



ANALYZING THE EFFICIENCY OF INDUCTION MOTOR REACTIVE POWER COMPENSATION IN FODDER GRINDING DEVICES

Abdullo Panoev

PhD, Associate Professor (docent) "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University Bukhara Institute of Natural Resources Management. Uzbekistan.

panoev_abdullo@mail.ru

Makhsun Bozorov

PhD, Associate Professor (docent), Bukhara Institute of Engineering and Technology

Annotation. The article deals with the urgent problem of energy saving in agriculture, in particular, when using induction motors in forage chopping plants. The authors analyze electricity consumption in agriculture in Uzbekistan and note a significant share of electric motors in the total volume of energy consumption. Reactive power compensation using static capacitors is proposed as a method to improve energy efficiency. The authors describe the compensation method, provide a formula for calculating the capacitance of capacitors and evaluate the effectiveness of the method on the basis of experimental studies.

Keywords: Induction motor, active power, reactive power, total power, power factor, load, energy saving, reactive power compensation, static capacitors, agriculture, energy efficiency

INTRODUCTION

In the conditions of rapid development of the electric power industry of the Republic of Uzbekistan, which is one of the key sectors of the national economy, optimization of energy consumption is of particular importance. After all, economic performance and competitiveness of the country directly depend on the efficient use of energy resources. In this regard, agriculture, as one of the major consumers of electricity, is an important object for the introduction of energy-saving technologies.

According to the Ministry of Energy of Uzbekistan, agriculture accounts for about [20%] of electricity consumption in Uzbekistan, which is about 15.6 billion kWh. A significant part of this energy is used for operation of electric motors that drive various agricultural equipment: pumps, fans, conveyors, shredders, etc. In particular, increasing the efficiency of operation of feed shredding plants equipped with asynchronous motors comes to the forefront in the context of achieving energy and resource saving, as well as ensuring the production of high-quality products.

The legal and regulatory framework of the Republic of Uzbekistan in the field of energy saving, formed on the basis of a number of decrees and resolutions of the President of the Republic of Uzbekistan, plays an important role in stimulating the development of energy efficient technologies. The fundamental documents include:

- Decree of the President of the Republic of Uzbekistan from December 22, 2016 № PP-2692 "On additional measures to accelerate the renewal of physically worn out and obsolete machinery enterprises of industries, as well as reducing the cost of production", aimed at modernizing production facilities.

- Decree of the President of the Republic of Uzbekistan No. PP-3238 dated August 23, 2017 "On measures for further introduction of modern energy efficient and energy saving technologies", which

stimulates the introduction of innovative solutions in the field of energy saving.

- Decree of the President of the Republic of Uzbekistan No. UP-4947 dated February 7, 2017 "On the Strategy of actions for further development of the Republic of Uzbekistan in 2017-2021", which defines strategic objectives to reduce energy intensity of the economy, wide introduction of energy-saving technologies in production and increase labor productivity.

The present study is intended to contribute to the realization of the above-mentioned objectives, as well as to complement the provisions enshrined in the following legal acts:

- Law of the Republic of Uzbekistan "On Rational Use of Energy" (No. 412-1) of April 1997, which establishes the legal basis for energy conservation.

- Presidential Decree No. PP-3012 of May 26, 2017 "On measures to improve energy efficiency in social and production spheres, further expanding the use of renewable energy sources in 2017-2021", promoting diversification of the energy sector.

In modern conditions, agriculture of the Republic of Uzbekistan demonstrates sustainable dynamics of development and technological improvement. There is an increase in the use of feed shredders due to the growing demand for this equipment. In this regard, it should be noted that electric motors consume a significant part of electricity generated by power plants (about 70-75%), which emphasizes the relevance of research aimed at optimizing their operation.

In modern conditions of intensification of agricultural production, optimization of energy consumption is of particular relevance. One of the most energy-intensive processes is forage grinding, which is carried out by means of electromechanical units equipped, as a rule, with asynchronous motors. In this regard, there is a need to analyze the operating modes of induction motors in order to improve their energy efficiency and, consequently, to reduce operating costs.

In the process of operation of an induction motor converting electrical energy into mechanical energy, there are a number of negative phenomena, such as energy losses due to the presence of reactive power component, as well as the risk of short circuits that can lead to equipment failure. In order to minimize these negative factors, it is necessary to apply a set of measures including improvement of motor control systems, introduction of energy-saving technologies, as well as ensuring the stability of electrical network parameters.

Asynchronous motors, due to their constructive simplicity, relatively low cost and reliability in operation, have become widespread in the agricultural sector. Three-phase induction motors characterized by satisfactory power and mechanical characteristics are predominantly used. According to research data [1-15], the share of asynchronous motors in the total fleet of electric motors operated in agriculture is more than 70%.



