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THE EFFECTIVE METHOD OF COMPENCATING THE REACTIVE POWER IN CONTACT

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Abstract: This article presents the results of an experimental study of a low voltage reactive power automatic compensation device, its capabilities, energy saving, which is the most effective way to reduce electricity consumption from the network directly at an industrial enterprise. Using the device, it was possible to save active power by 21.95 kW per hour, and compensate for reactive power by 9.15 kW per hour. This device proved to be energy efficient and economical. It is shown that the correct compensation of reactive power saves 7-35% of the current consumed from the network, depending on cosφ, as well as reduces the heating of wires and insulation wear.

Keywords: reactive power, active power, inductive coupling, power factor – cosϕ.

Introduction

As we know, reactive power compensation is used to save energy. This issue is very relevant, especially for large industrial enterprises. It is worth noting that the decision of the President of the Republic of Uzbekistan PQ-2343 of May 5, 2015 set the task of reducing energy capacity in economic sectors and the social sphere, and introducing energy-saving technologies and systems. Within the framework of the decision, comprehensive measures aimed at ensuring energy efficiency in the economy and social sectors of our republic are being implemented in the following years. Scientists around the world are conducting a lot of scientific researchs on this problem, creating new energy-efficient technologies and devices. [1-5].

One of the most effective ways to reduce power consumption from the network is to use devices that automatically compensate for reactive power. By the order of the head of the "Uzenergonazorat" inspection (Reg. 1864-2 dated 5.09.2018), changes were made to the regulation on the procedure for organizing work on reactive power compensation. According to the introduced changes, it is applied to consumers, energy supply organizations and organizations designing electrical equipment of new, expanded and reconstructed enterprises with an active power calculated from 20 kW at each input. In the previous regulation, it was defined as 50 kW. According to the regulation, it is necessary to correctly choose the type, power, connection point and operating mode of the compensating device for power networks with a voltage of 1000 V and higher. If earlier the resolution of these issues was only related to

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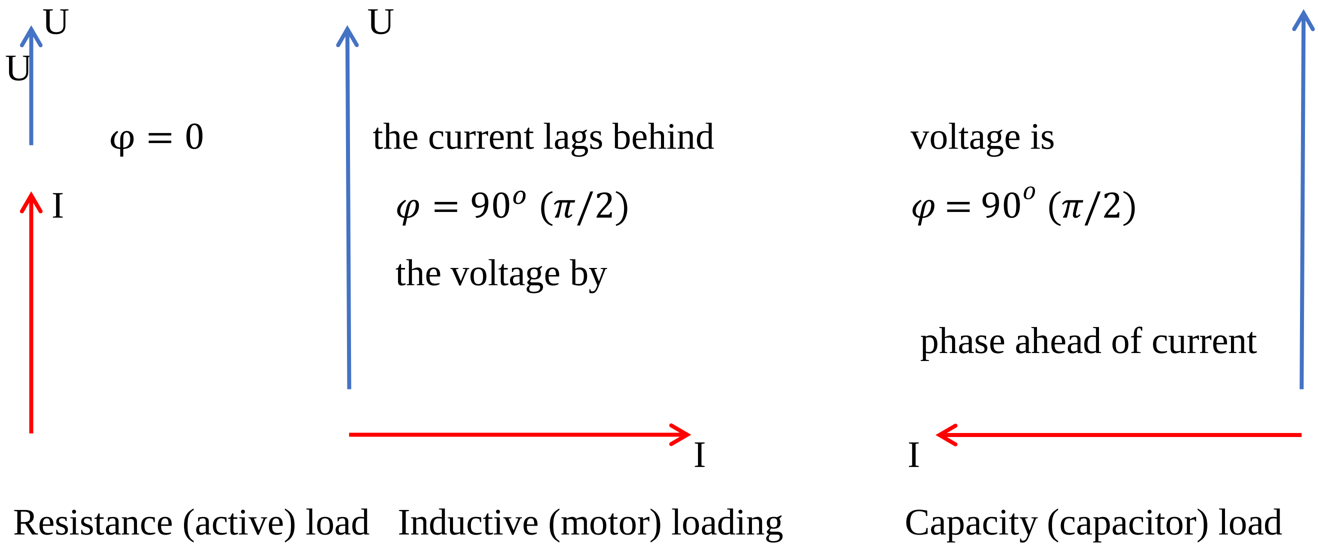
industrial enterprises, now all categories of consumers mentioned above are considered. So, it follows that the most effective way to reduce the power consumption from the network is to compensate for reactive power.

