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ELIMINATION OF ENERGY LOSSES IN PUMPING INSTALLATIONS BY MEANS VARIABLE FREQUENCY DRIVE.

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ABSTRACT

This article addresses the issues of the economical mode provided by pressure stabilization in the fluid supply system of pumping units.It is shown that the main control parameter in systems stabilizing the pressure in the network is the pressure at the dictating point.It is proved that the stabilization of the pressure at the dictating point provides the necessary minimum pressure in the network and reduces the energy consumption spent by the pumping station for water supply.

Keywords: Pressure, automatic control system, pressure sensor, proportional-integral controller, pump unit, pump speed, pressure, water taps, dead zone.

INTRODUCTION

For a significant group of pumping units, the economical mode is ensured by stabilization of pressure (pressure) in the fluid supply system. Such installations include pumping stations of the second and third elevations of industrial and urban water pipelines, pumping stations of pumping, stations of closed irrigation systems and the like.The need to stabilize the pressure in the network of these stations is due to the variable nature of the water consumption regime. The probabilistic nature of water consumption requires continuous changes in the operating mode of the pump unit. Changes must be made in such a way that the required values of technological parameters (feeds, heads) in the system as a whole are maintained and at the same time the minimum possible energy consumption of the pump unit is ensured.

MAIN PART

This problem is solved by an automatic control system (ACS) of the pump installation, stabilizing the pressure in the network at a given value.It is almost impossible to stabilize the pressure at all points of a complex branched network. Therefore, we can talk about stabilizing the pressure at some individual points in the network, called dictators.As dictatorships, points are chosen where the provision of normal pressure at which ensures the maintenance of the same or higher heads at other points of the network. As a dictating point, a section of the water supply network located at the highest geodetic elevations and the most distant from the pump station in the hydraulic ratio is selected, i.e., the section to which the pressure losses are of the greatest importance.The location of the dictation points is determined by hydraulic calculation of the network or empirically, as well as by the results of long-term operational observations. With a significant redistribution of water flows in the network, the dictating point can change its location. When the network is working in conjunction with pumping stations that are close to the consumers, for example, pumping stations, the dictating point can be located on the pressure head of the station. The main control parameter in systems that stabilize the pressure in the network is the pressure at the dictating point (s). Stabilization of the pressure at the dictating point provides the necessary minimum pressure in the network and reduces the energy consumption spent by the pumping station for water supply[1].

Below we consider the process of stabilizing the pressure at a dictating point using the example of a simple unbranched water supply network. Suppose that one pump is operating at the station(Fig.1). For normal water supply to consumers at dictating point A, the so-called free head Hfr must be maintained. Point A is located at Z2 above the water level in the tank. Losses of pressure in the conduit depend on the flow rate to the second degree. Therefore, in order to raise the water from the mark Z1 to the mark Z2, to overcome the hydraulic resistance and provide a given free head, it is necessary to develop the water head

$$H = (Z_2 - Z_1) + H_{fr} + SQ^2. \qquad (1)$$

Graphically, the dependence of the required pressure at the outlet of the pumping station on the flow rate is shown by curve 1 in Fig. 2. If this dependence is observed, a stable required pressure H_{fr} is maintained at the dictating point.

However, this pressure during operation of the pump with a constant speed is only supported in maximum flow mode.The rest of the time, when the pump operates at a low flow rate, for example at 7 h, the system operates at a high pressure. In fig. 2 shows how the pressure changes at different times of the day depending on the change in the water supply of the pump unit.

