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Effective Use of Electrical Energy in Hydro Station

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ABSTRACT: The article presents the issues of energy saving, which are becoming increasingly relevant due to the constant increase in tariffs and the introduction of the law on energy efficiency and energy saving. To save energy on pumping units, the characteristics of controlling the electric drive of pumping stations by frequency-controlled control are considered. For adequate adjustment of the technological process of water movement and power supply, the corresponding analytical dependences were obtained. An analysis of the physical expressions of water pumping processes made it possible to determine energy-saving operating modes and technologies for improving the efficiency of equipment operation. It has been determined that the operation of a frequency-controlled electric drive of pumping units according to a given control algorithm makes it possible to reduce their consumption of electrical energy by 30-40% compared to an unregulated one.

KEYWORDS: Hydro station, electrical energy, pumps, pressure, flow, pipelines.

I.INTRODUCTION

The issues of saving electricity are becoming more acute due to the constant increase in tariffs and the relevance of energy efficiency and energy saving issues in the water sector of the republic. Statistical data of the republic say that a significant part of the cost of land reclamation is the cost of operating pumping stations. The operating experience of this type of installation shows that in every cubic meter of pumped water, 74% of the costs are for electricity. One of the main problems of waste pumping stations is the unsatisfactory condition of the control systems of pumping units. Often they are in an inoperable state or work inefficiently. This is due to the fact that they were created during the construction of pumping stations and are now very outdated. In this regard, it is promising to consider the issues of possible energy-saving measures at pumping stations.

II. RESEARCH AND METHODOLOGY

Centrifugal pumps are controlled by changing the rotational speed of the impellers or changing the degree of opening of the valve (gate) on the pressure line. Covering or opening the shutter .change the steepness of the characteristic G - H of the pipeline (Fig. 1), which depends on its hydraulic resistance. Covering the gate, increase the steepness of the characteristic, while the operating point of the pump A_1 moves to position A_2,the flow decreases to the value G_2, head,developed by the pump increases to the value of H_2, and the pressure in the pipeline behind the gate decreases to the value of H'_2 due to pressure losses ΔN_P in the gate [1].

By increasing the degree of opening of the shutter, the steepness of the pipeline characteristics is reduced. This control method is considered uneconomical, since additional energy costs are required to overcome additional hydraulic resistance in the gate.

When the pump speed changes, the position of the characteristic G - H *changes*pump, reducing the speed, move the characteristic down parallel to itself. In this case, the operating point, moving along the pipeline characteristic, occupies position A_2sequentially, the flow decreases in the same way as the pressure in the network and the pressure developed by the pump.

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The power of the pump motor (kW) is determined by the expression [2]

$$P_n = \frac{k_{zap}(G_H+\Delta H_C)}{377200\eta_n\eta_{ed}}\gamma \quad (1)$$

wherek $_{zap}$ - safety factor (at G_n<100 m ^{3}/ hk_{zap} = 1.2-1.3; at G_n>100 m3 $^/$ hk_{zap} = 1.1-1.5); H_c - static head (the sum of the suction and discharge heights), m water column; ΔH - pressure loss in pipelines, m water column; η_n - pump efficiency; η_{ed}- efficiency of the electric motor; γ - liquid density, kg/m ^{2}; G_n- pump flow, m ^{3}/ h.

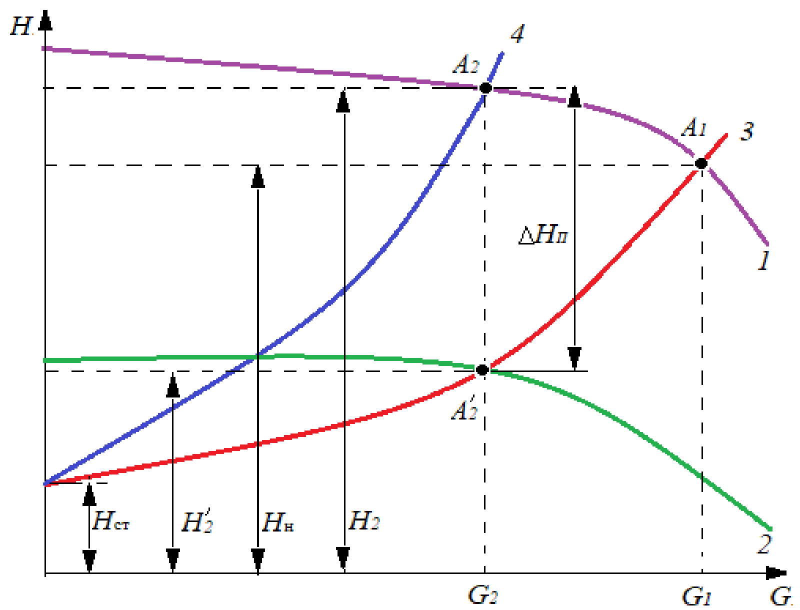

Figure 1. Regulation of the operating mode of a centrifugal pump: *1* - characteristic *G - H*pump at rated speed; *2* - the same with a reduced speed; *3* - characteristic *G - H*pipeline when the valve is fully open; *4* - the same with a decrease in the degree of opening of the shutter.