In this work, the results of an experimental study of the low-voltage reactive power automatic compensation device, its importance, possibilities, and energy efficiency, which is the most effective way to reduce the electric power consumed from the network, are presented directly in an industrial enterprise. The experiments were carried out on the example of a 315 kW asynchronous electric motor in the 14th post of the water and sewage treatment plant of the "Kungirot Soda Plant" belonging to "Uzkimyosanoat" JSC. In it, the active and reactive power in the network circuit to which the asynchronous motor is connected, as well as its technical parameters, were fully studied.

In order to properly evaluate the results of the study, we need to understand the physical processes that occur in the experimental object chains. As you know, alternating current flows through a conductor in both directions in a circuit. Ideally, the consumer should fully absorb and process the received energy. If there is a mismatch between the generator and the consumer, the electric current flows simultaneously from the generator to the consumer and from the consumer to the generator (the consumer returns the energy stored in it to the circuit). Such a situation occurs only if there are reactive elements with inductive and capacitive resistance in the alternating current circuit. An inductive reactance element tends to keep the current flowing through it, and a capacitive element tends to keep the voltage constant. In ideal resistive and inductive elements, the current flowing through them reaches its maximum value when the voltage is zero, and vice versa, in capacitive elements, the voltage is maximum when the current is close to zero. Picture 1 shows vector diagrams showing the phase difference between current and voltage in active, inductive, and capacitive load circuits.



Picture 1. Vector diagrams showing the phase difference between current and voltage in active, inductive and capacitive load circuits.

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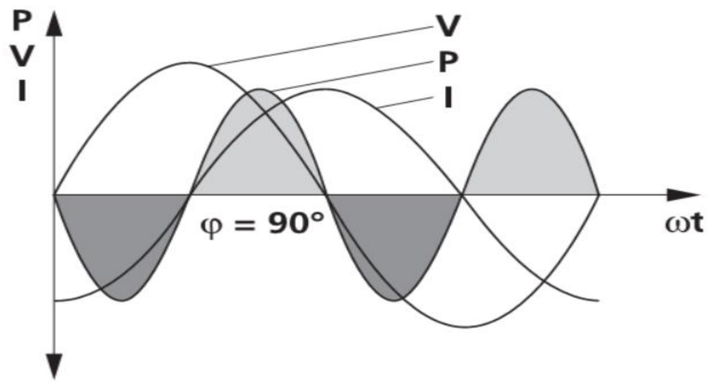
Reactive power is the power generated by the electromagnetic fields absorbed by the consumer and the torque of the motors. Reactive power occurs in devices with inductive coupling. For example, electrical devices used in agriculture, water management, construction, food, pharmaceutical, energy and machine-building industries (transformers at all stages of transformation, asynchronous electric motors, stabilizers, which consume 35% of the full power used for household and personal needs, 40% electric furnaces 8%, electric networks 7%, transformers 10%, etc.) magnetic fields are generated in devices for their normal operation. These are "Inductively Coupled Consumers". If the consumer (resistor) has an active character in electrical circuits, the phase difference between current and voltage is zero. If the consumer has an inductive connection (motors, transformers are in the operating mode only), the current lags behind the voltage. When the consumer has capacitive coupling (capacitors), the current leads the voltage.

One of the properties of an inductance is that it creates a phase difference between the current and the voltage as it maintains the current flowing through it. The phase difference between the current and the voltage leads to a decrease in the energy of the electromagnetic field supplied by the inductance network. For many industrial consumers, this means that in addition to active energy that does useful work, reactive energy that does not do useful work flows through the networks between the electricity generator and the consumer. Active and reactive power make up total power, and the ratio of active power to total power is determined by the cosine of the phase angle between current and voltage - cosφ. At the same time, the reactive current flowing in the opposite direction through the conductors and coils reduces the amount of active current passing through the network and causes significant additional losses in the conductors - active losses by turning part of the energy into heat. Picture 2 shows the frequency dependence graph of voltage, current and power under the influence of reactive load only ($\varphi=90^0$). As can be seen from the graph, the phase of current and voltage changes under the influence of reactive load.