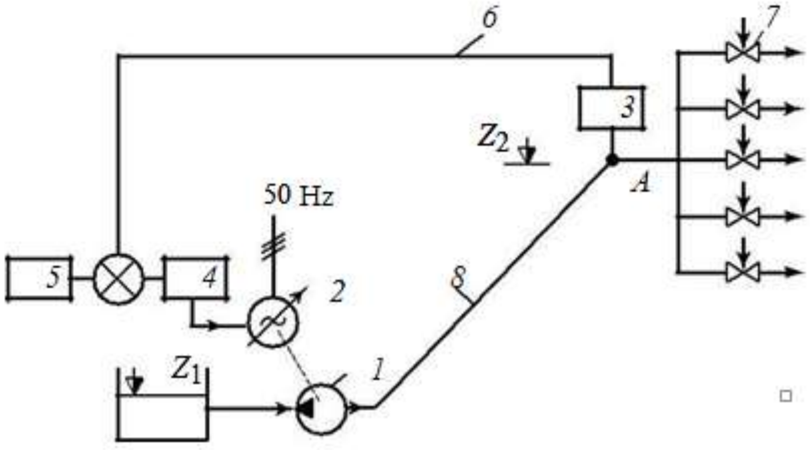

Fig.1. Schematic diagram of the stabilization of pressure in the dictating point A of the water supply network:

1 - centrifugal pump; 2 - adjustable electric drive; 3 - pressure sensor; 4 - PI controller; 5 - master device; 6 - communication channel; 7 - water-folding devices; 8 - water conduit.

In order for the pump installation to work without exceeding the pressure for any water consumption, it is necessary to equip it with an appropriate automated control system (ACS), which includes adjustable electric drive. Such a system consists of a pump unit equipped with an adjustable electric drive, a pressure sensor, a proportional-integral controller (PI controller), a master device and communication channels between the converter and the controller (see. Fig.1).The master device determines the required pressure value at the dictating point of the water supply network.The signals from the pressure sensor installed in the dictating point of the network, and from the master device are fed to the PI controller, where they are compared with each other, processed accordingly and then transmitted to the control system of the controlled electric drive of the pump unit.

If the pressure at the dictating point is higher than the set value, then a command is sent to the adjustable electric drive to reduce the speed of the pump motor, and vice versa. Changing the speed of the pump stops when the pressure at the dictating point matches the set value.

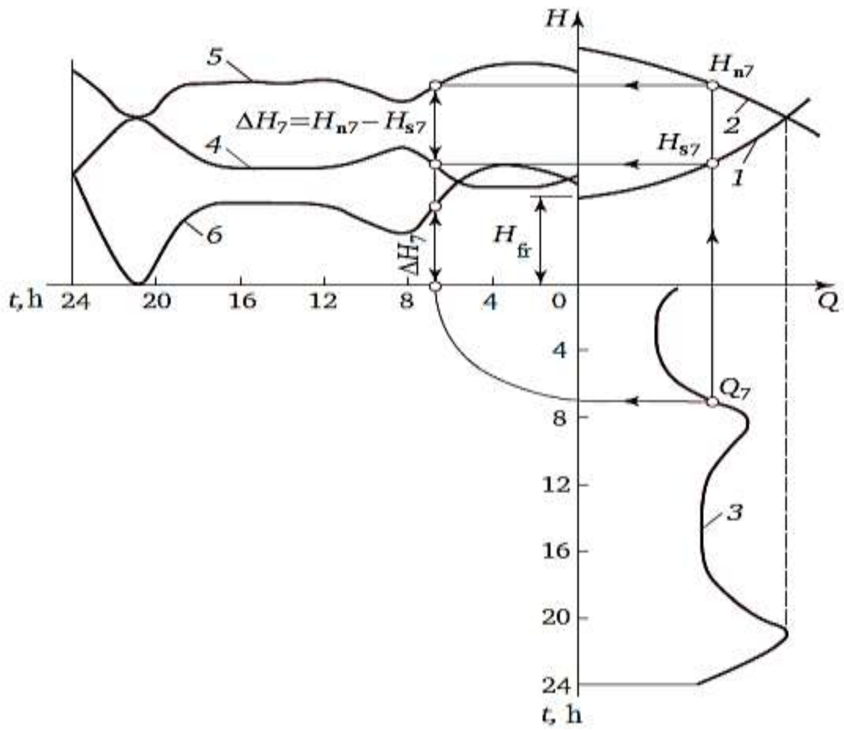

Fig. 3.2. Diagrams of daily changes in pressure developed by the pump unit:

1 - characteristic of the pipeline; 2 - pressure characteristic of the pump; 3 - is a graph of water consumption; 4 - the required pressure at the outlet of the pumping station; 5 - the actual pressure at the outlet of the pumping station; 6 - changes in time overpressure.

