GALAXY INTERNATIONAL INTERDISCIPLINARY RESEARCH JOURNAL (GIIRJ)
ISSN (E): 2347-6915
Vol. 13, Issue 10 October (2025)

METHODS FOR REDUCING REACTIVE POWER CONSUMPTION

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ABSTRACT

Reactive power is a type of power that does not perform useful work in the electric power system, but is used to create magnetic and electric fields necessary for the operation of electrical equipment. Excessive consumption of reactive power creates additional load on electrical networks, leads to a decrease in voltage, increased energy waste, and a decrease in the efficiency of electrical equipment. Therefore, compensation and reduction of reactive power is one of the important directions for ensuring energy efficiency in industrial enterprises, energy systems, and consumers. The main methods of reducing reactive power include installing compensating capacitors, using synchronous compensators, using reactive power control devices, operating transformers and electric motors in optimal mode, as well as reducing losses in cables and electrical networks. This scientific work analyzes the technical and economic effectiveness of reducing reactive power and highlights the role of modern automated control systems in increasing energy efficiency.

Keywords: Reactive power, electric energy, compensation, capacitor banks, synchronous compensator, energy efficiency, electrical network, voltage, power factor, technical efficiency.

INTRODUCTION

Reactive power is one of the main indicators characterizing the state of the power supply system. It is worth noting that the concept of reactive power can be introduced and applied only in symmetrically installed modes of sinusoidal voltage and current circuits, and in other cases, when it is present in practice in the study of power circuit modes, it can violate the state of the description of the energy regime. Due to the reasons that occur in the direct transmission of reactive power, active power is expressed in terms of additional losses of active energy in all elements of the network. We can see that the problem of energy losses in the transmission of reactive power is closely related to the transmission capabilities of power transmission networks. The modern power supply system is characterized by a high level of reactive power consumption in networks for consumers of electricity. The best use of electrical equipment due to reactive power compensation is considered to be higher than when the equipment is loaded with reactive power, which leads to a decrease in active power losses or allows it to be loaded again.

The main consumers of reactive power are:

1. Asynchronous motors (AD) - they consume 60% of the total reactive power.
2. Power transformers - consume about 20% of reactive power.
3. Controlled rectifiers, induction furnaces, etc. consume about 15-20%.

To reduce the consumption of reactive power from the system at enterprises and workshops, capacitor banks (KB) with a voltage of up to 1000 and above 1000 V, high-voltage synchronous motors (SM), synchronous compensators and static sources of reactive power are used. In addition, it is possible to reduce reactive power consumption by influencing the process and structure of technological mechanisms and electrical devices. In the design and operation of ETS, 2 types of measures are used to compensate for reactive power:

1. Compensation using a special reactive power source;
2. Compensation measures without using a special source by influencing the technological process, the design and parameters of electrical devices.

Let's consider these measures:

1. Limiting the idle time of an asynchronous motor in a mechanism or machine. Since the AD consumes mainly reactive power when idle, and its power factor cosφ has a small value. Therefore, a device is installed that automatically disconnects the motor from the network if the idle time exceeds 10 seconds.
2. If the design of the mechanism allows, replace the ADs with a small load factor with a motor of smaller power.

In this case, if the load factor of the motor is Kyu < 0.45, a high-power motor can be replaced with a low-power one without performing economic calculations. If 0.45 Kyu < 0.7, it can be replaced based on technical and economic calculations.

3. Reducing reactive power consumption by reducing the voltage supplied to the stator windings of lightly loaded ADs and SMs by reconnecting the windings from a triangle to a star. This can be used for 4A series motors with delta connections at rated voltage.
4. Whenever possible, replace ADs installed in mechanisms with a constant operating mode with SMs (pumps, compressors, fans). Because SM can generate reactive power without consuming it and supply it to the network.
5. For mechanisms with a constant operating mode (for large-capacity pumps, compressors, fans), consider installing SMs during the redesign period.

The capital costs for carrying out the above measures are small. Therefore, they can be carried out first, and then, if necessary, special sources of reactive power can be used.

Power coefficient of AD and ways to increase it

a) Determining the power coefficient of AD

The power coefficient of AD is determined by the following expression

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

in this $P = M\omega_0 + 3I_1^2 R_1$ - active power;

$Q = 3I_\mu^2 x_\mu + 3I_1^2 x_1 + 3I_2^{\prime 2} x_2$ - reactive power;

$S = \sqrt{P^2 + Q^2}$ -full power.

Nominal power factor for most ADs $\cos\varphi_n \approx 0{,}8\div0{,}9$ is equal to . For these values Q= (0,1 0,75) P, That is, for each kilowatt of active power, AD receives 0.1 to 0.75 kilovars of reactive power from the network. The smaller coc□, the more reactive power AD receives from the network and loads it with additional current, creating additional losses in it.