Figure 1: General view of the forage grinding plant

Thus, the study and optimization of asynchronous motors in forage chopping plants is an urgent scientific and technical problem, the solution of which contributes to improving the efficiency of agricultural production and rational use of energy resources.

METHODS

In order to improve the energy efficiency of feed choppers, an effective method of reactive power compensation using static capacitors is applied in this work. This method allows to reduce power consumption and improve power quality.

Method Description

Reactive power is the part of the total power that does not perform useful work, but only circulates in the network, creating additional load on equipment and transmission lines. Reactive power compensation consists in installing additional devices that generate reactive power of the opposite sign, thus reducing its consumption from the grid.

Static capacitors were used as compensating devices in this work. Capacitors have the ability to accumulate electric charge and give it to the network, thus generating reactive power.

Choice of method

The choice of reactive power compensation method using static capacitors is due to the following factors:

- **Easy to implement:** The installation of condensers does not require complex technical solutions and can be easily implemented on any agricultural enterprise.
- **Cost-effectiveness:** The cost of capacitors is relatively low, and the effect of their use can be significant, as power losses are reduced and the service life of the equipment is increased.
- **Reliability:** Capacitors are passive elements with no moving parts, which ensures their high reliability and durability.

Capacitor capacity calculation

For effective reactive power compensation, it is necessary to calculate the capacitance of capacitors correctly. The following formula was used in this work:

$$C = \frac{P * (\tan\phi_1 - \tan\phi_2)}{\omega * U^2} \quad (1)$$

Where:

- C - capacitance of the capacitor, F;
- P - active power of the consumer, W;
- $\tan\phi_1$ - tangent of the phase angle before compensation;
- $\tan\phi_2$ - tangent of the phase angle after compensation;
- $\omega = 2\pi f$ - angular frequency, rad/s;
- U - mains voltage, V.

Evaluating the effectiveness of the method

To evaluate the effectiveness of the reactive power compensation method, experimental studies were conducted on the basis of an agricultural enterprise. During the research the following parameters were measured:

- Power factor before and after compensation.
- Power consumption before and after compensation.
- Shape of phase voltage before and after compensation.

Results

To evaluate the effectiveness of the proposed method of reactive power compensation, experimental studies were carried out. As an object of research was chosen a forage chopping plant equipped with an induction motor. Oscillograms were obtained using oscilloscope brand "**Peak Tech-1240**" manufactured in

Germany. Figure 2 shows the oscillogram of the phase voltage of the induction motor in no-load mode. It can be seen that the voltage waveform is close to sinusoidal, which indicates the normal mode of operation of the motor.

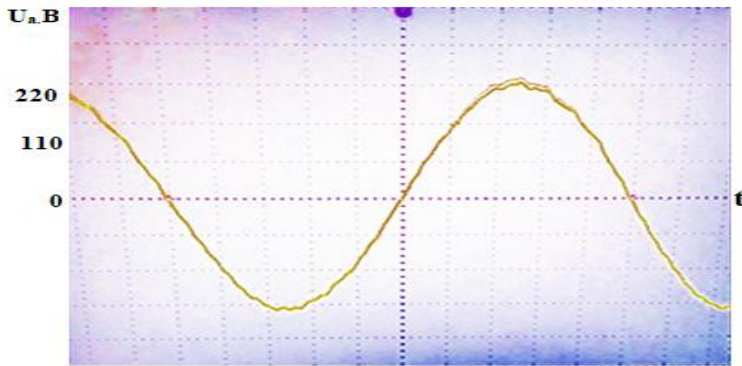


Figure 2: Oscillogram of the phase voltage of the asynchronous motor of the forage shredder operating at idle speed

Figure 3 shows the oscillogram of the phase voltage when the motor is running under load without reactive power compensation. There is a significant distortion of the voltage waveform caused by reactive power consumption.

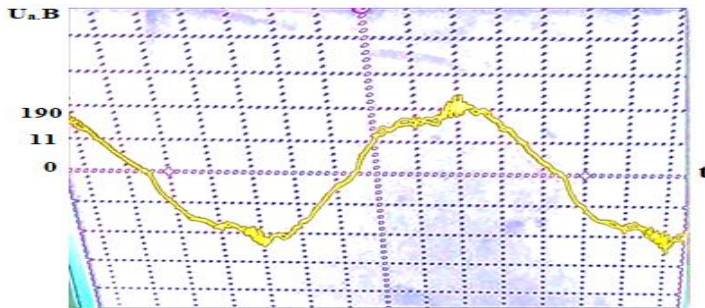


Figure 3: Oscillogram of phase voltage of induction motor under load without reactive power compensation

Figure 4 shows the oscillogram of phase voltage after installation of capacitors for reactive power compensation. The voltage waveform became more sinusoidal, which indicates the effectiveness of the applied method.

