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Methods for Regulating the Performance of Pumping Units

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ABSTRACT: The article presents ways to control the performance of pumping units. Characteristics of pump performance regulation by throttling are obtained. An analysis of the existing methods of quantitative regulation of the pump performance was made, which showed that they significantly reduce the energy performance of the unit, and sometimes complicate its design, reduce the service life of hydraulic equipment and make it difficult to automate the process. The regulation of the performance of the pumping unit by changing the rotational speed of the impeller is considered and their energy characteristics are obtained. The effectiveness of the frequency-controlled electric drive of pumping units and its advantage are shown.

KEY WORDS: pumping units, control methods, performance, speed, frequency-controlled electric drive.

I.INTRODUCTION

Irrigation in Uzbekistan, in the course of its long development, has formed into a complex diversified engineering system that provides water to the national economic complex of the republic, which includes more than 200 large irrigation systems, more than 30 reservoirs, hydraulic structures, pumping stations (PS) and wells [1-2].

Constant growth of pumped irrigation areas and reclamation lands on the basis of an increase in the number of electric pumping stations and wells, their capacity in the republic determine a steady increase in electricity consumption. The main consumers of electricity are pumping stations - the most energy-intensive part of the water industry [2].

An analysis of the water supply schedule according to the National Assembly shows that the discrepancy between the water supply schedule and the capacity of pumping stations is 15-20%, which leads to excessive consumption of electricity and irrigation water. An analysis of the state of power consumption of the PS shows the presence of significant reserves of energy savings, reaching an average of up to 10%, and in some cases 17%, depending on the design features of pumping stations and their purpose [3-4].

A promising direction for solving this problem is the development and improvement of the control of the PS modes on the basis of an automated electric drive. At the same time, the development of an automated electric drive of pumping stations should solve problems related to the control of the operating modes of PS to ensure a given water flow, reduce energy intensity and specific energy costs, which are very high for irrigation PSs [5-8].

In modern pump engineering, there are two fundamentally different ways to smoothly control the performance of pumps: quantitative - at a constant speed of the pump impeller by changing the characteristics of the pressure pipeline, the

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geometry of the pump flow channels, the kinematics of the flow at the inlet to the impeller and qualitative - changing the speed of the impeller [1-3].

In the practice of machine irrigation systems, the following methods of quantitative regulation are used [4]: a) pressure valve (throttling); b) bypassing part of the water from the pressure pipeline to the suction pipeline; c) air inlet into the suction pipeline; d) changing the diameter of the impellers; e) by turning the blades of the impeller or guide vanes.
In these ways, it is possible to regulate the performance of the pump below the nominal flow rate.

II. RESEARCH PROBLEM AND METHOD

The most common is throttling, which is widely used on small pumping units, where performance control is required for a short time [5]. This method is based on an increase in local resistance in the pressure pipeline. It is possible to find out the advantages and disadvantages of this method, as well as to determine the scope of its application by constructing the characteristics of regulation.

On Fig. 1. The abscissa axis shows the values of the pump productivity Q, and the ordinate axis shows the corresponding head values H, the change in the efficiency factor $Q–\eta$ of the power consumption $Q–N$ of the pump is shown. The nominal operating mode of the pump is set on the graph by the operating point A, which is the point of intersection of the $Q–H$ curve with the characteristic of the pressure pipeline H_p, in which the supply $Q_A=Q_{MAX}$, the pressure H_A, the power N_A and the pump efficiency η_A are provided.

