Compensation of Reactive Power in Asynchronous Motors of Agricultural Enterprises

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ABSTRACT

This article provides information about the series and ratings of three-phase asynchronous motors with a squirrel-cage rotor used in agricultural enterprises. The amount of active and reactive power consumed by an agricultural enterprise in 2022-2023 was also analyzed, and a proposal was made to compensate for reactive power.

Keywords: asynchronous motor, active, reactive and apparent power, power factor, load, power factor, line losses, motor efficiency, power quality.

Introduction: As you know, the agrarian sector in our republic is improving and developing more and more. Three-phase asynchronous motors are the main consumers of electricity used in agricultural enterprises. 70-80% of the generated electricity is used in electric motors[1].

However, the main part of the main reactive power consumption in electric motors is in asynchronous motors. Given this, compensating for the excess of the reactive power in an asynchronous motor used in agricultural machinery and $\cos\varphi$ increase is considered one of the main problems [2].Therefore, during the operation of electrical devices used in agriculture, a number of measures should be taken to start the asynchronous motor of the devices, as well as to stabilize the supply voltage [3]. During the operation of the asynchronous motor of electrical appliances used in agricultural enterprises, a lot of reactive power is consumed. At the same time, to increase the power factor of an asynchronous motor and reduce power losses in electrical equipment during operation of an asynchronous motor, which is mainly used in devices [4], the following measures are taken:

Method. The dynamics of reactive power change is expressed by the reactive power factor [5]:

$$tg\varphi = \frac{Q}{P}, \quad (1)$$

Here $Q = U \cdot I \cdot \sin\varphi -$ Reactive force, $P = U \cdot I \cdot \cos\varphi -$ active power, $\varphi -$ angle between voltage and current vectors. Although $tg\varphi$ A more complete power factor is used to fully describe the operating modes of electrical consumers:

$$\cos\varphi = \frac{P}{U \cdot I}, \quad (2)$$

Here $S = U \cdot I$ - full power.

Power factor is a factor that characterizes how much of the total power is used for useful work. With a decrease in the power factor of the consumer, the total power in the network increases, i.e. [2]:

$$S_T = \frac{P_P}{\cos\varphi}, \quad (3)$$

Here P_p – active consumer power and U with constant values of indicators

$$I_P = \frac{P_p}{\sqrt{3} \cdot U \cdot \cos\varphi} \quad (4)$$

the value of the reactive current increases, which leads to an increase in operating costs, that is, an increase in electrical energy losses in the network:

$$\Delta P = 3 \cdot R \cdot I_P^2 = \frac{R \cdot P_P^2}{U^2 \cdot \cos^2\varphi}, \quad (5)$$

Here R – active resistance of one phase of a three-phase device.

Determine the power factor of AD.

The AM power factor is determined by the following expression [3]:

$$\cos\varphi = P / S = P / \sqrt{P^2 + Q^2} \quad (6)$$

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

$Q = 3 \cdot I_\mu^2 \cdot x_\mu + 3 \cdot I_1^2 \cdot x_1 + 3 \cdot I_2^2 \cdot x_2$ -Reactive force;

$S = \sqrt{P^2 + Q^2}$ - full power. (7)

$\cos\varphi$ = 1.0 a battery of additional capacitors is usually required. The calculation of the capacitance of the capacitors required for reactive power compensation is carried out according to the following formula:

$$C = \frac{P}{\omega \cdot U^2} \cdot (tg\varphi_1 - tg\varphi_2), \quad (8)$$

Here $P = I_a \cdot U$ – active power of the electric consumer, $\omega = 2\pi f$ – angular frequency, U – mains voltage, φ_1, φ_2 – current vector before and after reactive power compensation $\dot{I}$ with mains voltage U angles between the capacitance of capacitor banks is determined by the following formula [3]:

$$Q = P \cdot (tg\varphi_1 - tg\varphi_2). \quad (9)$$

In industrial enterprises, the main consumers of reactive power are three-phase asynchronous motors, transformers, power lines and fluorescent lamps. Asynchronous motors consume 65-70% of reactive power, three-phase transformers in the power supply system - 15-25%, power lines, reactors, fluorescent lamps and other consumers - 5-40%. The dynamics of reactive power change is expressed by the reactive power factor:

$$tg\varphi = \frac{Q}{P}, \quad (10)$$

Here $Q = UI\sin\varphi$ – Reactive force, $P = UI\cos\varphi$ – active power, φ – angle between voltage and current vectors.

