ALGORITHMS FOR SIMULATION OF THE PROCESS OF WATER SUPPLY OF PUMPING STATIONS EQUIPPED WITH AXIAL BLADED AND CENTRIFUGAL PUMPING UNITS AND HYDRO-ENGINEERING FACILITIES

Mamatkobil Nurmamatovich Esonturdiev
Senior Lecturer of Chirchik State Pedagogical University

ABSTRACT

The article is devoted to the development of algorithms for modeling the process of water supply to pumping stations equipped with pumping units and hydraulic structures. The article also shows the algorithmic determination of the operating modes of the pumping station.

Keywords: main channel, water flow, mathematical model of pumping

Introduction. The processes of water resources management in the VHS with overregulation basins are described by complex algebraic equations, ordinary differential equations and partial differential equations. The joint solution of the system of equations of a particular water management system is a very difficult task, in each case it is necessary to choose your own methods of numerical solution of problems with the development of their algorithms. Taking into account the above, this the topic is relevant today.

Body. The operating modes of the pumping station are determined algorithmically according to the following sequence:

1 Lifting height (statistical head) - is defined as the difference in the levels of the upper and lower reaches of the pumping station:

$$H = z_{вб} - z_{нб} \quad , \qquad (1)$$

where is the elevation of the water level of the upper stream, $z_{вб}$

$z_{нб}$ - The water level of the lower reaches.

2 The permissible area of operation of the pump unit is determined in coordinates as follows: $D\ Q-H$

$$\left.\begin{aligned} D^i_{1\max} &= \Omega_T^{i\max} \cap \Omega^i_{H,Q,\varphi}, \\ D^i_{1\min} &= \Omega_T^{I\min} \cap \Omega^i_{H,Q,\varphi}, \\ D^i_{2\max} &= \Omega^i_{H,Q,\varphi\max}, \\ D^i_{2\min} &= \Omega^i_{H,Q,\varphi\min}, \end{aligned}\right\} \qquad (2)$$

where $\Omega_T{}^{\max}$, $\Omega_T{}^{\min}$ is the characteristic of the pipeline at the maximum and minimum geometric lifting height; $\varphi_{\max}$, $\varphi_{\min}$ – maximum and minimum angles of rotation of the pumping unit blades.

If the specified values are located inside the region of , then it is considered that the required water flow can be provided by this unit, otherwise this mode cannot be implemented by this unit. When multiple aggregates are running, the boundaries of the allowable area are determined by summing the costs within the boundaries of the areas at a constant height of lift. $Q\ H\ D$

3 Flow rate, gauge lifting height and efficiency of the operating pumping unit, i.e., the state of each operating pumping unit is characterized by a triple: $(z_{нб}, z_{вб}, \varphi)$, where: -angle of rotation of the blades of

the operating pumping unit. Consequently, the flow rate and efficiency of the pumping unit is determined as the point of intersection of the operational characteristics with the pressure characteristics of the pipeline φ_p^i

$i\ i$

$$\Omega_p^i\left(Q_p^i, H_p^i, \varphi_i^p\right) = \Omega_T^i \cap \Omega_{H,Q,\varphi},$$
$$\Omega_p^i\left(Q_p^i, \eta_p^i, \varphi_i^p\right) = \Omega_T^i \cap \Omega_{H,Q\ ,\eta}, \qquad (3)$$
$$\varphi_i = \varphi_i^p, \qquad \Omega_{H,Q,\varphi} \subset \Omega_э^i, \quad \Omega_{H,\eta,\varphi}^i \subset \Omega_э^i$$

4 The total flow rate and power consumption for the pumping station as a whole is defined as the algebraic sums of the costs and capacities of the operating unit:

$$Q_{HC} = \sum_{i \in N^p} Q_p^i, \qquad N_{HC} = \sum_{i \in N^p} N_p^i, \qquad (4)$$

where: -power of the pumping unit; $N_p{}^i = \gamma^H{}_i Q^i{}_p / 102\eta^i{}_p\ кBm / \ i$

γ -volumetric weight of the pumped liquid.

Thus, the water consumption and power consumption of the pumping station at each time are determined by algorithmic dependencies.

$$Q_{нс}(t) = F_1\Big(t,\ \ z_{вб}(t),\ \ z_{нб}(t),\ \ \big(N_i(t),\ N_i^p(t),\ \varphi_i^p(t)\big)\Big)$$
$$N_{нс}(t) = F_2\Big(t,\ \ z_{вб}(t),\ \ z_{нб}(t),\ \ \big(N_i(t),\ N_i^p(t),\ \varphi_i^p(t)\big)\Big) \qquad (5)$$

where $F_1\ F_2$ *are* the algorithmic operators, $N^p(t)$ - the set of operating pumping units, - the water level of the upper stream, - the water level of the lower stream. $z_{вб}(t)\ z_{нб}(t)$

In the discrete form of expression (5) presents

$$Q_{нс}^{k+1} = F_1^{k+1}\Big(k,\ \ z_{вб}^k,\ \ z_{нб}^k,\big(N^k,\ N^{pk},\ \varphi^{pk}\big)\Big)$$
$$N_{нс}^{k+1} = F_2^{k+1}\Big(k,\ \ z_{вб}^k,\ \ z_{вб}^k,\big(N^k,\ N^{pk},\ \varphi^{pk}\big)\Big) \qquad (6)$$

The structural model of the hydraulic structure is presented in the form of Figure 1.