The regulatory process is as follows.At some point in time t1, the pump operates at a speed of n1, flow Q1 and pressure H1 (Fig. 3). This mode corresponds to a pressure loss h1.

Then the pressure at the dictating point A (see Fig.3) is equal toHA=H1-h1. We assume that this pressure at the beginning of the process corresponds to the set pressure value at the dictating point Hset [2].

Suppose that at the next time t2, the consumer, closing one of the water taps, reduces the water withdrawal from the system.A reduced pump flow Q2 corresponds to an increased head H2 and a reduced head loss h2. Due to the changes in the system operating mode, the pressure at point A can be written as HA2=H2H-h2. As can be seen from fig.3, HA2 is greater than the set pressure value Hset = HA1. The signal from the pressure sensor installed at point A is compared with the signal from the master. The converted error signal is fed into the control system ofthe control drive. Under its influence, the speed of rotation will begin to decrease until the pressure at the dictating point assumes again the set value:Hset = HA1.When the speed changes, the pressure characteristic of the pump will occupy the position corresponding to the rotation speed n_2, and a new pressure value H_2 will be established on the pump station manifold. Thus, the operating point of the pump in the graph sequentially takes position *1*, then *2*, and finally 2′ (see Fig. 3).

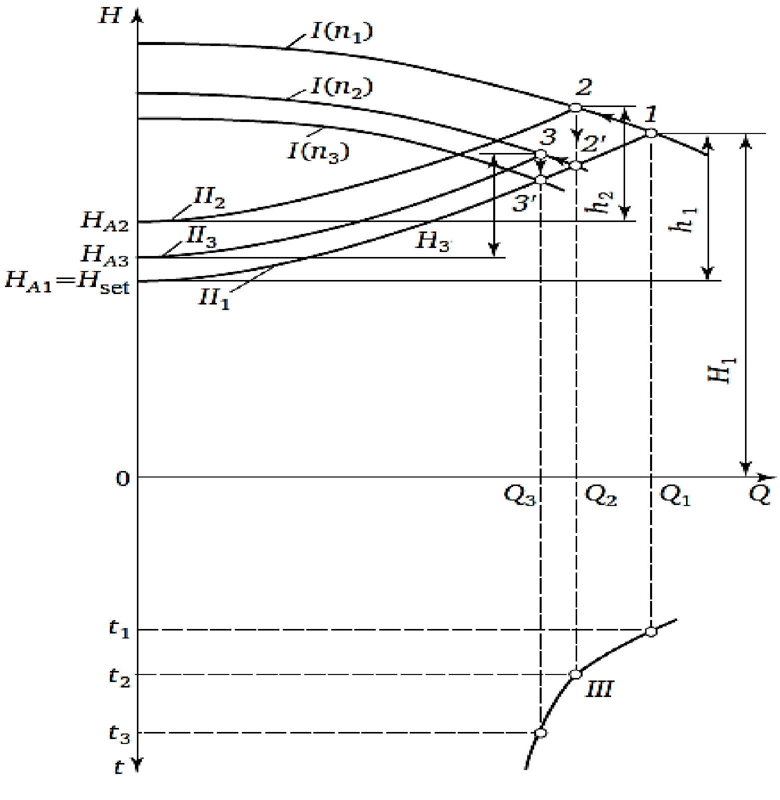

Fig.3. The process of stabilizing the pressure at the dictating point A (see Fig. 1): I(n1), I(n2), I(n3) - characteristics of the regulated pump at n1, n2, n3, respectively; II1, II2, II3 - characteristics of the conduit at different times t1, t2, t3, respectively; III - water consumption schedule.

Ifdue to the closure of another tap, a further decrease in water consumption to Q3 occurs, the operating point of the pump will sequentially move from point 2′ to point 3, and then 3′. In this case, as a result of the ACS action, the pressure characteristic of the pump moves to the position corresponding to the speed of rotation n3.

