 1.v). Suppose that the estimated value of power consumption at each i-step of the load graph is found at the nominal voltage U, i.e.

$$\Delta P_i = \frac{S_i^2}{U^2} R$$

If we consider that $R/U^2 = const$, the energy consumed in the case of constant active power coefficient $cos\varphi$ during time Δt_i is on a certain scale $S_t^2 \Delta t_i$, that is, on the surface of a rectangle with sides equal to Δt_i and S_t^2 equal (Fig.1.c). Based on this, the waste of electrical energy is equal to the surfaces bounded by the figures depicted in the graphs in Fig. 1 on a certain scale. In this case, the formula for the loss of electrical energy can be written in the following form

$$\Delta W = \frac{R}{U^2}\left(S_1^2 \Delta t_1 + S_2^2 \Delta t_2 + ... + S_n^2 \Delta t_n\right).$$

The following definition can be added to this expression:

$$S_{\text{o'r.kv.}} = \sqrt{\frac{S_1^2 \Delta t_1 + S_2^2 \Delta t_2 + ... + S_n^2 \Delta t_n}{8760}}.$$

Here: 8760 – number of hours in a year.

So, according to the above formula for energy loss, it looks like this:

$$\Delta W = \frac{R}{U^2} S_{\text{o'r.kv.}}^2 \cdot 8760.$$

In this formula, the mean square value of the power is $S_{\text{o'r.kv.}}$, the method of determining the energy loss based on the formula is called the method of calculating the mean square power. This method has a number of disadvantages, and it can only be used in cases where there is a loading graph. Therefore, this method is not widely used.

τ - as defined above

$$S_{\max}^2 \tau = \sum_{i=1}^{N} S_i^2 \Delta t_i \ .$$

This gives the following expression for the maximum time spent:

$$\tau = \frac{\sum_{i=1}^{N} S_i^2 \Delta t}{S_{\max}^2}.$$

For peak-shaped graphs, the value of τ is found from the following empirical formula:

$$\tau = (0{,}124 + \frac{T_{\max}}{10000})^2 \cdot 8760 .$$

The above formula can be used for one year, i.e. $T = 8760$ hours. To increase the accuracy of the calculation for a relatively small time, it is recommended to use the following expression instead of above:

$$\tau = 2T_{\max} - T + \frac{T - T_{\max}}{1 + \frac{T_{\max}}{T} - \frac{2P_{\min}}{P_{\max}}} \left(1 - \frac{P_{\min}}{P_{\max}}\right)^2 .$$

Based on the calculations for cases where the load graphs are of different nature, it is possible to construct the relationship $\tau = f(T_{\max}, \cos\phi)$ and using it to determine r from known values of $T_{\max}$ and $\cos\varphi$ (Fig. 2).

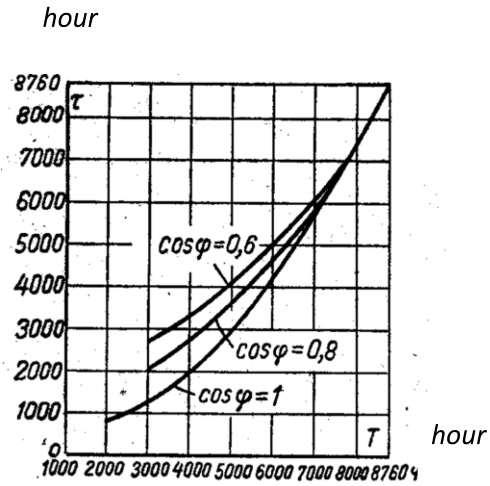

Figure 2. $\tau = f(T)$ connections.

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