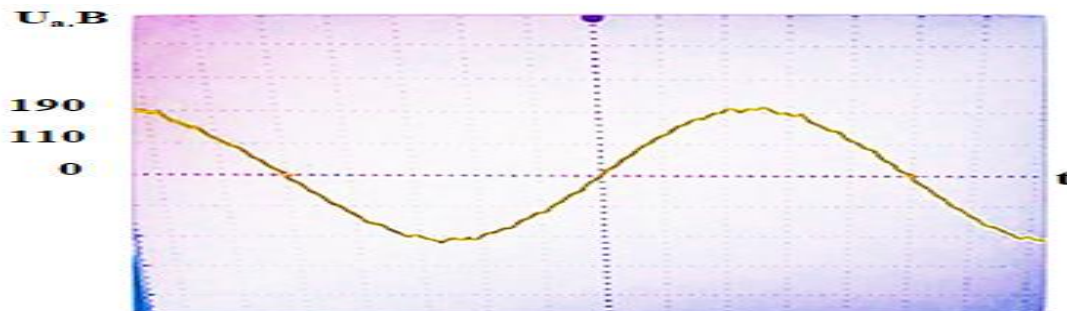


Figure 4: Oscillogram of phase voltage of induction motor under load with reactive power compensation.

Measurements

During the experimental studies, power factor ($\cos\phi$) and power consumption (P) before and after reactive power compensation were measured. The measurement results are presented in Table 1.

Table 1. Measurement results.

Parameter	Before compensation.	After compensation
Power factor ($\cos \phi$)	0,75	0,92
Active power (kW)	10,5	9,8
Reactive power (kvar)	14	4,6
Total power (kVA)	17,5	10,6
Current (A)	26,6	17,1
EFFICIENCY (%)	85	90
Power losses (kW)	2,625	1,06
Voltage (V)	380	380
Frequency (Hz)	49.9	49,9

Table 1 presents the results of experimental studies to determine the energy characteristics of the forage grinding plant before and after reactive power compensation.

Analysis of the data in the table shows that installation of capacitors for reactive power compensation resulted in the following positive results:

- **Significant increase in the power factor:** from 0.75 to 0.92. This indicates a more efficient use of electricity and a reduced load on the power grid.
- **Some reduction in active power consumption:** from 10.5 kW to 9.8 kW. This is due to the reduction of power losses in the motor and transmission line.
- **Significant reduction of reactive power:** from 14.0 kvar to 4.6 kvar. This reduces the load on the power grid and reduces power losses.
- **Reduced full power:** from 17.5 kVA to 10.6 kVA. This also contributes to reducing the load on the grid.
- **Noticeable reduction in current:** from 26.6 A to 17.1 A. This reduces the heating of the conductors and reduces power losses in the transmission line.
- **Reduced power losses:** from 2.625 kW to 1.06 kW. This confirms the increased energy efficiency of the system.
- **Increase in efficiency:** from 85% to 90%. This indicates a more efficient conversion of electrical energy into mechanical energy.

Thus, the data in Table 1 clearly demonstrate the effectiveness of the reactive power compensation method for improving the energy efficiency of forage grinders.

In order to improve the energy efficiency of the power supply system of the forage grinding shop, reactive power compensation is envisaged. In order to implement this measure, a specialized cabinet with a capacitor bank will be placed on the territory of the agricultural enterprise, near the input switchgear.

Calculation of capacitor capacity will be performed taking into account the total power of induction motors used in the shop, as well as the power factor requirements established by current regulatory documents.



Figure 5: General view of installed capacitors for reactive power compensation in the forage grinding shop, conclusion and discussion

In conclusion, it is important to emphasize that the use of static capacitors for reactive power compensation in forage chopping plants allows to achieve a significant increase in energy efficiency. The results of experimental studies confirm the effectiveness of this method, which provides not only a reduction in energy consumption, but also an improvement in power quality.

Application of reactive power compensation contributes to the realization of tasks set in the normative-legal acts of the Republic of Uzbekistan in the field of energy saving, as well as increasing the efficiency of agricultural production.

Further research in this area could be directed towards:

- Development and implementation of more sophisticated reactive power compensation systems, e.g. using controlled capacitor banks.
- Investigation of the possibility of applying other methods of increasing energy efficiency of feed choppers, such as the use of variable frequency drives.
- Economic analysis of the efficiency of implementing energy-saving technologies in agriculture.

Introduction of energy-saving technologies in agriculture is an important direction of the industry development, contributing to the reduction of production costs and increasing competitiveness.

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