The control system is adjusted so that changes in the rotation frequency occur when there are small deviations of the values at the dictating point from the set values.For this reason, the curved triangles1, 2, 2′, and 2′, 3, 3′ on the graph are small. As a result, the operating point of the pump moves almost smoothly along the characteristic of the pipeline and, therefore, the system works without exceeding the pressure, i.e., in the economical mode.The process of stabilizing the pressure at the dictating point of the network when working with several pumping units is more complicated.If all operating units are equipped with the adjustable electric drive, the control process proceeds in the same way as described above, with the difference that the command to change the rotational speed is sent simultaneously to all operating pump units. Then the speed of the working units changes synchronously, and as a result of this, the pressure characteristics of all pumps simultaneously and uniformly change their position. Due to this, the operating parameters of adjustable pumps (supply, pressure, efficiency, etc.) change the same and, therefore, the distribution of loads between the working pump units occurs evenly.The task is more difficult to solve in those cases when both regulated and unregulated pumping units work simultaneously.In this case, the regulation process is carried out by changing the speed of the adjustable units and sequentially changing the number of working unregulated pumps.

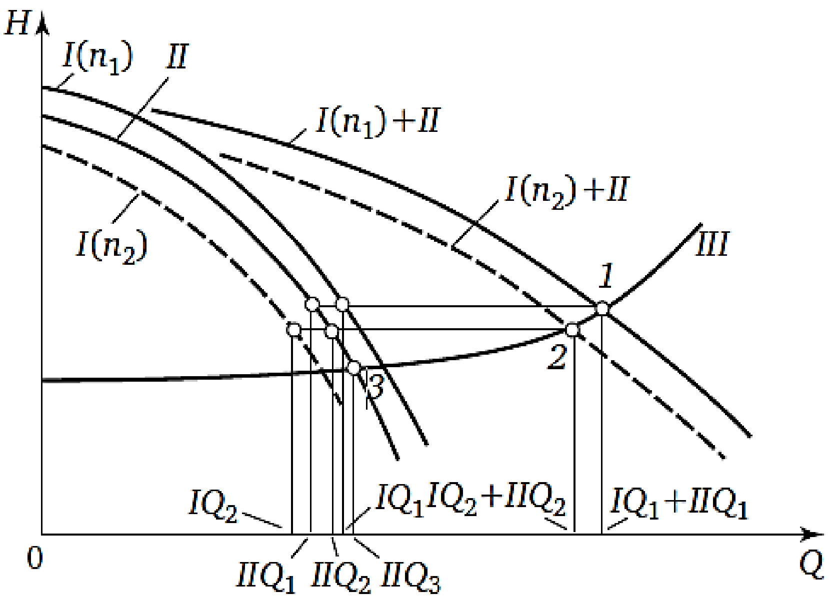

Fig.4. Schedule of joint operation of the network and pumps (regulated and unregulated):I(n1) - pressure characteristic of an adjustable pump at a speed of n1; I(n2) - the same for n2; II - pressure characteristic of an unregulated pump; I(n1)+I(n2)+II - total pressure characteristics of both pumps at n1 and n2, respectively; III - characteristics of the pipeline

In fig. 4 is a graph of the joint operation of the network and two pumps: regulated and unregulated. As in the previous case, when the water consumption changes and the pressure increases at the dictating point, the speed of the adjustable pump decreases, and when the pressure decreases, it increases.But at the same time, the characteristic of an adjustable pump changes its position, while an unregulated pump remains unchanged.For this reason, although the pumps operate with the same pressure, their supply is different.With a decrease in speed, the variable displacement pump operates at a lower flow rate, while the noncontrollable flow increases. Other operating parameters of regulated and unregulated pumping units (efficiency, power, etc.) also differ. In the event of a significant change in water consumption, there comes a time when the flow of the regulated pump decreases to zero, and the flow of the uncontrolled pump increases to a certain value of IIQ3 (see Fig. 4, point 3).At this time, the pressure of an unregulated pump becomes greater than a regulated one. The check valve of the adjustable pump closes, and if it is absent, water flows through the pump in the opposite direction.As a rule, when equipping the pump unit with an adjustable drive, the presence of a check valve is mandatory. Due to the senselessness of this mode, self-propelled guns at this point in time turn off the uncontrolled pump and force the speed of the controlled pump to the maximum value. To exclude the occurrence of such modes, modern frequency converters are endowed with a special function that prevents such a mode. With a further decrease in water consumption, the regulation process is carried out only by changing the speed of the adjustable pump.If an adjustable pump, due to increased water consumption, reaches the maximum possible speed, but, despite this, cannot provide water in the required quantity, and the pressure at the pump station outlet begins to decrease sharply, then the self-propelled gun should give an impulse to turn on the unregulated pump and reduce the frequency rotation of the adjustable pump to the desired value.

