Saving electrical energy by using induction motors with pole changing windings in the water supply system

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Abstract. This article provides information on the level of provision of clean drinking water to the population of Republic of Uzbekistan and the work carried out in the field, as well as the deficiencies that arise in the water supply enterprise and measures to eliminate them. The operation modes of the enterprise's pump units, the analysis of the main parameters and the possibility of saving electricity and water consumption due to the application of two-speed asynchronous motors with pole change winding for such equipment are presented.

1 Introduction

The world's demand for electricity is increasing at a high rate, the main reasons for which are the growth of the world's population, the development of industry and agriculture.

According to the International Energy Agency, electric motors consume 46% of the electricity produced in the world. This indicator makes up about 70% of the electricity consumed by the industry. As a result, the demand for energy-efficient and high-efficiency electric motors has increased [1].

In order to further accelerate the ongoing work on providing the residents of our republic with clean and high-quality drinking water and improving wastewater services, to create decent living conditions and maintain their health by increasing the coverage of drinking water supply and wastewater services.

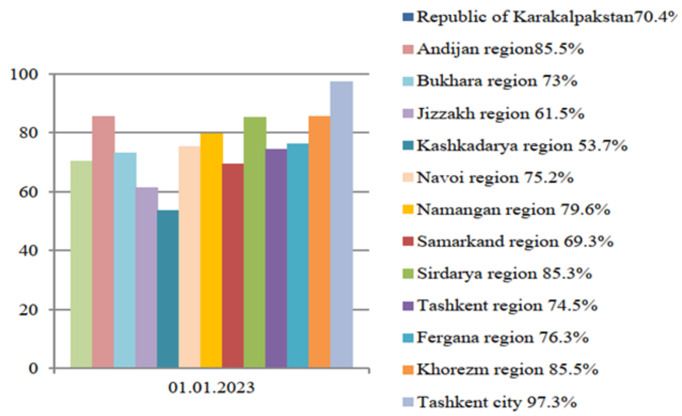

Fig.1. The level of provision of clean drinking water to the population of Uzbekistan

The development strategy of the President of New Uzbekistan for the period of 2022-2026 basically sets the tasks of bringing the level of drinking water supply to the population of the republic to 87%, updating wastewater systems in 32 large cities and 155 district centers.

If we pay attention to the pictures given above, it can be seen that the level of provision of clean drinking water in some regions and cities of our Republic is low. Conducting research in the field and creating modern energy-saving technologies is an urgent issue of today.

2 The current state of the problem

The provision of centralized clean drinking water to the population of Bukhara region is 69% as of January 1, 2022, and 73% as of January 1, 2023.

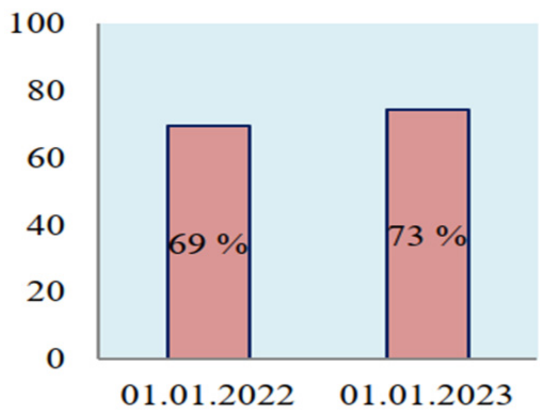

Fig.2. Clean drinking water consumption in the period of 2022-2023 of Bukhara region

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It can be seen that providing the population with drinking water is an urgent issue today. Here it is worth noting that repairs of pump aggregates of currently operating water supply enterprises, extending their service life, saving electricity, reducing water wastage, protecting the environment and preventing emergency situations, it is important to provide timely and quality service, use of automatic tools.

In the course of conducting research, one-speed electric motors, malfunctions in water pipes due to pressure changes, several times connecting and disconnecting motors to the network due to changes in water consumption, and a number of other problems may be encountered in the water supply company. Such problems lead to a decrease in the efficiency of the water supply company.

The power consumption graph of the electric motors of the city water supply company is variable, due to the increase and decrease of the demand for clean drinking water during the day, the motors work with full load and without load. When the motors work without load, the waste of electric energy increases and efficiency decreases. If we take the Bukhara water supply company as a research object. There are 2 asynchronous motors for 800 kW and 400 kW with a total power of 1200 kW are operating at the pump station. Water consumption mainly occurs in June, July and August. At these times, an additional 400 kW electric motor is activated, and the total power consumption reaches 1600 kW.