The specific power consumption in pumping units is determined by the expression, kWh/m ^{3} [3]:

$$\omega_{yd} = \frac{0{,}00272\,(H_c+\Delta H)}{\eta_n\eta_{ed}} \quad (2)$$

As can be seen from expression (2) and Fig. 1, energy savings in pumping units can be achieved:

1) the right choice of characteristics of the pumping unit (G_n,*H);*
2) increasing the efficiency of pumps and drive motors;
3) increasing the load of pumps and improving the regulation of their work;
4) reduction of pipeline resistance;
5) reduction of water consumption and losses.

The study of pumping stations [4-6] shows that in some cases there is a discrepancy between the passport characteristics of pumps (G_n,*H)* the actual characteristics of the water supply systems.

When the pumping unit operates with a flow rate less than the calculated one, a discrepancy arises between the pressure developed by the pump and the pressure required to supply one or another amount of liquid (i.e., the pump

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pressure is exceeded). From fig. 1 it can be seen that with a decrease in the flow, the pressure required for the network decreases, and the pressure developed by the pump increases.

The difference between these pressures

$$\Delta H_p = H_n - H_c (3)$$

From the graph of the combined operation of the pump and the pipeline (see Fig. 1) , it can be seen that the value of Δ H $_p$the greater, the steeper the characteristics of the pump and pipeline and the lower the actual pump flow compared to the calculated one.

The annual loss of electricity due to the increase in pressure will be, kWh:

$$\Delta W = \frac{k_{zap}}{36720\eta_n\eta_{ed}} \gamma \cdot \sum_{i=1}^{n} G_{Hi} \cdot \Delta H_{pi} \cdot T_g \qquad (4)$$

where T_g is the annual operating time of the pump with an excess of pressure by Δ H $_p$

If the pump is running at variable head and pressure, then

$$\Delta W = \frac{k_{zap}}{367200\eta_n\eta_{ed}} \gamma \cdot \sum_{i=1}^{n} G_{ni} \cdot \Delta H_{pi} \cdot T_g (5)$$

where G_{ni}- pressure on the i-thtime interval, ΔH_p - excess pressure on the i-thtime interval; T_{ri}- annual duration of the i-th interval; n is the number of pressure change intervals.

*Regulation of the pumps.*In practice, there are no permanent (permanent) water supply regimes. The pumps operate in variable mode depending on the modes of water consumption (Fig. 2). Therefore, the correct change in the operating modes of pumps, i.e., rational regulation, provides significant energy savings. Regulation of the operating mode of the pumps can be carried out by a pressure or receiving valve; changing the number of parallel pumps; changing the speed of the electric motor.

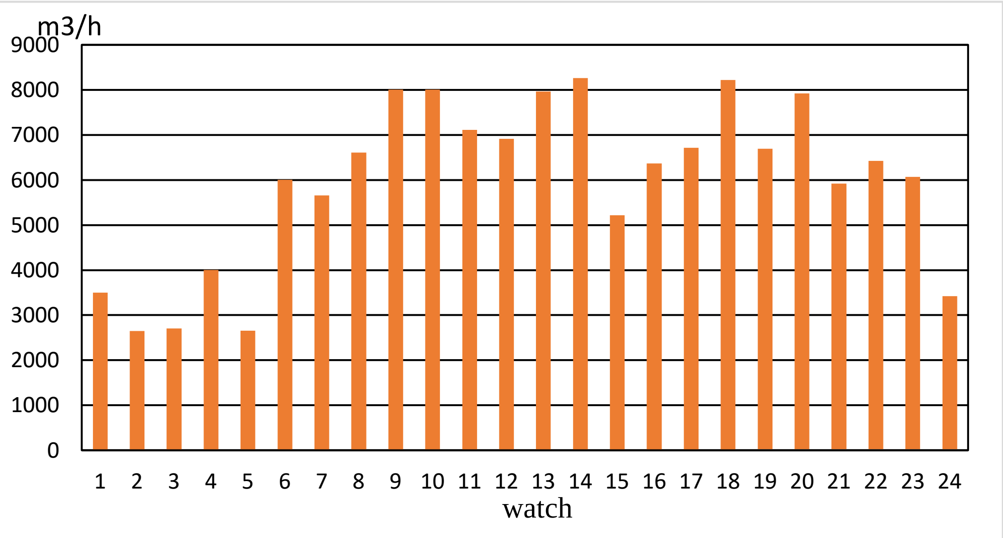

Figure 2.Daily release of water from the 2nd lift of the waterworks [4]

