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Automation of water distribution management during the reconstruction of main irrigation canals

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Abstract. Canal automation allows increasing the efficiency of projects for the reconstruction and construction of irrigation systems. Modern technological and technical advances make it possible to regulate the flow of irrigation water at all levels of the system more accurately. The basic requirements for water accounting and water metering systems implemented on irrigation systems are applicable only to the conditions of water distribution static regulation. This is primarily due to the use of water-accounting and water-measuring devices developed and used in conditions of steady-state water flow, when there is an unequivocal relationship between the depth and water flow on the rise and on the decline of levels. Using world experience in connection with new achievements in the field of management theory research, it is necessary to consider how and when to implement automation of water distribution management in the context of reconstruction and construction of irrigation main canals. In addition, practical recommendations on other aspects of channel automation should be taken into account, including the dynamic nature of the system; irrigation infrastructure survey; use of SCADA-systems; improving the concept of water distribution management using automatic control methods.

1. Introduction

Canal automation has always had significant development potential for saving water and increasing the efficiency of projects for the reconstruction and construction of irrigation systems. Recently, a number of technological and technical advances in canal automation have been achieved. Despite the fact that these achievements were documented in conference materials and peer-reviewed journal articles, there is no comprehensive regulatory document that describes the current state of canal automation. Such a document could contain recommendations on how and when to automate canals in the context of reconstruction of irrigation systems with practical guidance on some of the most common canalization schemes.

In order to plan a successful program of canal reconstruction with specific goals and objectives that provide increased flexibility of water users, it is very useful to take into account the historical experience gained on the operated irrigation systems. For the implementation of a water distribution management system on irrigation systems, at present, there are two main methods for managing water distribution: centralized and decentralized. Centralized management provides for the implementation of control, analysis, and the development of management decisions in one centre (according to a single criterion for the quality of the irrigation system). This control is characterized by the use of centralized automation, reliable communication lines, high-speed remote control devices.

Decentralized management is based on the principles of sub-optimization of certain technological links of the irrigation system according to particular criteria. This structure of water distribution management is implemented with a relatively low reliability of communication lines and is characterized by the use of local control systems operating autonomously. Decentralized management provides for the use of feedback in the network of irrigation canals, with the implementation of centralized control.

2. The purpose of the work

Reconstruction (modernization) of the irrigation system should be a combination of technical, managerial and organizational improvement (as opposed to simple repair) of irrigation systems in order to improve the use of resources (including water, labour, economics, environment) and the provision of irrigation services [1]. Irrigation system designers often equate upgrades with methods such as canal lining, switching to closed irrigation systems, and local automation. However, such investments should include computerized local automation using mathematical models of unsteady water flow in the later stages of modernization, after the basic needs, such as flow measurement and water accounting procedures, have been completed. Under the modernization of irrigation systems, we will consider a process that sets specific goals and selects specific actions and tools to achieve them over a long period of time [2].

3. Materials and methods of research

There are no “general answers” about how and when to implement automation as part of modernization due to the complexity and diversity of combinations of water supply (surface and drip irrigation), water distribution policies, water quality, transit time, adequacy of water supply, topography, problems of aquatic vegetation, soil types, issues related to the filtration and stability of channel slopes, types of existing structures, etc. However, there are some basic principles that should be followed to achieve a high level success in the design, construction and implementation of the project for the automation of channels [3, 4]. Concepts that must be adhered to in order to implement effective projects for the reconstruction of irrigation systems include: identifying the potential benefits of modernization and automation; identification of incentives for modernization; identifying realistic and changing expectations and costs; evaluation of the existing system; determination of operational limitations associated with automation; selection of the appropriate channel operation strategy; developing an emergency response plan; determining where automation fits into the upgrade plan; determination of the overall sequence of actions in the modernization process.

To implement modernization projects, it is necessary to take into account the physical infrastructure on which the entire project will be based [5]. In appropriate conditions, it is necessary to provide for the required types of structures and devices used to control the flow or level of water in the tail water system. Advantages and disadvantages, power requirements and structure operability as well as measurements to be carried out using the structure are discussed for each structure or device [6-8]. The structures or devices that are useful only from an automation point of view are discussed. At the level of the physical infrastructure concept, the following factors have to be considered:

- Work with the existing irrigation system. Decisions need to be made on whether to include the existing infrastructure of the irrigation system or to replace the existing infrastructure with a new infrastructure;
- Features of the irrigation water supply system. The type of canal automation that is physically possible and depends on the physical characteristics of the existing canals and the water distribution scheme;
- Regulators for water distribution control systems. It is necessary to review and compare the options of widely available control system configurations, including programmable logic

controllers (PLC), uncontrolled PLC "automatic" control structures (for example, hydraulic automatons);
- Instruments and measurements. Issues related to devices that are common to canal automation, including water level, shutter position, and flow measurement are discussed;
- Pump equipment. Pumps are an integral part of many automation schemes that must supply or receive water at varying speeds, which may change over a short period of time without prior notice;
- Pools of daily regulation (PDR) in the irrigation system. Using PDRs can effectively reduce filtering losses and water supply costs during the day period, simplifying the work of the canals and increasing the flexibility of water delivery systems.

An integral part of automation projects during the reconstruction of irrigation systems is the design and implementation of Supervisory Control And Data Acquisition (SCADA), which will support advanced automation of the irrigation canal system [9]. The following considerations should be considered. SCADA refers to a wide and constantly changing spectrum of electronic equipment, software and communication infrastructure, which provides a platform for remote monitoring and control in various industrial applications. In canal applications (or irrigation systems), the complexity of the SCADA system varies from simple systems that allow operators to monitor several water levels or flow rates over a radio network, to large-scale multi-network systems that can automatically monitor networks of large channels over fibre optic networks, optical and microwave communication networks. Regardless of whether small or large SCADA systems are used, real-time monitoring can be carried out; remote dispatch or automatic control; alert or notification of an emergency; correction of current problems during operation of irrigation canals; automatic data presentation and archiving capabilities.

The SCADA system consists of a central base unit that provides means for storing, manipulating and visualizing data. The base unit communicates with one or several remote devices (for example, in the control channel structure) through some communication infrastructure. The remote unit communicates with the sensors and implements control instructions issued from the base unit.

The parameters of automatic control for SCADA systems can be divided into three main groups: local control, central control and distributed control. When choosing the final implementation scheme, it is necessary to take into account such factors as the assessment of the reliability and safety of the system, the possibility of building integration into the existing management system, system maintenance and cost.

The adopted schemes for managing water distribution on irrigation canals affect, among other things, the possibility of implementing a particular SCADA [8, 9]. These schemes can be grouped into two categories: supply-oriented and demand-oriented. It is important to note that most channel control strategies include aspects of both supply-oriented and demand-oriented systems. A common approach to canal automation is a sequential adjustment of the gates at each blocking structure, and then a return to each gate to make corrections depending on the observed situation. These initial changes and current impacts can be interpreted as direct and reverse control actions, respectively. The initial changes in the settings for providing new flows downstream are actions related to forcing, while corrections based on the actual situation are feedback actions. Remote control, in which observations are transmitted to the central control room, and from there, shutter settings can be remotely implemented, simply allows users to perform these actions faster, more often, with better time and with the ability to immediately see the channel's operating conditions. Automatic control allows making these settings automatically. Automation allows controlling the actions more often and, theoretically, more accurately. But fundamentally, these different approaches (manual; local, manual; remote, automatic) use the same basic methods.

4. Research results and discussion

Automation of irrigation management helps to solve such issues as:

- provision of crops with water in accordance with their water demand (water use plan), which contributes to increasing yields, preventing groundwater levels from rising, and as a result of secondary soil salinization;
- saving water resources and the possibility of irrigating additional areas.

As the implementation of automated tools, it is possible to consider constructions of the Gorodishchenskaya irrigation system (IS). The blocking facilities are automatized by water level in the downstream tail water (DTW) with water level protection in the upstream tail water (UTW), i.e. the structure automatically maintains the water level in the DTW and is protected from the critical water level in the UTW, upon reaching which the gate (s) of the structure opens, the water drops to the lower pool. The discharge stops when the water level in the upstream tail water of the normal water mark is reached. For the implementation of dispatching control and management of operating modes of structures, the project provides for the possibility of monitoring from the control room the following parameters:

- the position of the shutter;
- water level of the lower and upper tail waters of the construction;
- consumption of facilities;
- the settings of the machine that regulates the water levels of the lower and upper tail water of the construction.

Local automatic control is performed by a programmable logic controller (PLC), which gives commands to turn on the gate motors (raise or lower the shutter) depending on the water level before construction and behind the construction (at the critical water level in UTW). Local manual control (by the electric motors of the construction gates) is carried out from the sensor control unit (SCU).

At the same time, in the event of a power failure at the construction, it is possible to raise or lower the shutter using a manual drive.