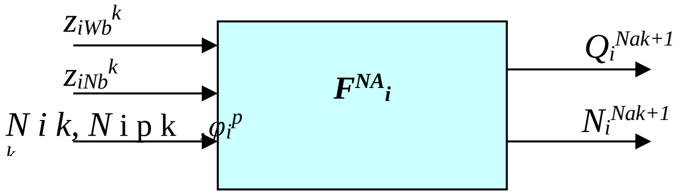

Figure 1. - Unit describing a pumping station equipped with axial pumping units

Similarly, it is possible to imagine a mathematical model of a pumping station equipped with centrifugal pumping units in the form of

$$Q_{нс}(t) = F_3\Big(t,\ \ z_{вб}(t),\ \ z_{нб}(t),\ \ \big(N_i(t),\ N_i^p(t)\big)\Big)$$
$$N_{нс}(t) = F_4\Big(t,\ \ z_{вб}(t),\ \ z_{нб}(t),\ \ \big(N_i(t),\ N_i^p(t)\big)\Big)$$

or (6) in discrete form

$$\begin{aligned} Q_{нс}^{k+1} &= F_3^{k+1}\left(k,\ z_{вб}^{k},\ z_{нб}^{k}, \left(N^k,\ N^{pk}\right)\right) \\ N_{нс}^{k+1} &= F_4^{k+1}\left(k,\ z_{вб}^{k},\ z_{вб}^{k}, \left(N^k,\ N^{pk}\right)\right) \end{aligned} \qquad (7)$$

The main difference here is the absence of blade turning angles, i.e. in centrifugal pumps they are fixed, i.e. the universal characteristics of such pumps do not depend on the angles of rotation of the blades. It should be noted that in pumping stations with centrifugal pumps, the configuration of the pipeline depends on the layout of the pumping station, so the characteristics of the pipelines are determined by systems of equations described by the movement of the liquid in complex pipelines. The structural model of the hydraulic structure is presented in the form of Figure 2.

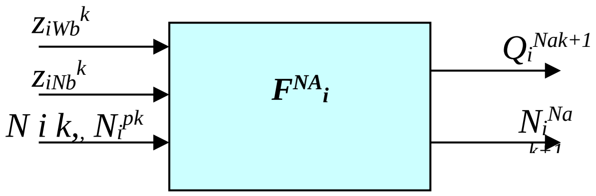

Figure 2. - A unit describing a pumping station equipped with centrifugal pumping units

Hydraulic structures. The flow rate of water through the hydraulic structure is determined by the formula

$$Q_i^{k+1} = F_i^{гтсk+1}(a_i^{k+1}, z_i^{в6k}, z_i^{нбl}) = \mu_i^k a_i^{k+1} b_i \sqrt{2g\left(z_i^{в6k} - z_i^{в6k}\right)}, \qquad (8)$$

where μ *is the* flow coefficient of the hydraulic structure located at the beginning of the canal section, a *is* the height of the gate opening, $б$ *is* the width of the gate, $Z_{вб}$ *is* the water level of the upper stream, g *is* the acceleration of gravity, $Z_{нб}$ *is* the water level at the beginning of the canal or the lower reaches of the hydraulic structure. The structural model of the hydraulic structure is presented in the form of a drawing 3.

Figure 3. - A unit describing a pumping station equipped with centrifugal pumping units

The hydraulic structure unit has three input signals and one output signal. The input signals of the unit $w = \left\{a,\ z_{вб}\ и\ z_{нб}\right\}$ and the output signal Q *are* the water consumption. Here a *is* the area of the open openings of the gate, $Z_{вб}$ - the water level mark at the beginning of the channel, $Z_{нб}$ - the water level mark at the end of the channel, Q - the water consumption.

The output signal of this unit Q - the water consumption of the hydraulic structure is uniquely determined by the known values of the input signals at the appropriate time.

The conditions for connecting water management facilities depend on the type of hydraulic structure and the modes of its operation.

Conclusion. Algorithms for modeling the processes of water resources management with reservoirs, consisting of algorithms for modeling the unstable movement of water in the main areas, have been developed, and it has been shown that the operating modes of pumping stations are algorithmically determined sequentially.

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