Picture 2. Voltage, current and power under reactive load only ($\varphi=90^0$).

The power factor cosφ is an important indicator of the utilization of the full power of the electrical energy developed by the alternator. It should be noted that when Cosφ < 1, the generator must generate more voltage and current than the active

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power. For example, if the active power in the grid is 1000 kW and cosφ=0.8, then the total power is:

$$S = \frac{P}{cos\varphi} = \frac{1000}{0.8} = 1250\text{кВА}$$

Let's assume that the active power in this case is 100 kV voltage and 10 A current. However, the generator must produce 125 kV for full power:

$$S = 125 * 10 = 1250\text{кВА}$$

It is clear that using a generator for higher voltages is not useful, because at higher voltages the insulation of the conductors must be improved to prevent breakdowns. This leads to an increase in the price of the electricity grid. The need to increase the generator voltage due to the presence of reactive power is typical for a series connected circuit with active and reactive resistance. If there is a parallel connected circuit with active and reactive resistors, then the generator must produce more current than is required for one active resistor. In other words, the generator is loaded with additional reactive current. For example, for the above values P=1000 kW, cosph=0.8 and S=1250 kVA, when connected in parallel, the generator should deliver a current of 12.5 A instead of 10 A at a voltage of 100 kV. In this case, not only the generator must be designed for a larger current, but also the wires of the power line through which this current flows must be thicker. This increases the cost of the line. However, if there is 10A wire in the line and generator terminals, then 12.5A will obviously cause heat build-up in those wires. Thus, when the additional reactive current transfers reactive energy from the generator to the reactive consumer and vice versa, it leads to unnecessary energy losses due to the active resistance of the wires.

Currently, the parts of the electrical networks with reactive resistance are connected to the parts with active resistance both in series and in parallel. Therefore, generators must increase the production of excess current and voltage to generate useful active power and reactive power. From what has been said, it can be seen how important increasing the value of cosφ is for electrification. Its decrease is due to the appearance of reactive load in the electrical network. For example, electric motors or transformers with high inductive coupling operating in idle mode and in load mode generate significant reactive loading. To increase Cosφ, it is important that electric motors and transformers operate at full load. For example, if the device has a cosφ of 0.75-0.90 at full load, it will decrease to 0.20-0.40 at light load. Lightly loaded transformers also have low power factor.

There are several ways to increase cosφ. As we know, all three powers (S,P,Q) are related to each other in the following relationship:

$$S^2 = P^2 + Q^2$$

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That is, full power is not an arithmetic sum of active and reactive power, but full power is a geometric sum of P and Q powers. When cosφ=1, full energy reaches the consumer. When cosφ = 0 the current in the wire doubles because the same amount of current flows in both directions at the same time. In this mode, no active power is consumed by the load due to the heating of the conductors. Thus, the load takes almost all the energy from the chain and gives it back to the chain. This means that consumers are forced to pay for energy that is not actually used.

Unlike inductive elements, capacitive elements (capacitors) tend to maintain a constant voltage, that is, for them, the current precedes the voltage. Since the amount of electrical energy consumed is never constant and can vary over a significant range in a very short period of time, the corresponding active energy consumed relative to the total energy (cosφ) can vary. In this case, the lower the asset loads of the consumer, the lower the cosph value accordingly. It follows that reactive power compensation requires a device that can control the cosφ as the device's operating state changes.

Usually smooth control of cosφ is provided by synchronous generators and synchronous compensators. Step-by-step control of reactive power is provided by compensation devices consisting of a battery of capacitance elements (capacitors), switching equipment and control devices. The principle of operation of the automatic reactive power compensation device is to connect the number of capacitors corresponding to the instantaneous value of the reactive power available in the network.