The remote control provides for the transmission of commands for raising/lowering the shutters, as well as changing the software settings on the PLC from the dispatcher’s computer via the GSM communication channel. Operational information about the state of the equipment and the current sensor readings are displayed on the SCU of the control cabinet, and also transmitted to the dispatcher's computer.

By activating the regulators in the pools, the main load on the use of tanks falls on pools 10-30 (figure 1). The use of automatic regulators with a fixed setpoint, on the one hand, allows to provide the necessary level of control over irrigation distribution channels in water extraction units throughout the canal, and on the other hand, to reduce the load on the tail section of the canal [3, 10].

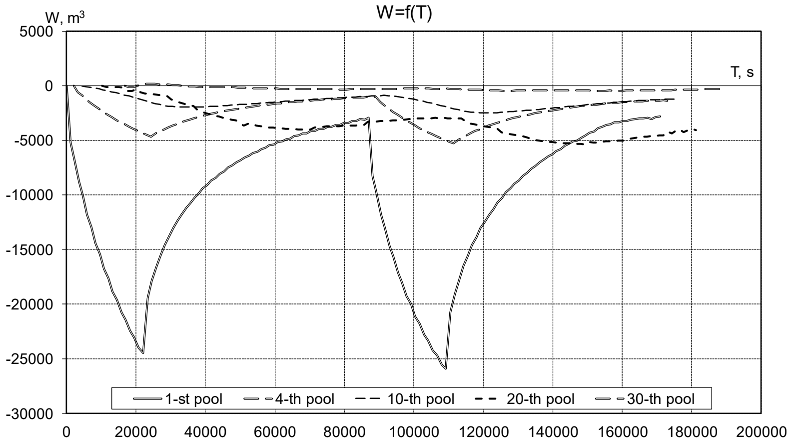

Figure 1. Use of canal capacities in pools in the process of water distribution management with local regulation of water levels at constructions with 100% availability of water withdrawals at water points.

When implementing automation systems for irrigation canals, users want to be sure that the automatic control system will function in the light of solving their current and strategic tasks. To control the specified processes with a given degree of accuracy and to ensure the reliability and safety of the system, it is necessary:

- provide for testing the performance of automated channel logic;
- perform performance testing using non-stationary models taking into account dynamic processes in the main canals of irrigation systems. Simulation is a necessary tool for determining the potential efficiency of automation of water distribution management in irrigation canals. It is recommended to check the performance of the control algorithm even for one shutter for the upstream and downstream (depending on the adopted control circuit), taking into account non-stationary water movement. This allows you to check the regulators in different hydraulic conditions of the system in a dynamic mode;
- track performance indicators that can be used to assess how effectively the channel automation system controls the water distribution management system.

At the stage of implementation of channel automation systems as a project as part of a broader system modernization program, it is required to set up management software, install and commission field devices and central server software, progressively activate control throughout the channel system, measure the overall performance of the new systems and personnel training operations. General concepts for the implementation of automation control systems include as follows:

- the main elements in any automation project is the definition of project objectives. These may include improving the maintenance levels of the sprinklers, saving water and better control over the water level, saving operating costs. Clear, quantitative goals help ensure success by harmonizing the irrigation area and the implementation team and ensuring an objective measure of performance;
- software configuration and customization. Based on the analysis, the software of remote terminal units (RTU), programmable logic controllers (PLC), communication software, SCADA software, water demand management software and irrigation network presentation software are selected;
- commissioning, when the equipment is tested, start-up and initial settings are performed to check whether it functions in accordance with its design goals or specifications;
- immediately after commissioning of the SCADA system, the management system is being deployed or activated. Sometimes the behaviour of a real system may differ from what was originally modeled. Consequently, fine-tuning of the controllers may be required during the operational phases;
- an automated channel system requires that operators acquire a number of new computer competencies and adapt to new work styles, which include responding to operational problems and making decisions according to changing conditions, and not just executing sub-programs.

5. Conclusions

In addition to the power provided by computer technology, the creation of a number of supporting technologies that need to be adapted to control water distribution on irrigation canals is required. Such technologies include equipment for measuring the water level, flow rate and gate control in digital form, as well as communication equipment and new reliable communication channels for transmitting and receiving monitored data. As each of these technologies evolves, engineers and researchers responsible for operating irrigation systems would adapt these new technologies to their projects. This will allow for the most efficient implementation of various water distribution control schemes in the diversion system of irrigation canals.

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