The power of the frequency converter is determined by the expression

$$R_{p.h} \backslash_{u003d} (1.1\text{-}1.2)\ R_n . (6)$$

The annual energy savings when introducing a converter is defined as

$$\Delta W = \frac{H_{\text{вых}} - H_{\text{необ}}}{367\eta_n\eta_{ed}} \sum_{i=1}^{n} G_{ni} \cdot T_g (7)$$

Where H $_{you\ x}$ - head at the pump outlet, m water column; H *is* $_{necessary}$ - the pressure maintained in the line, behind the valve, m w.c.

Increasing the efficiency of pumps. Replacing obsolete pumps with new ones with a higher efficiency allows you to save energy [4]

$$\Delta W = 0{,}00272 \frac{H}{\eta_{ed}} \cdot \frac{1}{\eta_{\text{н.н}} \cdot \eta_{\text{н,см}}} G_{ni} \cdot T_g (8)$$

*Reducing the resistance of pipelines.*The reasons for the increased specific electricity consumption for water supply are the incorrect configuration of the pipeline, when the flow experiences sharp turns, clogged suction devices, etc. Elimination of these causes leads to a decrease in pipeline resistance and a decrease in electricity consumption.

Head loss in the pipeline in a straight section

$$\Delta H = 0{,}083 \cdot \lambda \cdot L \cdot G^2 / d^5, (9)$$

$$\Delta H = 0{,}083 \cdot f \cdot G^2 / d^4, (10)$$

where λ *is the coefficient of friction of water against the pipe walls (* λ *= 0.02-0.03);*L- *length of the pipeline section, m;* G- *actual consumption, m* ^{3} */ s;* d- *pipeline diameter, m;* f- *coefficient of local resistance: for gate valves* f = *0.5, for a 90° elbow* f = *0.3, for a check valve* f = *5.0.*

Leaks of water through leaky connections of pipelines and fittings lead to direct losses of electricity. The values of these losses are determined in the following ways:

1) in the presence of flow meters at the beginning and end of the section of the distribution network, the losses are determined by the difference in the measured water flow rates for the reporting period at the beginning and end of the section;

2) with an extensive network with a large internal volume, water losses can be determined by an accurate flow meter by disconnecting all consumers from the network.

The measured water losses must be multiplied by the actual specific energy consumption for the water supply of this pumping station, the resulting value is equal to the energy losses caused by the poor condition of the water supply network.

A large amount of water in industrial plants is used to cool various process units. Water for these purposes can be used repeatedly in a closed cycle. The introduction of recycling water can reduce the consumption of primary | water by 2 times and save electricity by 15-20%.

It is possible to reduce water consumption and, accordingly, electricity consumption by improving the cooling systems of electrical equipment, as well as by using automatic control schemes for the supply of water for cooling.

III. CONCLUSION

An analysis of these regulation methods shows the following:

- When regulating with a valve with a decrease in water flow, the efficiency of the pump decreases, and the pressure values increase. Consequently, with a decrease in water consumption, the specific consumption of electricity increases rapidly;

- When regulating by changing the number of pumps operating in parallel, the efficiency of the motor and pump remain unchanged. The pressure due to the decrease in consumption and losses in the networks decreases, which leads to a decrease in the specific consumption of electricity;

- when regulating by changing the pump speed, the efficiency of the pump and the electric motor practically does not decrease with a decrease in flow, but the head decreases. Therefore, the specific energy consumption is reduced.

Frequency regulation is carried out using frequency converters. It allows :

- Automatically maintain the required water pressure when the volume of water consumption changes;

- increase the service life of electric motors and pumps by 2-3 times due to the elimination of overloads during water consumption, as well as during voltage drops in the network; increase the service life of pipelines due to the absence of excess pressure;

- reduce water consumption by reducing losses at excess pressure (in water supply systems, each excess atmosphere causes an additional 7-9% of water losses due to large leaks;

- reduce labor costs for the operation of water supply systems due to the uninterrupted operation of pumps, as well as automatic shutdown with the generation of a command signal to connect a backup pump and the use of control automation from the process control system.

The annual economic effect in the application of frequency regulation consists of three components [7] :

1) the effect of reducing electricity losses by increasing the efficiency of pumping units;

2) the effect of reducing water consumption due to pressure stabilization in water supply and distribution systems;

3) the effect of increasing the service life and overhaul periods of electrical and mechanical equipment, the cost of purchasing, installing and maintaining stop valves.

The use of a frequency-controlled electric drive of pumping units with the considered control algorithm makes it possible to reduce their consumption of electrical energy by 30-40% compared to an unregulated one.

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