It should be borne in mind that the process of changing water consumption does not always go monotonously. Often, when the supply limit value Q3 is reached, the process can stop and go in the opposite direction. In such cases, a situation arises in which an uncontrolled pump will repeatedly turn on and off.To avoid such phenomena, self-propelled guns must contain a locking device that allows you to turn off or turn on an unregulated pump only if there is a steady trend in water consumption. In some cases, for example, if water consumption for a long time fluctuates around the boundary value of Q3, it is advisable to equip both adjustable electric drive pumps so that in this mode they both work with a reduced speed.When installing different types of pumps at the pumping station, in order to avoid the formation of the so-called dead zones (DZ), it is advisable to equip the largest pumps with the most gentle characteristic with an adjustable electric drive.

A dead zone occurs if the adjustable electric drive is equipped with a pump, the pressure characteristic of which lies below the characteristics of an unregulated pump. Under these conditions, when the limit value of the supply Q3 is reached, the uncontrolled pump cannot be turned off, since the adjustable pump, working even with the maximum speed, will not provide the necessary supply IQ1 <IIQ3. At the same time, it can no longer influence the regulation process, since the pressure it develops is less than the pressure IIH3 created by an unregulated pump (Fig.5).If a larger pump is equipped with a controlled electric drive, the self-propelled gun can give an impulse to turn off the unregulated pump with some lead,

while water consumption has not yet decreased to the limit value of water supply Q3.An impulse to turn on an uncontrolled pump can also be given in advance, until water consumption increases to the limit value Q3.This prevents the operation of the pump unit in the zone of low values of efficiency, which increases the efficiency of the regulation process[3].

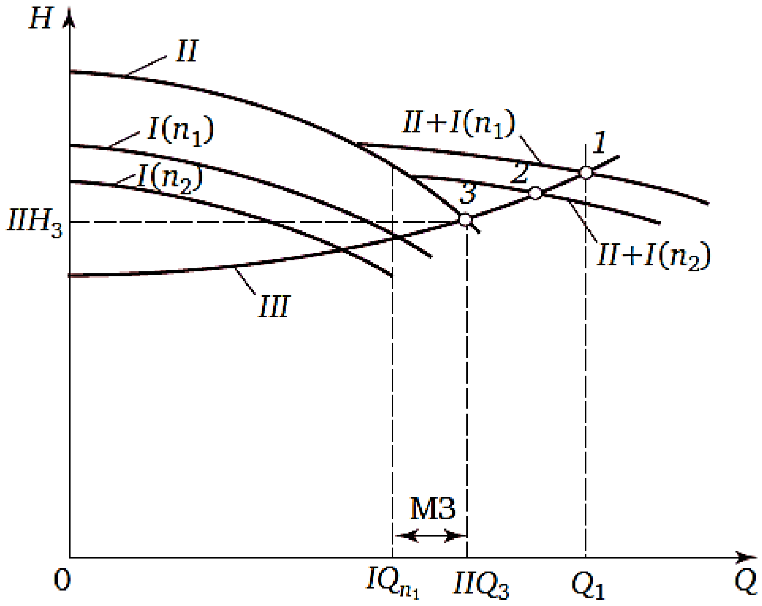

Fig.5.The formation of dead zones (MOH) in the process of regulating a pumping unit: I(n1) - pressure characteristic of an adjustable pump at a speed of n1;I(n2) - the same for n2; II - pressure characteristic of an unregulated pump; III - characteristics of the pipeline

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