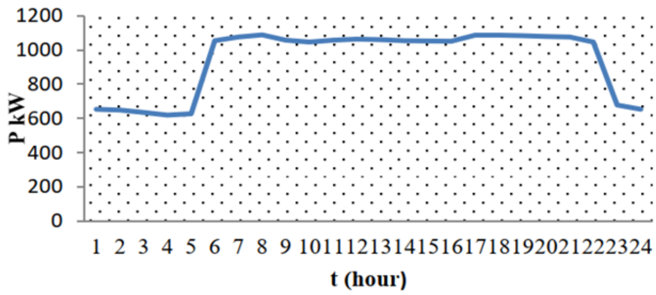

Fig.3. The daily power consumption of the water supply company

It can be seen from the above figure that the water consumption during a day is variable, mainly between 24:00 in the evening and 5:00 in the morning, as the pressure in the water pipes increases and the consumption decreases. As a result, electric motors run without load and waste power.

With aim to find the power consumed by the water supply company, may be determine the average power consumption and determine the electricity consumed during the year [1-5].

We determine the average power consumption of pump units using the following formula.

$$P_{avg} = \frac{\sum_{1}^{i=24} P}{i}; \qquad (1)$$

Average power consumption based on the above values

$$P_{avg} = 950\ kW \text{ ; is equal to}$$

Can be determine the electricity consumption of asynchronous motors without changing the rotation speed is equal to

$$W = P_{o'r} \cdot T = 950 \times 8760 = 8322000 \,; kW \cdot \text{h} \qquad (2)$$

According to the pictures obtained from the water supply company in Bukhara, the electric energy consumed by electric motors in one year is 8 322 000 $kW \cdot$ h.

3 New proposed idea, obtained results

Speed control of single-speed asynchronous motors, which are used in practice at pumping stations, due to changes in water consumption, starting and determining their main parameters in these processes is the main factor of economy.

In world practice, there are several ways to control the speed of asynchronous motors, including asynchronous valve cascade, thyristor frequency converter, as well as multi-speed asynchronous motors with changing poles. The method of speed control with multi-speed pole-changing asynchronous motors is the simplest and relatively inexpensive method.

In addition, the voltage can drop by more than 30% as a result of direct starting of motors that receive power from weak mains.

In this case, first of all, the torque developed by the electric circuit decreases, and secondly, the electronic and microprocessor devices that record the voltage drop disconnect the electric circuit from the network.

The use of pump units powered by a two-speed asynchronous motor facilitates the step-by-step start-up process of high-power motors [3-11, 12].

There are several advantages to applying adjustable electrical drives to water supply pumps.

In this case, opportunities are created to optimize technological processes, reduce the number of pumping units, save water consumption, adjust the pressure in water pipes, facilitate service, and save electricity. Also, during the start-up of high-power single-speed electric motors in the water supply company, malfunctions occur in the pipes as a result of the increase in pressure in the water pipes. Based on the above information, there is a need to apply adjustable electrical circuits to the pumps in the water supply company. Instead of single-speed asynchronous motors, the power consumption of two-speed motors with a ratio of 4/6 poles is shown in the graph below [13-20].

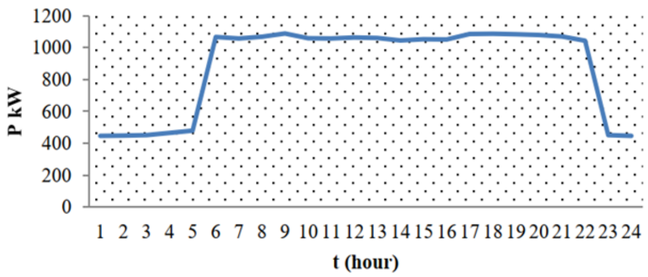

Fig.4. The graph of power consumption in the case of applying two-speed asynchronous motors with changing poles to the pumps of the water supply company.

It can be concluded from the graph that in times of low water consumption, the speed of the electric motor is reduced, i.e. it is changed to 1000 rev/min. As a result, power consumption of motors is reduced, and electricity saving is achieved.

Electric energy consumed by the use of two-speed asynchronous motors with alternating poles for water supply pumps [4 - 8].

