STATE OF REMOTE CONTROL AND MANAGEMENT SYSTEMS OF TECHNOLOGICAL MODES OF WATER RESERVOIRS

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ABSTRACT

In order to improve the technical condition of currently working hydrotechnical structures, develop automated systems, and improve the efficiency of the correct distribution of water resources, many scientific studies are being conducted in the world to improve the management systems of water distribution processes in reservoirs. The ongoing large-scale modernization and reconstruction programs of hydrotechnical facilities require the creation of high-efficiency remote control, that is, the automation of the process of distributing flows in reservoirs with high accuracy.

Key words: Reservoirs, hydrotechnical gate, automatic control, remote control.

INTRODUCTION

Today, in the world, serious attention is being paid to such problems as rational use of land and water resources, increasing the productivity of irrigated croplands, their waterlogging and salinization, preventing water wastage in irrigation networks that supply water from the water source to the fields, as well as in the process of irrigation.

20% of the water used in our republic is formed on the territory of our country, and the remaining 80% is taken from transboundary rivers - Syrdarya and Amudarya. On average, 60-65 billion cubic meters of water is consumed in our country per year, and more than 85% of water resources are used for irrigation in agriculture [1]. Most of the water used in agriculture enters the territory of the republic through neighboring countries. The most effective use of these reserves requires the introduction of water-saving technologies, that is, the use of irrigation methods such as sprinkler, drip, subsoil, film on irrigated fields, and flexible portable plastic pipes [2].

At the same time, in the world and in our republic, special attention is being paid to the introduction of advanced and modern technologies that save water resources, and a number of regulatory legal documents are being developed in this regard [2]. However, despite the measures being taken, the results achieved in this direction cannot be considered satisfactory. Since the water supply service is carried out at the expense of the state, the responsibility of farmers and farms to save water is not well established. Therefore, water-saving irrigation technologies have been introduced in 331,000 hectares of the total 4.3 million hectares of irrigated land in our country, or only 10% of the total cultivated area [2].

METHODS

Several foreign scientists have conducted research on the management of hydrotechnical facilities. In [3], researches were carried out on the management of hydrotechnical structures located in dams. The control is carried out from the operator's point through a cable, and the control signal is sent in analog form. Their disadvantage is that when data is transmitted via cable, excessive costs occur.

In [4] SCADA system was used to control hydrotechnical facilities. Data collection, processing, analysis and management of facilities is achieved through the SCADA system. SCADA is an open system, that is, the software system is open, and the interface allows external communication if data is passed to the interface in the required format, depending on the component being designed. Its main disadvantage is that this system is expensive, and a system with hydraulic structures cannot pay for itself in a year or two.

[5] worked on automatic control of hydraulic valves. The proposed method is optimal, convenient, effective. Its disadvantage is that it does not focus on the cryptographic security of the transmitted data.

In the study in [6], a large-scale encryption key algorithm was developed for remote control systems, the main drawback of which is that it cannot be used in large objects due to the small memory for SMS encryption and the low performance of mobile phones.

In [7], a control system for hydraulic structures, in particular, dams in channels, is proposed, the main drawback of which is that there is no feedback on the state of the dam based on the transmitted data.

In [8], a hydraulic facilities management system was developed, and they developed a secure key used to encrypt short messages using symmetric encryption of data transmitted in facilities management. Because this system deploys elliptic curves and a symmetric encryption algorithm, it has great computational advantages over the previously proposed public key solution, while providing as many security services as possible. The main disadvantage of this system is that data processing is very slow, which causes excessive waste in hydrotechnical facilities.

In [9], a system of automatic control of reservoir gates was developed, they did not take into account water consumption and level changes in the lower and upper reservoirs in their work.

[10] proposed a wireless water level monitoring system. An ultrasonic system of distance measurement was used in it. At this time, the remote stations are considered as simple measurement units with a communication interface that can work under the control of the base station. The advantage of the system is the absence of mechanical details. The disadvantage of this system is that the control of the water level is slow, cryptography issues for remote control have not been developed.

[11] proposed the use of microcontrollers for automatic water control for a dam. In this work, the DSPIC30F4011 microcontroller-based terminal (MAT) installed at a distance is mainly designed for accurate measurements, storage and transmission of equipment output to the computer server (CS).