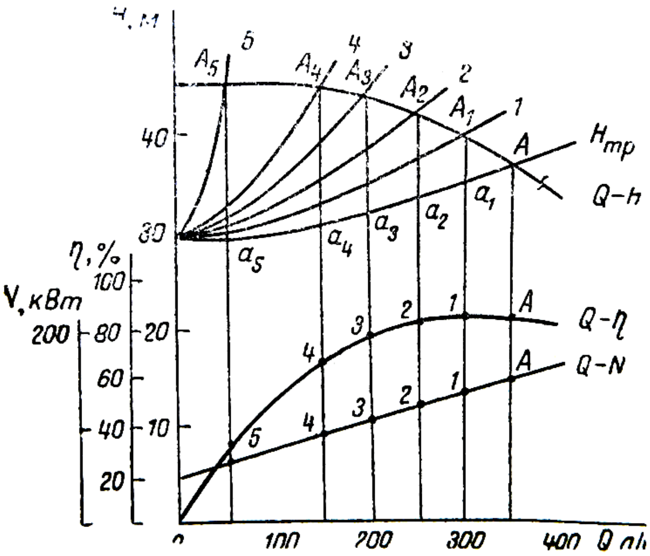

Fig. 1. Regulation of pump performance by throttling

As the pressure valve is introduced (additional resistance), the aerodynamic resistance of the pipeline increases, and each value of the valve position will have its own characteristic H_p. For example, the specified throttle position corresponds to the characteristics of the pipeline H_p, 1-5. In this case, the supply provided by the pump is determined by the regime points of intersection of the characteristics H_p and Q - H.

A decrease in pump performance by closing the pressure valve leads to a decrease in the power on the shaft of the pump unit and its efficiency with an increase in the difference between the required and developed pump heads (Fig. 1). This increases the energy for unproductive costs.

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The throttle control method is simple: no need for additional equipment and the possibility of smooth control of the pump flow in the range from Q_{max} to zero. Its main disadvantages are inefficiency due to an increase in unproductive energy costs that worsen the efficiency of pumping equipment, and accelerated valve wear, especially when water contains a large amount of suspended particles and silt (rivers of Central Asia) [2].

Regulation by water bypass is carried out by changing the opening of the valve installed on the bypass pipeline, in which the supply of the required fluid flow is achieved by bypass from the pressure pipeline in the suction part of the pump supply. The regulation of productivity in this way is mainly used to eliminate the unstable operation of pumps.

Its use is most expedient only for pumps with a speed coefficient L5 > 300 [5], in which the power decreases with increasing flow. In centrifugal pumps with a lower speed factor, bypass control results in an increase in pump power, which can overload the drive motor.

This method of regulation, despite the improvement in the cavitation qualities of the pump, contributes to a decrease in its efficiency, complicating the system, increasing the number of fittings and overall dimensions of the pumping unit [5].

Controlling the pump performance by introducing air into the suction pipeline is more economical than throttling [1]. This method can be used in cases where the pump operates on an unbranched network, the nature of which does not require special devices for removing air, and the suction height for this pump is actually much less than the permissible one. With the air inlet, the flow-pressure characteristic of the pump, as it were, shifts down. With a constant value of the characteristics of the pressure pipeline and the points of their intersection, the mode of operation of the pumping unit is determined.

Thus, by changing the amount of air entering the suction pipeline, it is possible to select the mode of operation of the coca, corresponding to the required performance conditions. With an increase in the amount of air, despite the improvement in the power consumption of the pump unit, its efficiency deteriorates due to a drop in pressure, and the flow control range is limited due to a decrease in the cavitation qualities of the pump.

The regulation of pump performance by turning the impellers along the outer diameter without changing the shape of their blades is carried out mainly at pumping stations equipped with the same type of pumping equipment, in which it becomes necessary to use a pump of this type with a lower value of power consumption while providing them with the required performance according to the conditions of the schedule for covering the pumping station. stations. Usually, the largest amount of turning of the pump impellers is 15-20% [5]. The method under consideration, compared with throttling, provides significant power savings and has a higher efficiency.

The main disadvantage of regulating the pump performance by turning its impeller is that this technique refers to changing the pump flow for an indefinite period of its operation, does not provide smooth flow control and has a limited range of performance changes.

Performance regulation by changing the angle of installation of the impeller blades is most effective in systems with low static pressure and is carried out only in axial and diagonal rotary-vane pumps.

