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Rizayeva Mahzuna Amir qizi

assistent, Jizzakh Polytechnic Institute

REACTIVE POWER COMPENSATION IN THE POWER SUPPLY SYSTEM

Abstract: This article presents the problem of reducing power losses in electric networks by compensating reactive power, methods for solving it, and algorithms for calculating optimal reactive power.

Key words: Electrical energy waste, reactive power compensation, active power waste, organizational technical measures.

One of the main issues in the design of power supply of industrial enterprises is the issue of reactive power compensation. As we know, system generator together with active power also produces a certain amount of reactive power depending on the coefficient of reactive power tg φ of the generator. Analysis of the technological process of industrial enterprises shows that asynchronous motors are the main power consumers in enterprises. It is asynchronous motors that are the main consumers of reactive power, i.e. consumers of 60-65% of the total generated reactive power. Based on this, the consumption of reactive power in industrial enterprises is increasing compared to active power. If we analyze the expressions of waste in electrical networks:

$$\Delta P = \frac{P^2 + Q^2}{U^2} R; \qquad \Delta Q = \frac{P^2 + Q^2}{U^2} X; \qquad \Delta U = \frac{PR + QX}{U}.$$

From the above expressions for active and reactive power, voltage dissipation and loss, it is clear that reactive power dissipation is directly proportional to the square of the power flowing from the network. That is, the more reactive power is transmitted to the consumer through electric networks, the greater the amount of waste in the networks. This leads to the deterioration of technical and economic indicators. Therefore, it is desirable to produce reactive power close to consumers. In this, special devices that generate reactive power are used.

The above considerations are explained with the help of the following example. Two cases are considered. In the first case, the reactive power needed by the consumer is transmitted directly from the power system. In the second case, the reactive power required for the consumer is produced at the consumer itself. As a result of the comparison of two cases, the relevance of the reactive power compensation issue and its impact on the technical and economic indicators are determined.

Case 1. The amount of reactive power needed by the consumer is transferred from the power system. The consumer's demand for active power is 500 kW, and his demand for reactive power is 450 kVAr.

S=P+jQ =500+j450.

Taking into account the losses of this power in lines and transformers, 600 kW of active power and 550 kVAr of reactive power are transferred from the generator of the station.

So, in order to transfer the amount of power S=P+jQ=600+j550 through lines and transformers, transformers, overhead and cable lines, and switching equipment should be selected that will transfer this power.

Case 2. The amount of reactive power required by the consumer is generated at the consumer itself. In this case, as in case 1, the consumer's demand for active power is 500 kW, and his demand for reactive power is 450 kVAr. Only 450 kVAr reactive power is not transmitted from the power system. This power is produced in the consumer itself with the help of special compensation devices. It can be seen that 600 kW of active power and 100 kVAr of reactive power are transmitted from the generator of the station, taking into account the losses of power in lines and transformers [1,2].

So, we need to choose transformers, overhead and cable lines, and switching equipment to transfer the amount of power S=P+jQ =600+j100 through lines and transformers.

If the two cases are analyzed, the power transmission in the first case S=P+jQ=600+j550 is much more economical compared to the power in the second case S=P+jQ=600+j100. It is characterized by the selection of high-power power transformers and the increase of cross-sectional areas of overhead and cable lines. If these indicators worsen the economic indicators of the system, the difference between the amount of wastages as a result of calculating the values of the capacities in the first and second cases in the above expressions of wastage is sufficiently noticeable, it represents the deterioration of the technical indicators of the system.

From the above cases, it can be seen that reactive power compensation is an important issue for industrial enterprises [3].

In this practical exercise, the issue of reactive power compensation for the workshops of an industrial enterprise is considered, in which the amount of reactive power produced by the consumer and transmitted from the energy system is calculated using expressions [4].

Many measures have been developed to reduce the waste of electrical energy, and since the issue of choosing the most optimal one of them is complicated, it is appropriate to divide them into types.

Such activities are mainly divided into three groups:

- organizational events;

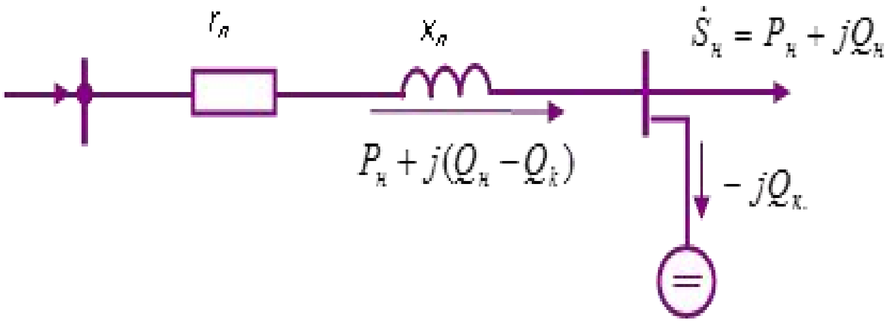
- technical measures;

- accounting and technical accounting of electricity

measures to improve acquisition systems.