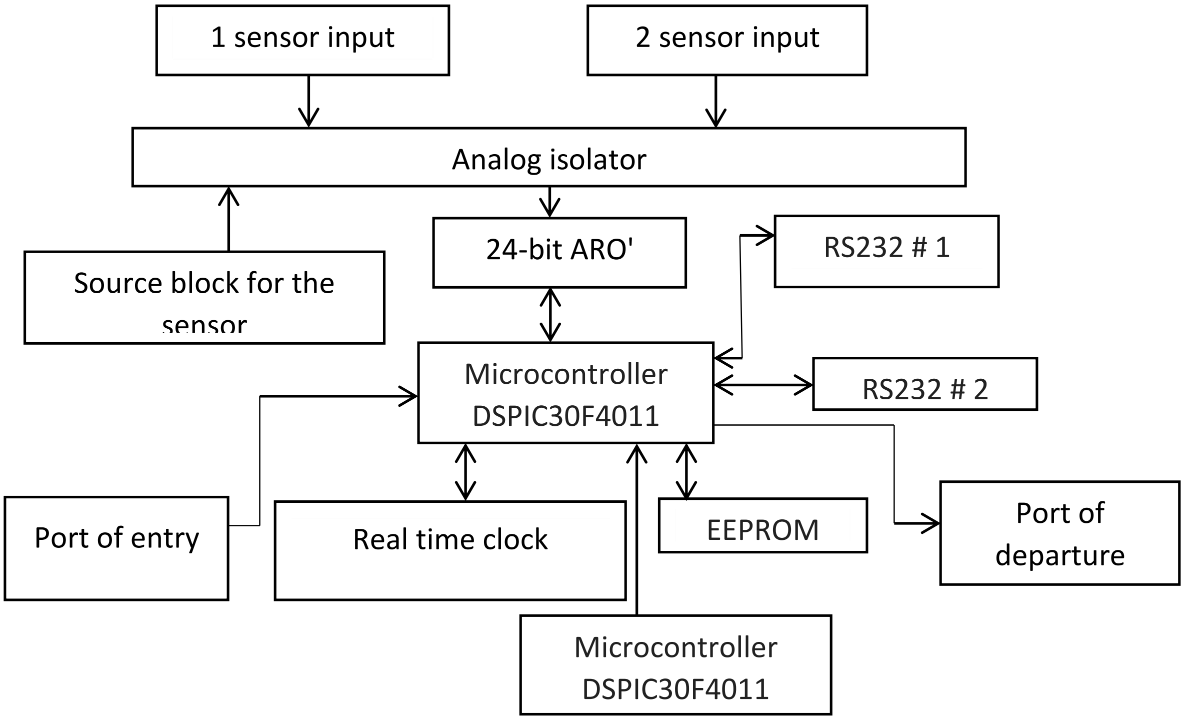

Figure 1. Hardware scheme of the remote terminal

Thus, there are many control strategies in the theory and practice of remote control of hydrotechnical facilities, each of them can be used in the management of specific hydraulic facilities. The choice of management methods depends on the object's management characteristics and management goals.

RESULTS

Hydrotechnical structures as control objects are characterized by significant delays and non-stationarity. Building these types of facility management systems is a rather complex task. Berk states that the presence of delay in the system reduces the region of stagnation, resulting in overcorrection and increased oscillation [12].

Currently, mathematical models of unsteady water movement in open water streams are constructed using St. Vincent's differential equations [13].

$$i_0 - \frac{\partial H}{\partial S} = \frac{a}{g}\left(v\frac{\partial v}{\partial S} + \frac{\partial v}{\partial t}\right) + \frac{v|v|}{c^2 R}, \quad (1.1)$$

$$\frac{\partial F}{\partial t} + \frac{\partial Q}{\partial S} = 0, \quad (1.2)$$

where S is the spatial coordinate along the channel; t – time; H is the depth of flow in the channel; v – average speed of water flow in the channel; Q – average discharge in the channel; c - Chezy coefficient.

In general, the channel section can be represented as shown in Figure 2.