Now we will focus on the results of the study conducted on the example of the 315 kW (cosφ=0.91) asynchronous electric motor in the 14th station of the water and sewage treatment plant belonging to "Kungirot Soda Plant" JSC. First, the power coefficient of the electric motor, the reactive and active power in it, as well as the current and voltage at the input and output were determined, and the automatic compensation device of the reactive power was designed accordingly. As a result, a compensation device suitable for the studied asynchronous electric motor was created and installed in the circuit. Table 1 shows the results of the study of current changes in the circuit of a 315 kW asynchronous electric motor with and without a compensation device.

Table 1

№	Automatic reactive power compensation device status	I_1	I_2	I_3	$I_{Average}$		ΔI
The result of experiment 1	Current value when the automatic reactive power compensation device is not connected	458A	460A	456A	458A		30A
	The value of the current when the automatic reactive power compensation device is connected	429A	425A	430A		428A	

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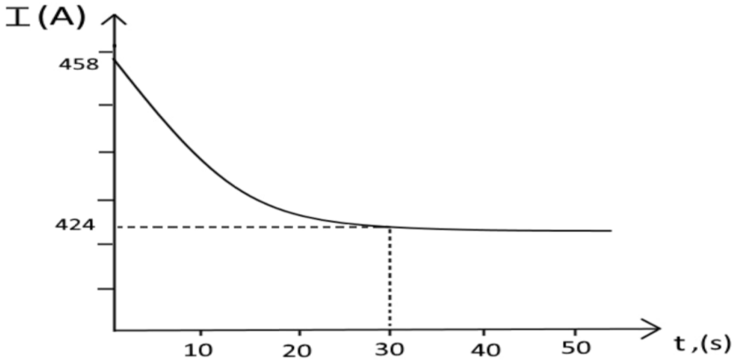
The result of experiment 2	Current value when the automatic reactive power compensation device is not connected	460A	457A	454A	457A		35A
	The value of the current when the automatic reactive power compensation device is connected	422A	422A	423A		422A	
The result of experiment 3	Current value when the automatic reactive power compensation device is not connected	455A	456A	456A	456A		34A
	The value of the current when the automatic reactive power compensation device is connected	423A	422A	422A		422A	

As can be seen from the table, the current was measured at three points (I_1, $I_{2,}$ I_3) when the automatic reactive power compensation device was not connected to the circuit and its average was equal to 457A. After connecting the automatic reactive power compensation device, the current was studied at three points (I_1, $I_{2,}$ I_3). In this case, the current value was 424A. So the value of the current is reduced to 33A. Picture 3 shows the current reduction after connecting an automatic reactive power compensation device to an induction motor.



Picture 3. Change of current strength over time.

Based on the above, we can calculate the active power and full power values in the three-phase alternating current circuit without the automatic compensation of reactive power connected ($P_{1,}$ S_1) and when the automatic compensation of reactive power is connected ($P_{2,}$ S_2) according to the regulation of inspection of "Uzenergonozorat" as follows.

$$P_1 = \sqrt{3}\, U_L I_L cos\phi = 1.71*397В*457A*0.91 = 282,3кW$$

$$P_2 = \sqrt{3}\, U_L I_L cos\phi = 1.71*397В*424A*0.98 = 282,0кW$$

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$S_1 = \sqrt{3}\, U_L I_L$=1.71*397B*457A=310,2кBA

$S_2 = \sqrt{3}\, U_L I_L$=1.71*397B*424A=287,8кBA

Δ S = 310,2 – 287,8 = 22,4 кBA

We determine the reactive power from the following expression

$Q_{kVar} = \sqrt{(S_2 kVA - P_2 kW} = \sqrt{96224{,}04\, kVA - 79636{,}84 kW} = \sqrt{16587{,}2\, kVA} = 128{,}79\, kVar$

The difference of full electric energy after connection of the automatic reactive power compensation device is ΔS=22.4 kVA, FIK η=22.4/315 = 7.1%. It can be seen that the automatic reactive power compensation device saved 7.1% of total electricity. This means for one year:

Reactive energy Q_{kVar} = 9,15 kVar x 19,5 sum x 24 hour x 333 day = 1 425 051,56 sum, active energy P_{kW} =21,95 kW x 450 sum x 24 hour x 333 day = 78 940 980 sum economy. So, if this device is installed in production enterprises, it can pay for itself in two months. Calculations show that with the help of this device, it is possible to save 21.95 kW per hour of active energy, and 9.15 kVar per hour of reactive power. This makes the device energy efficient and cost effective.