The rotation frequency of an asynchronous electric motor is determined by the following formula.

$$\omega = \frac{2\pi f(1-s)}{p}; \quad (3)$$

In here; f - industrial frequency; s- slip; p- number of pairs of poles

We take a slip to s=0,03 in the nominal operating mode of the electric motor, the result of this, angular velocity of the electric motor $\omega_{p=2} = 152{,}3\, {rad}/{s}$; is equal to;

When the speed of the pump units is changed, the water consumption is determined as follows.

p_1=2 namely n=1500 rpm;

$$\frac{Q_1}{Q_2} = \frac{\omega_1}{\omega_2}; \quad (4)$$

$$\frac{1500}{Q_2} = \frac{157}{152{,}3};$$

$$Q_{p=2} = 1455\frac{m^3}{h} = 0{,}0404\frac{m^3}{s}; \text{ is equal to.}$$

$$p = 3;\ \omega_{p=3} = 101{,}5; \text{ is equal to.}$$

$$\frac{Q_1}{Q_3} = \frac{\omega_1}{\omega_3}; \quad (5)$$

$$Q_{p=3} = 1000\frac{m^3}{h} = 0{,}28\frac{m^3}{s};$$

The method of finding the discharge height of the pump unit is as follows.

$$\frac{H_1}{H_2} = \left(\frac{\omega_1}{\omega_2}\right)^2;\ H_2 = 61m; \quad (5)$$

$$\frac{H_1}{H_3} = \left(\frac{\omega_1}{\omega_3}\right)^2;\ H_{p=3} = 28m \quad (6)$$

The power consumed by the pump is determined by the following formula.

$$N_{p=2} = \frac{\rho \cdot Q \cdot H}{102 \cdot \eta} = \frac{1000 \cdot 0{,}404 \cdot 61}{102 \cdot 0{,}74} = 330\,kW; \quad (7)$$

$$P_{p=2} = \frac{N}{\eta} = \frac{330}{0{,}88} = 375\,kW; \quad (8)$$

$$N_{p=2} = \frac{\rho \cdot Q \cdot H}{102 \cdot \eta} = \frac{1000 \cdot 0{,}28 \cdot 28}{102 \cdot 0{,}72} = 103\,kW; \quad (9)$$

$$P_{p=2} = \frac{N}{\eta} = \frac{103}{0{,}72} = 143\,kW; \quad (10)$$

Above are the results obtained when the rotation speed of the 400 kW asynchronous motor is changed from 1500 rpm to 1000 rpm, and the above formulas were used to change the parameters of the 800 kW motor as a result of the speed change [21-25]. The results of recalculation of two-speed asynchronous motors are presented in the table below.

Table 1. The results of changing the parameters of the pump unit due to the adjustment of the rotation speed of the asynchronous motor.

№	n rpm	P kW	Q m^3/sec	H m	N kW
1	1500	P_1=375	0,42	65	330
	1000	P_2=146	0,28	28	103
2	1500	$P_1' = 772$	0,89	65	687
	1000	$P_2' = 300$	0,58	28	220

$$W_2 = [(P_1 + P_1') \cdot t_1 + (P_2 + P_2') \cdot t_2] \cdot 365 \quad (11)$$

Here P_1 and P_1' are the power consumption of the first P_2 and P_2' second electric motors at 1500 and 1000 rpm

t_1 is the time of increased water demand

t_2 is the time of reduced water consumption

$$W_2 = [(375 + 772) \cdot 8 + (146 + 300) \cdot 16] \cdot 365 = 5953880\ kW \cdot h$$

$$\Delta W = W_1 - W_2 = 8322000 - 5953880 = = 2368120\ kW \cdot h \quad (12)$$

2368120 $kW \cdot h$ electric energy was saved in one year due to the use of economical two-speed motors with alternating poles instead of asynchronous motors of the water supply company's pumping station [1-11].

4 Conclusion

Summarizing the above research work on rational use of electrical energy and water resource through using of motor with pole-changing windings in the power supply system, can conclude the following:

- the use of two-speed asynchronous motors of the water supply enterprise allows to obtain economic benefits of 710 436 000 sums (around 6,3 million dollar) in one year, as well as to use drinking water efficiently.
- the use of high-power two-speed electric motors with alternating poles facilitates the start-up process and reduces power consumption.
- that allows to adjust the pressure in the water pipes and prevent malfunctions.
- it give the opportunities for rational use of water due to changes in water consumption. It is advisable to use such two-, three- and four-speed asynchronous motors with alternating poles for water supply pump electric drives.

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