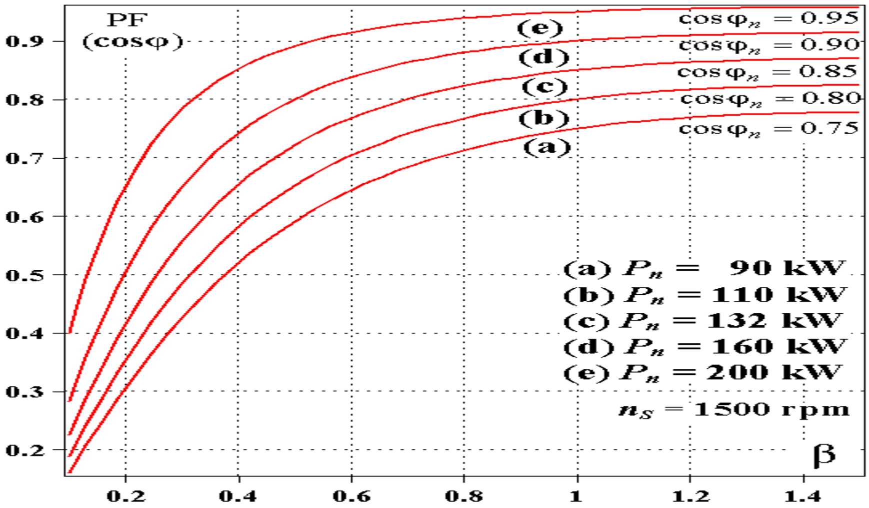

Figure 1. Dependence of power coefficients of 7A series ADs on the load level.

The power coefficient largely depends on the AD load. In the pure operation mode of the AD, the power coefficient is not very large, since at full power the reactive power is greater than the active power. With an increase in the AD load, its sos_n also increases and reaches its maximum value in the nominal load range of the AD. The relationship of sos_n with the load for ADs is shown in Figure 1.

Figure 2 shows the relationship between the nominal power coefficient for different nominal powers and the number of pole pairs r. It can be seen from the figure that with an increase in the nominal power of the AD sos_n also increases. Also, small-pair, high-speed ADs have a higher nominal power factor.

ADs are the main consumer of reactive power in the power supply system (its consumption is 60-65% of the total), therefore, increasing their power factor is an important technical and economic task.

b) Methods for increasing the power factor of ADs

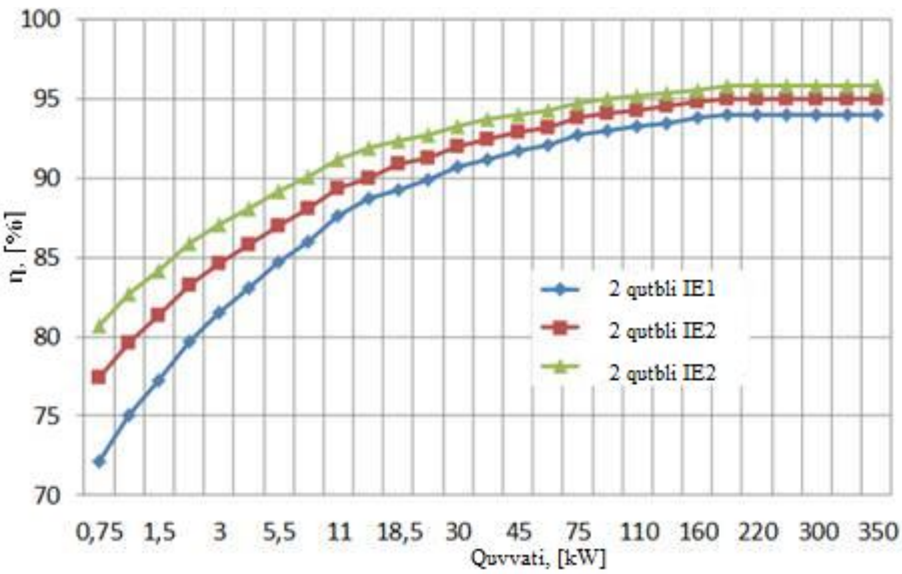

Figure 2. Values of nominal power coefficients of 4A series ADs at different speeds and nominal powers.

Currently, the following main measures have been developed and used to increase the power coefficient of AD:

1. Replacing underloaded ADs with low-power engines. When replacing with low-power ADs, the engine operates at its rated (or close to it) power on its shaft, and
cosφ will be higher. It can be added that in this case the useful working coefficient of the AD will also be higher.

Calculations show that if the average load of the AD is less than 45% of its nominal capacity, then it is advisable to replace it with an AD of smaller capacity, if the load of the AD is more than 70%, then it is not advisable to replace it, if the load of the AD is in the range of 45-70%, the feasibility of replacing them must be proven by additional technical and economic calculations.

2. Limit the time of operation of the AD in the only running mode. In such a mode, the AD is small cosφ If this mode lasts for a long time, it is advisable to disconnect the AD from the network, taking into account the fact that it has a low load.

3. Reduce the voltage of the AD operating with a small load. When the voltage supplying the AD is reduced, the reactive power it receives also decreases and
cosφ ncreases. The possibility of implementing this method is associated with the reconnection of the motor stator windings from the "delta" scheme to the "star" scheme, which leads to a threefold decrease in the voltage in each phase winding.

4. Replacing the AD with a synchronous motor (SD) (if the conditions of the technological process of the working machine allow this). SD, as is known, has a very valuable property: it cosφ =1 It can operate in standby mode (i.e., it does not take reactive power from the grid) and, when necessary, generates reactive power to the grid.

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