The presence of reactive power is a parasitic factor that is unfavorable for the grid as a whole. As a result, additional losses associated with the increase in current appear in the conductors, and the conductivity of the electricity distribution network decreases. The voltage in the network deviates from the nominal value. Reactive power degrades the performance of the power system, i.e. increases fuel consumption for power plant generators with reactive currents.

Conclusion: All of the above is the main reason why power supply companies require consumers to reduce the share of reactive power in the network. Reactive power compensation as a solution to this problem is an important and necessary condition for the economical and reliable operation of the enterprise's power supply system. Picture 4 shows a recommended scheme for installing an automatic reactive power compensation device in power supply systems. It can be seen from the picture that in the power supply systems used in practice, the characteristics of the electric energy generated in the generator change at 3 points of the network before reaching the consumer, that is, in the distance from the generator to the first low-voltage circuit of Tr-1, in the distance to the high-voltage circuit of Tr-2, and directly to the consumer itself. changes in intervals. Therefore, it is possible to effectively compensate the reactive power by installing an automatic reactive power compensation device in the parts of the power network with inductively coupled devices. In order to deliver full energy to the consumer without excessive losses, it is advisable to install a compensating device at 3 points.

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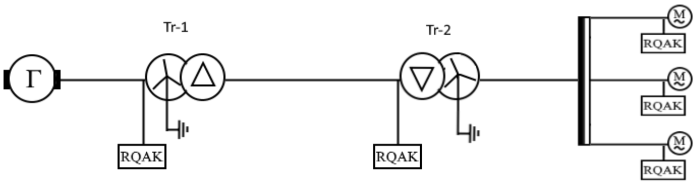

Picture 4. Recommended scheme for installation of automatic reactive power compensation device in power supply systems.

Correct compensation of reactive power reduces the total cost of electricity and the heat losses of the current. By reducing the load on the elements of the electric power distribution network (supply lines, transformers and switchgear, etc.), it extends their service life. In addition, it reduces the level of high harmonics that appear when using certain types of devices, eliminates disturbances that appear in the network, and reduces the phase difference. It provides opportunities to increase the reliability and efficiency of electric power distribution networks.

Currently, reactive power compensation is an important factor that allows solving the problem of energy saving in almost any enterprise. According to the estimates of local and leading foreign experts, the share of energy resources, in particular, electricity, in the cost of production is 30-40 percent. Reactive power compensation is the key to energy conservation. Accordingly, when the reactive power is compensated (with the help of automatically controlled capacitor blocks), the current consumed from the network is reduced by 7-35%, depending on the cosφ, as well as the heating of the conducting wires and the wear of the insulation.

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References:

1. Ershov S.V., Pozdnovsky V.V. Reactive power compensation system for a section of a network of industrial enterprises. News of TulGU. Technical science. 2012. Issue. 12. Part 3,
2. Balametov A.B., Musakhanova G.S., Khalilov E.D. Investigation of the solution of the problem of optimizing the modes of electrical networks in terms of voltage and reactive power by the method of sequential linearization and linear programming. Electricity. 2003. No. 3.
3. Yu. Fan wa technologylar Taraққiyoti. Ilmiy - technical journal, 2020. No. 6. 107-111 b.
4. Burkov A.T., Mirsaitov M.M. Modes of the electric traction network during the operation of electric locomotives VL-80R and UTY-1, Izvestiya PGUPS, 2016. No. 2. 146-160 pp.
5. Dikiy E.T., Parkhomenko G.A. Characteristics of brushless DC micromotors with a bridge switch when windings are connected in a star and a delta. Proceedings of TPU named after S.M. Kirov, 1971 Volume 212, 312-315 pp.