Although $tg\varphi$ A more complete power factor is used to fully describe the operating modes of electrical consumers:

$$\cos\varphi = \frac{P}{UI}, \quad (11)$$

Here $S = UI$ - full power.

Power factor is a factor that characterizes how much of the total power is used for useful work. If the power factor of the consumer decreases, the total power in the network increases, i.e.:

$$S_T = \frac{P_P}{\cos\varphi}, \quad (12)$$

where PP is the active power of the consumer and U is in constant values of the indicators

$$I_P = \frac{P_p}{\sqrt{3} \cdot U \cdot \cos\varphi} \quad (13)$$

the value of the reactive current increases, which leads to an increase in operating costs, that is, an increase in electrical energy losses in the network:

$$\Delta P = 3RI_P^2 = \frac{RP_P^2}{U^2 \cos^2 \varphi}, \quad (14)$$

where R is the active resistance of one phase of a three-phase device.

Asynchronous motorsto determine the power factor.

Asynchronous motorsThe power factor is determined by the following expression.

$$\cos\varphi = P / S = P / \sqrt{P^2 + Q^2} \quad (15)$$

whence P = Mω0+ 3 $I_1^2 R_1$ - active power; (16)

Q"="

$3I_\mu^2 x_\mu + 3I_1^2 x_1 + 3I_2^2 \ x_2$ -Reactive force; (17)

C= $\sqrt{P^2 + Q^2}$ - full power. (18)

If the power factor sosφthe smaller it is, the more reactive power the AD takes from the network and loads it with additional current and creates additional losses in it. The power factor largely depends on the load of asynchronous motors. In the clean mode of operation of asynchronous motors, the power factor is not very high, since the proportion of reactive power is greater than the active power at full power. With an increase in the load of asynchronous motors, its cosφsi also increases and reaches its maximum value in the area of the rated load of asynchronous motors [6,7,8].

Asynchronous motors are the main consumer of reactive power in the power supply system (its consumption is 60-65% of the total), so increasing their power factor is an important technical and economic task. Ways to increase the power factor of asynchronous motors [9,10]. Currently, the following main measures have been developed and are being applied to increase the power factor of asynchronous motors:

In addition, artificial power factor compensation is carried out by capacitors, synchronous motors, compensators, transverse filters and semiconductor static reactive energy sources.

The calculation of the capacitance of the capacitors required for reactive power compensation is carried out according to the following formula:

$$C = \frac{P}{\omega U^2}(tg\varphi_1 - tg\varphi_2), \quad (19)$$

Here $\mathrm{P} = I_a U -$ active power of the electric consumer, $\omega = 2\pi f -$ angular frequency, $U -$ mains voltage, $\varphi_1, \varphi_2 -$ current vector before and after reactive power compensation $\dot{I}$ and the angles between the mains voltage U. The capacity of capacitor banks is determined by the following formula:

$$Q = \mathrm{P}(tg\varphi_1 - tg\varphi_2). \quad (20)$$

Installing your own calculated reactive power compensation devices for each individual consumer frees the power supply networks from excessive reactive power load and ensures maximum economic efficiency.

Results. Comparative characteristics of the energy characteristics of asynchronous motors of standard and new series with a power of 0.75 kW and 18.7 kW are given. This is achieved by increasing the rice in induction motors to reduce cartridge resistance and power losses in the magnetic system. The stator and rotor cores are made of high quality steel; stator and rotor cores have a high content of copper and aluminum; the dimensions of the lamellas and the dimensions of the air groove between the stator and the rotor are adjusted to optimal values[11,12].

Table 1. An analysis of power losses in asynchronous motors of standard and new series used in agriculture is presented

№	Basic energy losses	Standard induction motor (%)AIR71A2, AIR160M4	New series asynchronous motors (%) M2AA, EFF3, EFF2, EFF1
1.	Losses in the stator and rotor	50	47
2.	Waste in a magnetic field	30	25
3.	Mechanical power loss	5	5
4.	Additional power consumption	15	8
	Total power consumption	100	85

Table 2. Comparative characteristics of the energy indicators of standard and new series of asynchronous motors used in agricultural enterprises are given

Rated engine power, kW	Standard induction motor **AIR71A2, AIR160M4**		**New series of asynchronous motors M2AA, EFF3, EFF2, EFF1**	
	EFF, %	After compression	EFF, %	After compression
0.75	75	0.76	81.5	0.84
18.7	89	0.86	91.0	0.865

In addition to the high energy performance of these motors, it heats up less (which prolongs the life of the motor), makes less noise during operation, and the power factor does not depend on the quality of the voltage. True, the price will be higher than standard motors, but it will pay off in two years of saved electricity.

