ENERGY INDUSTRY

METHODS FOR INCREASING POWER FACTOR

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МЕТОДЫ ПОВЫШЕНИЯ КОЭФФИЦИЕНТА МОЩНОСТИ

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ABSTRACT

The article considers the issue of reactive power compensation, which is one of the main issues to be solved both at the design stage and at the stage of operation of industrial power supply systems, and includes the selection of appropriate sources, the calculation and regulation of their power, the placement of sources in the power supply system. Methods of increasing the power factor, reducing the loss of electricity are considered.

АННОТАЦИЯ

Статье расмотрена вопрос о компенсации реактивной мощности являюўимся одним из основных вопросов, решаемых как на стадии проектирования, так и на стадии эксплуатации систем промышленного электроснабжения, и включает выбор целесообразных источников, расчет и регулирование их мощности, размещение источников в системе электроснабжения. Расмотрены методы повышение коэффициента мощности, снижение потери электроэнергии.

Keywords: energy, electricity, power supply, components of electrical energy, power, active power, reactive power, compensation of electrical energy, compensating devices, capacitor bank.

Ключевые слова: энергия, электроэнергия, электроснабжение, составляющие электрической энергии, мощность, активная мощность, реактивная мощность, компенсация электрической энергии, компенсирующие устройства, конденсаторная батарея.

An industrial enterprise is a consumer of active and reactive energy. The main consumers of reactive energy are asynchronous motors, as well as transformers, overhead power lines, which constitute the overwhelming majority of consumers at the enterprise. Capacitive electrical receivers: static capacitors, cable lines are sources of reactive energy.

The ratio of the active power *P* to the total power consumption of the enterprise *S* is called the power factor *cosφ*:

$$cos\varphi = \frac{P}{\sqrt{P^2+Q^2}} \quad (1)$$

The power factor of an electrical installation without the use of special means to increase it is called natural, and for most enterprises is 0.6-0.8.

Generators to provide the enterprise with electricity are designed to operate with their rated power factor of at least 0.8, at which they are capable of delivering rated active power. A decrease in the power factor of consumers below this value can lead to the fact that the power delivered by the generators will be less than the rated power at the same apparent power. Therefore, at low power factors at the consumer, in order to ensure the transmission of active power, it is necessary to build

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more powerful power plants or take measures to increase the *cos φ*.

When reactive power flows in electrical networks, the latter causes additional losses of active power and additional voltage losses Δ*U*:

$$\Delta U = \frac{PR+QX}{\sqrt{U_n}} \quad (2)$$

where *R* and *X* are the active and reactance of the network.

The loss of active power in this case:

$$\Delta P = \frac{P^2}{\sqrt{U_n^2 cos^2 \varphi}} R \quad (3)$$

To increase the voltage at the consumer and reduce losses, one should strive to reduce the transmitted reactive power. This is achieved by increasing the power factor by:

Rationalization of the work of electrical equipment or natural compensation of electrical receivers;

Reactive power compensation.

Natural compensation of reactive power does not require large material costs. One of the main conditions for the rational power supply of the enterprise is the correspondence of the power of the electric motors and the power consumption of the mechanisms set in motion by these electric motors.

Natural compensation of reactive power includes:

- Streamlining the technological process leading to the alignment of the load schedule (uniform distribution of loads in phases, shift of lunch time for different shops, etc.),
- Creation of a rational power supply system by reducing the number of transformation stages,
- Replacement of old-design transformers with a new one with lower magnetization reversal losses,
- Replacement of lightly loaded transformers and motors with transformers and motors of lower power and their full load,
- Limiting the duration of the idling mode of electric motors,
- Disconnection of some power transformers at low load (for example, on weekends),
- Replacement of asynchronous motors with synchronous ones, since synchronous motors, when overexcited, can operate with a power factor close to unity, and even supply reactive power to the network.

Thanks to natural compensation of reactive power, it is possible to only partially unload the power supply system from reactive power. In most cases, natural reactive power compensation is not sufficient to increase the power factor to the required value. Therefore, to ensure the operation of generators with rated parameters and to unload the network from reactive power, it is advisable to generate a part of this power at the place of its consumption. This compensation is called "lateral" compensation.

The main sources of reactive power installed at the point of consumption are synchronous compensators and capacitor banks. The most widely used static capacitors are for voltages up to 1000V and 6-10kV. In cases where compensating devices remain connected to the network, and reactive power consumers are disconnected from it, overcompensation occurs. The result is an increase in total power losses and an increase in the complexity of voltage control devices. Therefore, controllable compensating devices based on semiconductor devices have found application.