The introduction of organizational measures does not require any additional capital costs [5-8].

Other activities require capital expenditure [9] .



Power dissipation in a network without reactive power compensation

$$\Delta P = \frac{P_н^2 + Q_н^2}{U_н^2}\ r_л$$

Power loss in a reactive power compensated network [10] :

$$\Delta P = \frac{P_н^2 + (Q_н - Q_k)^2}{U_н^2}\ r_л$$

As can be seen from the above dissipation formula, the larger the power Q KU of the compensating device (in the case where Q KU < Q), the smaller the power dissipation is. However, reducing wastage in this way requires additional costs for compensating equipment. These costs should be taken into account in technical and economic calculations.

Reactive power compensation is an important factor (means) of increasing the efficiency of the power supply. It not only reduces power loss, but also increases the quality of electricity and eases the load on power grids and power plants [11].

Reactive power sources include generators, compensators, synchronous motors, capacitors, and other static rectifier sources. Reactive power is also produced by EULs (important at 110 kV and higher voltages) [12-17].

The relationship between the active and reactive power of the generator

$$S = \sqrt{P^2 + Q^2}$$

is defined by equality.

An increase in active power leads to a decrease in reactive power and vice versa. However, loading it with reactive power at the expense of reducing the active power of generators is not effective in most cases.

It is required to find the optimal power of the reactive power compensator, which is connected to the consumer at the edge of the open electric network, whose scheme is shown in Figure 1, which ensures the minimum loss in the network [18]. .

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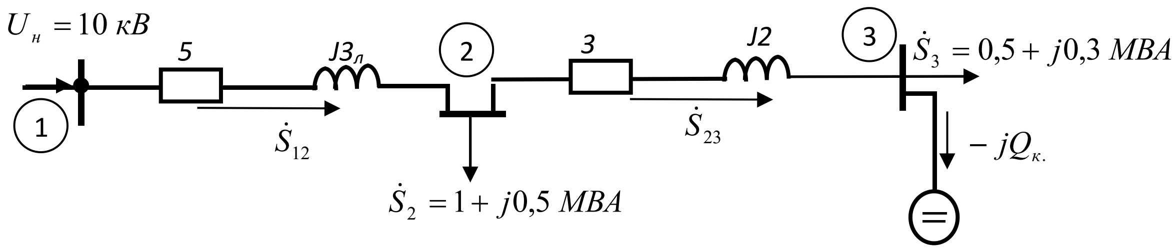

Picture 1

We express power flows in branches 1-2 and 2-3 using Kirchhoff's first law for nodes 2 and 3 [19]:

$$\dot{S}_{12} = 1,5 + j(0,8 - Q_k)\,,$$

$$\dot{S}_{23} = 0,5 + j(0,3 - Q_k)\,.$$

We express the loss of active power in the electrical network by the unknown power of the compensator [20-23]:

$$\Delta P = \frac{P_{12}^2 + Q_{12}^2}{U_н^2}\ r_{12} + \frac{P_{23}^2 + Q_{23}^2}{U_н^2}\ r_{23} = \frac{1,5^2 + (0,8 - Q_k)^2}{10^2}\ 5 + \frac{0,5^2 + (0,3 - Q_k)^2}{10^2}\ 3\,.$$

We find the optimal reactive power of the compensator using the necessary condition of the minimum of the active power dissipation function:

$$\frac{\partial \Delta P}{\partial Q_k} = -\frac{2(0,8 - Q_k)}{100}\ 5 - \frac{2(0,3 - Q_k)}{100}\ 3 = 0\,,$$

$$Q_{k,опт.} = \frac{0,08 + 0,018}{0,1 + 0,06} = 0,612\ \text{MVAR} = 612\ \text{kVAR}.$$

To evaluate the effectiveness of reactive power compensation, we compare the active power dissipation in the initial and post-compensator cases.

For the initial network:

$$\Delta P = \frac{1,5^2 + 0,8^2}{10^2}\ 5 + \frac{0,5^2 + 0,3^2}{10^2}\ 3 = 0,155\ \text{MW};$$

For a reactive power compensated network:

$$\Delta P_э = \frac{1,5^2 + (0,8 - 0.612)^2}{10^2}\ 5 + \frac{0,5^2 + (0,3 - 0,612)^2}{10^2}\ 3 = 0,117\ \text{MW}$$

Thus, the waste in it as a result of optimal compensation of reactive power at the end of the network

$\Delta\Delta P = \Delta P - \Delta P_э = 0,155 - 0,117 = 0,038\ \text{MW} = 38$ kW, which is a decrease of 24.5%.

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