Currently, the French company Jeumont-Schneider produces asynchronous motors of the FNBB, TNBB, RNBB, ISTAND, TNCB, PNCB series, as well as asynchronous motors of the DSOR, DKOK and other series manufactured by Helmke and Brown. The German company Boveri, as well as dozens of leading companies in the field of electromechanical production, such as Companysal Electric (USA), have 7-8% and 18-21% higher than the standard ratio of motors.

Table 3. Reactive power in asynchronous motors of agricultural enterprises claim for damages

Results	**Q. kvar**	**EFF %**
Reactive force when the compensation device is not installed results	49920	0.85
Reactive force results after installation of the compensation device	32 777	0.93

Discussion. The installation of capacitor banks designed for several groups of consumers leads to the efficient use of these capacitors. We are here to calculate the reactive power compensation in the textile industry using a computer program written in the **Delphi.**

This program is designed to calculate the reactive power compensation of the power supply system of agricultural farms. Using this program allows you to analyze the data of reactive power compensation of the power supply system of the enterprise according to a generalized indicator. The developed program provides:

- In agricultural farms, the taminot electrical system calculates the capacity of a capacitor bank to compensate for reactive power;
- universality of the program, i.e. the ability to use the program for any configuration of the distribution network scheme;
- information content of the calculation results and automatic receipt of analytical data on the reactive power of the industrial network;
- calculates the appearance of the representation of operating modes, as well as efficiency factors.

The program for calculating the reactive power of asynchronous motors of devices used in agricultural farms is presented in the Appendix.

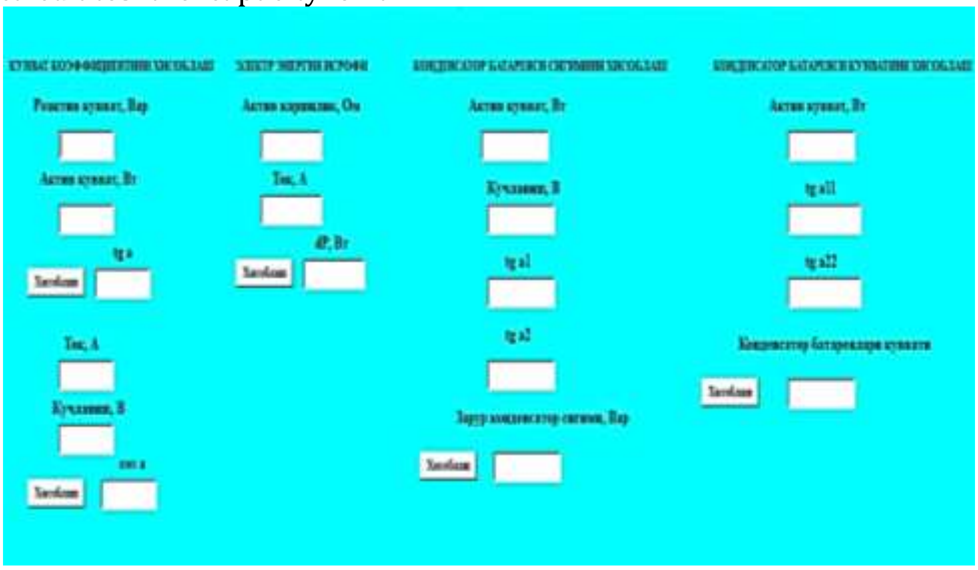

Fig. 1. Computer program "Analysis of the norm of reactive power compensation during the operation of asynchronous motors of agricultural machines"

Conclusion. The refore, it can be said that in asynchronous motors of devices used in agricultural enterprises withthe purpose of using sliding capacitor banks is not only to compensate for reactive power, but also to maintain the set value of the voltage transmitted from the network at maximum and minimum loads without change.

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