An analysis of the existing methods for quantitative regulation of pump performance showed that they significantly reduce the energy performance of the unit, and sometimes complicate its design, reduce the service life of hydraulic equipment and make it difficult to automate the process [6-7].

III. RESULTS

Consider the regulation of the performance of the pumping unit by changing the speed of the impeller. To determine the main characteristics, the law of similarity is used [7-9]. The head characteristics of the pump $H=\varphi(Q)$ are congruent curves, and the operating point, moving along the characteristic of the pipeline, gives different delivery values.

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Relations that allow describing the dependence of flow, head and power on the pump speed are called the law of proportionality (or the law of dynamic similarity).

The flow (capacity) of a centrifugal pump varies in proportion to the speed of the impeller.

$$\frac{Q}{Q_1} = \frac{n}{n_1} \tag{1}$$

The pressure developed by the pump varies in proportion to the square of the speed of the impeller.

$$\frac{H}{H_1} = \left(\frac{n}{n_1}\right)^2 \tag{2}$$

The power consumed by the pump varies in proportion to the cube of the speed of the impeller.

$$\frac{N}{N_1} = \left(\frac{n}{n_1}\right)^3 \tag{3}$$

Applying the law of dynamic similarity, according to the well-known method, we build the characteristics of the pump for the speed of rotation n1 according to the available Q-H_h, Q-η_h Q-N_H for the frequency n_H (Fig. 2).

Using the method of constructing pump characteristics, it is possible to identify the advantages and disadvantages of the method for controlling the performance of a water-lifting pump unit by changing the speed of the impeller, and also to determine the control range. It is possible to establish in which mode the pump will operate only if the characteristic of the pressure pipeline H_p is known. Having plotted it on the graph, with the known characteristics Q-H_h, Q-η_h Q-N_H, we obtain the nominal regime point A, which corresponds to the maximum supply Q_A. In Fig. 2 the construction is made on the example of a pump of type 14 NDs.

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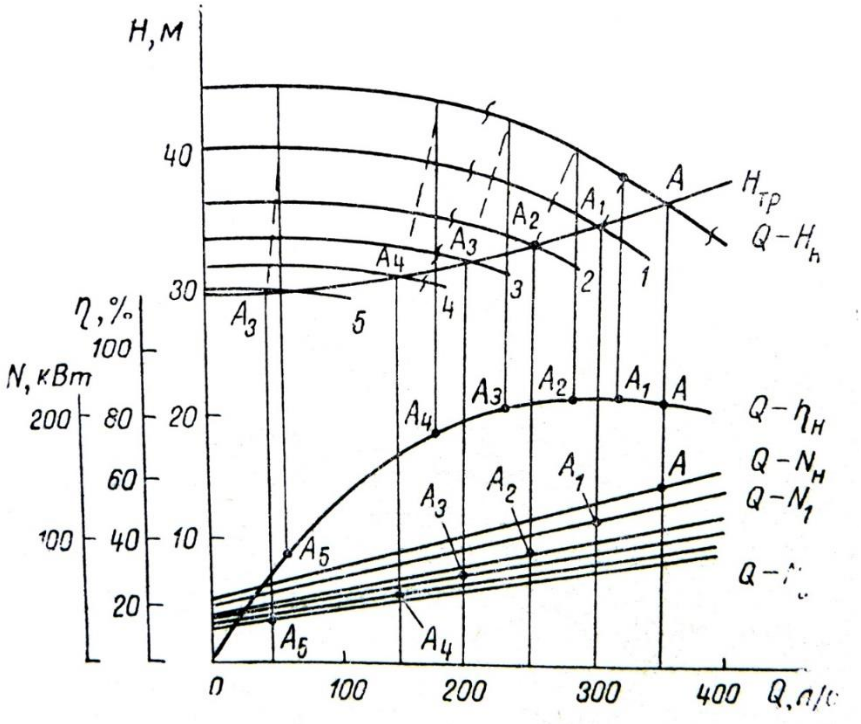

Rice. 2. Regulation of pump performance by changing the speed of rotation

With a decrease in the rotational speed $n<n_p$, the flow-pressure characteristic of the pump shifts downwards with the characteristic of the pressure pipeline H_p, on which the pump unit operates, remains unchanged. Points $A, A_1, A_2,..., A_5$ of the intersection of the flow-pressure characteristics with the Htr curve are the regime points of the "pump - pipeline" system, which correspond to their fixed speeds of the pump unit ($n_n> n_1>n_2... n_5$) and in which the required performance with the necessary value of the developed head is provided.