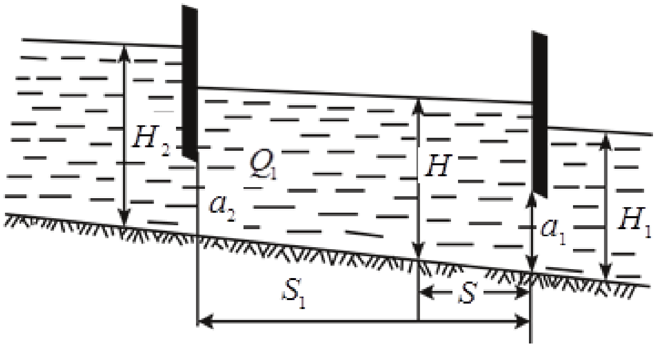

Figure 2. The part of the channel bounded by separating structures

R is the hydraulic radius of the channel; g – acceleration due to gravity; α is a coefficient describing the uneven distribution of velocities along the section of the channel.

The task of unsteady motion calculation is to determine the two properties that describe the one-dimensional flow state as a function of distance S and time t, that is, to obtain the dependences

$$Q = Q(S,t);\ H = H(S,t). \quad (1.3)$$

Currently, many methods have been developed to solve the differential equations of unsteady water motion, which are usually divided into strict and simplified ones. Rigid methods can be divided into linear and non-linear. Nonlinear methods include methods of characteristics, grids, and instantaneous modes. Linear methods include methods of solving differential equations (1.1), (1.2) by linear low-amplitude wave method, variational method, etc. [13].

The main element of the water distribution irrigation system is the units of hydrotechnical structures (GTI). According to the hydraulic mode, GTI units are divided into two types: free (Fig. 3, a) and with water flow coming out from under the valve (Fig. 3, b). In practice, they mainly use static relationships in the form of analytical expressions and calibration tables to describe the properties of partition structures [14].

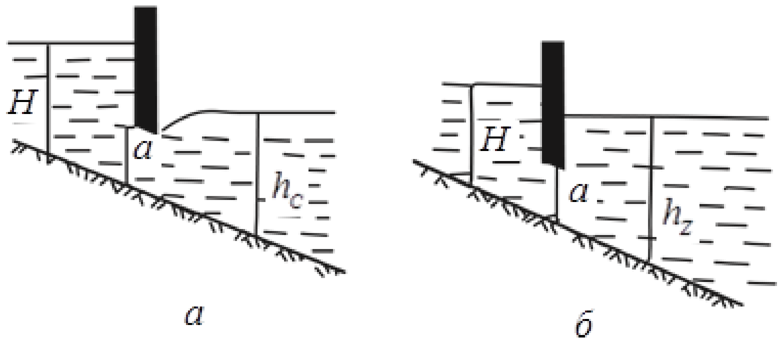

Figure 3. Free flow (a) and structures blocking the flow of water under the sluice (b)

The following formula is used to determine the water flow for free-flowing structures under the gate [15]

$$Q = \varphi \varepsilon a b \beta \sqrt{2gH_0}, \qquad (1.4)$$

here Q – consumption after blocking structure; φ – speed coefficient; ε - coefficient of vertical compression of the flow when exiting from under the gate; β – coefficient of lateral compression of the flow when exiting the hole; b – shutter width; a – shutter opening value.

In practical calculations, φ, ε, β it is difficult to determine the coefficients, so a simpler formula is adopted

$$Q = \mu a b \sqrt{2gH_0}, \qquad (1.5)$$

μ – is some generalized coefficient that $1 \le \mu \le 2$ varies between limits depending on structural and geometric dimensions of GTI.

The expression (1.4) is expressed in the following form in the case of blocking structures with water not flowing freely from under the trap

$$Q = \varphi \varepsilon a b \beta \sqrt{2g(H_0 - h_z)}, \qquad (1.6)$$

here h_z – the height of the water flowing under the sluice.

Similar to the case of free flow, the expression (1.6) can be reduced to a simpler form:

$$Q = \mu a b \sqrt{2g(H_0 - h_z)}. \qquad (1.7)$$

Let's consider the mode of operation of the GTI node with single barrier structures. To change the flow of water downstream, the position of the gate must be changed by a certain amount.