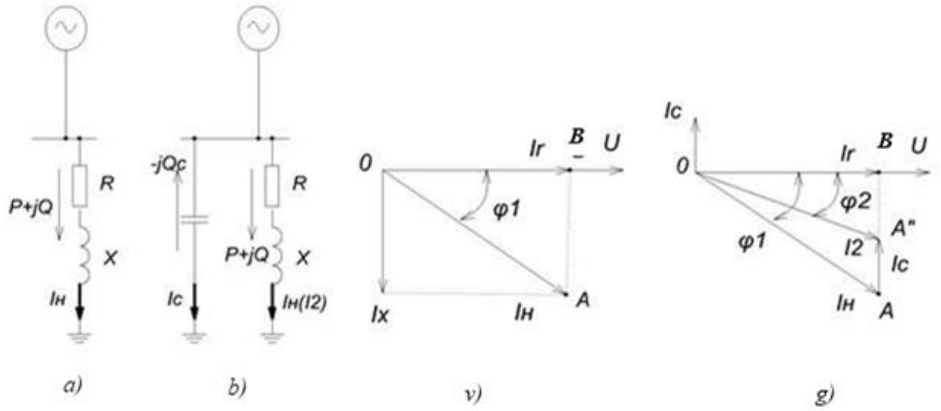

Figure 1. Schemes without compensation (a) and with compensation (b) reactive power and their vector diagrams

A visual representation of the essence of reactive power compensation is given in Fig. 1. Before compensation, the consumer had an active power *P*, respectively a current *Ir* and a reactive power from a reactive load *Q* with a corresponding current *Ix*. The vector *Iн* corresponds to the full power. Power factor before compensation cosφ$_1$.

After compensation, that is, after connecting a capacitor with a power Q_c in parallel to the load, the total reactive power of the consumer will be Q-Q_c (current I_x-I_c). The angle φ will decrease and the power factor will rise from $cos\varphi_1$ to $cos\varphi_2$. The total power consumption at the same active power will decrease from S_1 (current I_n) to S_2 (current I_2). Therefore, with the same cross-section, it is possible to increase the throughput of the line in terms of active power.

Ideally, it is necessary to carry out full compensation when $Q = Q_c$, but in reality such a situation is unattainable due to the constantly changing network configuration, changes in the operating mode of receivers, etc.

When compensating for reactive power, voltage losses in power transmissions are also reduced. If before compensation the voltage loss was determined by expression (2), then in the presence of compensation we will have:

$$\Delta U_k = \frac{PR+(Q-Q_c)}{U_n} X \qquad (4)$$

As already noted, reactive power compensation is carried out using capacitor banks, which are most widely used. The widespread use of capacitor banks is explained by their advantages: insignificant specific losses of active power, absence of rotating parts, ease of installation, relatively low weight and size and cost indicators, absence of noise during operation, etc. However, there are also disadvantages: fire hazard, residual charge that must be removed, sensitivity to overvoltage, the need for special conditions for the disposal of used batteries.

In networks with a sharply variable shock load, as well as for smooth adjustment of the compensation level, it is recommended to use combined high-speed reactive power sources (Fig. 2). In this case, inductance regulation is carried out by VS thyristors.

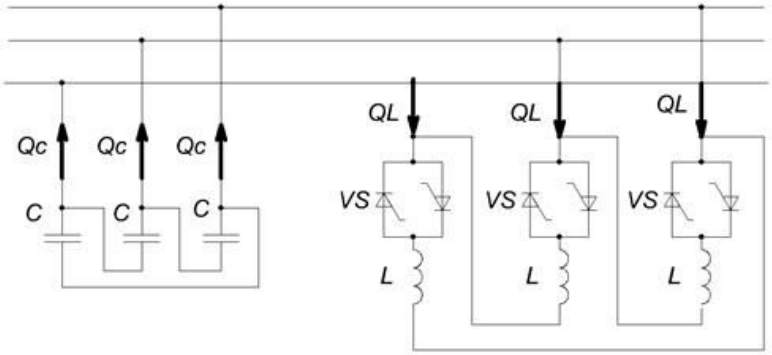

Figure 2. Schematic diagram of a fast-acting compensating device

Another technical means of reactive power compensation, which has become widespread, is a synchronous compensator. It is a synchronous motor with no shaft load. It can operate both in the reactive power generation mode and in the mode of its consumption. The change in the generated or consumed reactive power of the compensator is carried out by regulating its excitation.

The advantage of the synchronous compensator as a source of reactive power is the possibility of smooth regulation of the generated reactive power and high resistance in short-circuit and overvoltage modes.

The main difference between a synchronous motor and an asynchronous motor is that the magnetic field required for the operation of the motor is created mainly from a separate direct current source (exciter). As a result, in normal mode, the synchronous motor almost does not consume reactive power from the network, which is necessary to create the main magnetic flux, and in overexcitation mode (with a leading power factor) it can generate reactive power into the network.

Synchronous motors can generate reactive power at voltage U_{nom}:

$$Q=0,5P_{nom} \qquad (5)$$

One of the disadvantages of synchronous motors is the additional active losses in the winding caused by the generated reactive power:

$$\Delta P = \frac{Q_{nom}^2 r}{U_{nom}^2} \qquad (6)$$

Where Q_{nom} is the rated reactive power, r is the resistance of one phase of the motor winding.

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