The pump shaft power and its efficiency for the indicated speeds can be determined from the $Q\text{-}N_h$, $Q\text{-}N_{1...}$ $Q\text{-}N_5$ curves for the required flow rates, and the efficiency - from the $Q\text{-}\eta_н$ curve by determining the intersection points of the straight lines (perpendicular to the axis abscissa) passing through the corresponding intersection point of the curve equal to the $Q\text{-}H_h$ efficiency characteristic.

Obviously, the regulation of the pumping station performance to ensure the combination of water consumption schedules and their coverage and take into account changes in the water level in the supply channel can only be achieved by a combination of the number of operating units in combination with smooth regulation of the flow rate of one or a group of pumps that can satisfy any required water supply regime and improve energy efficiency. indicators of the pumping station [8-10].

The resource-saving effect of an adjustable electric pump drive is determined by its regulating capacity. Due to this, it is provided [4, 6-7]:

- reduction of mechanical, hydraulic and electrodynamic loads during start-ups and in transient conditions to the level of harmless ones;
- exclusion of current surges in the windings of electric motors during start-ups and reduction of starting currents to nominal values;
- maintaining the optimal hydraulic regime and eliminating the possibility of hydraulic shocks in pipeline systems. and ruptures of pipelines during start-ups, stops of pumps and in other transient conditions;
- exclusion of wear of pipeline fittings in connection with the removal of regulatory functions from them, etc.

In some cases, in the practice of using frequency converters, the economic effect obtained from increasing the reliability, service life and overhaul life of equipment due to “sparing” modes is estimated to be higher than the economic effect from saving electricity.

One of the components of energy saving in the electric drive is the type of engine start. As a rule, pumping stations use a direct start with 5-7 times the starting current [6]. These losses can be significantly reduced by using a soft start of the pumping unit, which will also help to increase its resource.

Along with frequency converters, an important tool widely used abroad is "soft starters" - simple thyristor devices that allow you to control the start and stop of the drive by controlling the voltage at the motor terminals, as well as providing energy savings by reducing the voltage on an underloaded motor, and a number of others. properties. These devices are produced by many foreign companies and are very useful, especially for working with powerful asynchronous motors with six to seven times the starting current.

Attempts to adapt these voltage regulators to control the speed of rotation of asynchronous motors operating in a continuous mode, for example, in electric drives of water supply pumps, were unsuccessful - motors were required that were overestimated by 2-3 times the power.

IV. CONCLUSION

A comparative analysis of the qualitative method (n=var) of pump performance control with the above quantitative ones (n=const) shows that for the same flow rates Q_{A1}, $Q_{A2,\ldots,}$ Q_{A5} we have a lower value of the power consumed by the pump with a more improved efficiency.

Along with this, changing the speed of the pump impeller allows you to smoothly adjust the flow rate Q=φ(p) in a wide range. In this regard, this method of regulating the performance of the pumping unit is economical and promising.

The efficiency of a frequency-controlled electric drive can be obtained when it is used on pumping, fan, turbocompressor and other installations due to its following advantages [7-8]:
- energy savings (up to 50%);
- saving the transported product by reducing unproductive costs (up to 25%);
- reduce the accident rate of the hydraulic or pneumatic network by maintaining the minimum required pressure;
- reducing the accident rate of the network and the unit itself due to the use of soft start;
- increase of reliability and reduction of accident rate; electrical equipment by eliminating shock inrush currents;
- reduce the level of noise generated by the installation;
- convenience of automation;
- convenience and ease of implementation, etc.

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