In hydrotechnical structures, the control class is considered separately according to the post-action or delay rule, as part of the control system, the mathematical model of the process in such systems is expressed in the form of general functional expressions, in the form of differential equations with deviant arguments. The presence of delay in the system makes it necessary to use special methods in creating the structure of the control system [16].

The delayed control object is often a priori parametrically uncertain [17]. Therefore, such an automatic control system is considered complex. For the development of this type of systems, it is considered appropriate to use a fuzzy approach based on various functions.

DISCUSSION

It should be to compensate for $\tau \leq \omega^{-1}$ the external disturbances that occur during the control process with the required accuracy, where τ - the delay time in the control channel; ω - the maximum spectrum of the influence of external disturbance. If there is a communication delay in the exchange of information between the subsystems of the network and the controller, the problem of compensating the effects of external behavior in the management of a network of dynamic objects becomes complicated. Existing algorithms for remote control of hydraulic facilities allow solving problems in two cases: the delay is constant and the remaining parameters can be changed, or all parameters except the delay are fixed and unchanging, and the delay is unknown and can be changed. Also, adaptive control algorithms have been developed for the case where the delay time and the parameters of the object are unknown in hydrotechnical facilities [18]. However, the methods proposed in [19] allow to solve the control problem only when the delay time is invariant and the assumptions about the models of the controlled object and the effects of external disturbances are strict.

The methods proposed in [20] did not take into account water consumption and level changes in the upper and lower reservoirs during the management of reservoirs. The disadvantage of this method complicates the process of synthesizing the control system of hydrotechnical objects, as a result of which transient processes are prolonged in a closed system. A shutter control system is proposed in [21].

In this method, the method of synthesis of delayed nonlinear systems is used. In almost all cases of synthesizing tuners for delayed objects, a prediction block is used to compensate for delays from the control loop. The initial data for solving the problem are the input and output signals of the system in the transient process, which are measured. Certain methods of modeling over time can be applied to this problem, where the a priori data must be reliable.

The issue of robust identification of hydraulic valves in transient processes is difficult from a practical point of view. For water resources systems, water storage, water inflows and outflows can also be expressed using fuzzy quantities due to their vague and ambiguous classifications. The water level and consumption in reservoirs varies, and the demand for water in growing different types of agricultural crops is also variable. This, in turn, requires the effective use of water in hydrotechnical facilities without excessive wastage in conditions where information is not clear.

Therefore, it is appropriate to consider methods of regularizing the state of dynamic systems in hydrotechnical structures and to create methods and algorithms for solving ambiguous problems.

It is known that in order to create a high-quality control system, it is necessary to obtain a high-precision mathematical model. However, there are limitations in obtaining a mathematical model of any process, and in many cases the obtained models are linear. This creates some inaccuracies in the model.

In this regard, this feature also exists for hydrotechnical structures, the resulting uncertainties are as follows:

- the models of reservoir structures are not clear.
- uncertainty of water level and consumption.
- sensor errors.
- errors in the management process.
- due to the use of microcontrollers, errors that occur as a result of quantization, etc.

All of them reduce the effectiveness of the management system in its development. Based on the above ideas, this article proposes a system for remote control of reservoir segmental gates using neural networks and elements of fuzzy logic, which allow taking uncertainties into account.

To achieve the set goal, the following tasks should be performed:

- development of analytical expressions of hydrotechnical structures taking into account environmental impact;
- construction of a model of hydrotechnical working modes of the zatvor;
- development of a seasonally adjustable reservoir modeling algorithm;
- construction of a segmented shutter control system based on elements of fuzzy logic;
- optimization of fuzzy logic adjuster based on genetic algorithm;
- development of a remote control and monitoring system of the segmented shutter;
- emulation of the algorithmic scheme of the developed remote control system;
- practical testing of the developed models and algorithms for the remote control system of the segmented shutter.

CONCLUSION

Solving these issues provides an opportunity to develop algorithms for the remote control system of hydrotechnical valves and to use them in practice. This, in turn, increases the efficiency of the use of hydrotechnical facilities.

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