Determining the economic efficiency of the intelligent system in an irrigation network

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Abstract. It is necessary to provide a technical and economic justification for the work carried out in the conditions of the market economy, such as construction, renovation and automation of production processes. It is the economic justification of cost and efficiency that means the feasibility of one or another investment in production. When calculating the economic efficiency, all costs of production of a unit product are taken into account. The article presents the calculation of technical and economic efficiency indicators for the application of the proposed intelligent sensor for measuring water flow and the horizontally opening and closing hydrotechnical valve to the facility. The use of improved technology in the measurement of water flow in open channels based on the calculation of technical and economic indicators made it possible to reduce the costs per hectare and get the expected economic effect in the amount of 6224070.72 soums.

1 Introduction

Nowadays, it is no secret that digital technologies are developing day by day. Digital techniques and technologies are being introduced and intellectualized in many areas of the world. We are trying to combine the normal brain with the artificial brain [3,4,12]. The advent of wireless sensor networks has opened the door to new developments in agriculture and farming [5,7]. Recently, the issue of widespread implementation of wireless intelligently controlled [13,14] techniques in the field of agriculture has received serious attention. As we know, open canals are an important facility in supplying water to agricultural products [6]. The demand for water-saving techniques and technologies is increasing at a time when water scarcity is increasing year by year [1,2]. Therefore, this article aims to determine the

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indicators of economic efficiency in the introduction of modern intelligent water-saving technologies to the facility.

Significant technological obsolescence of water metering control devices and energy system devices in open channels leads to excessive consumption of water and energy resources. Also, today's increasing consumer power shows the need to use resources wisely [8]. These situations require the rational use of modern technologies that save water and energy resources in the technological processes of water distribution systems [2].

Economic efficiency indicators are checked at the stages of automation and management of a technological process. In general, the following economic efficiency criteria are taken into account when introducing new techniques and technologies to the facility [15]:

1. Product cost reduction;
2. Maximizing product production;
3. Product quality improvement.

Taking these into account, we determine the indicators of economic efficiency in the application of the improved intelligent sensor to the object as a result of scientific research in the object.

2 Materials and methods

The intelligent sensor, developed on the basis of scientific research, is installed in an open channel that supplies 100 hectares irrigated land with a water level of h=2 m and flow Q=1.86 m3/sec. The error of the water flow measuring sensor (hydrostatic [9]), which was previously used in the facility, was 1.5-2%. This leads to inefficient use of water, the proposed multifunctional intelligent sensor allows to calculate water flow with an error of ±0.3%.

Let's consider the calculation of water flow during the growing season of cotton on 1 hectare of land.

Based on the information presented in Table 1, we calculate the volume of water flow during the growing season of cotton.

$$V=V_1+ V_2+ V_3+ V_4+ V_5+ V_6\text{, m3/ha} \quad (1)$$

where $V_1, V_2, V_3, V_4, V_5, V_6$ – are irrigation norms for a certain period and another.

$$V=930+1140+1140+1140+1140+850=6340 \text{ m3/ha}$$

Table 1. Irrigation norms during the growing season of cotton.

Development phase of cotton	Watering rate	Irrigation procedure	Watering date
The beginning of flowering	V_1=930 m3/ha	Watering 1	June 16
Flowering - fruit formation	V_2=1140 m3/ha	Watering 2	June 28
Flowering - fruit formation	V_3=1140 m3/ha	Watering 3	July 15
Flowering - fruit formation	V_4=1140 m3/ha	Watering 4	July 28
Flowering - fruit formation	V_5=1140 m3/ha	Watering 5	August 10
Achieving	V_6=850 m3/ha	Watering 6	August 28

The volume of water consumption required (for the vegetation period) for 100 hectares of irrigated land:

$$V=6340\cdot 100=634\cdot 10^3 \text{ m3}$$

When using a conventional sensor (prototype), the consumption volume of additional released water (for 100 hectares) is equal to:

$$\Delta V_{1(100)}=\Delta_1 V=0{,}018\cdot 634\cdot 10^3=11412 \text{ m3};$$

For one hectare: $\Delta V_1=\dfrac{\Delta V_{1(100)}}{S}=\dfrac{11412}{100}=114.12$ m3/ha,

where $\Delta V_{1(100)}$ – is the volume of water consumption for 100 hectares irrigated land;

Δ_1 - measurement error of a conventional sensor (1.8% on average);

S – irrigated land area.

When using the developed multi-functional intelligent sensor, the additional water consumption (for 1 hectare) is as follows.:

$$\Delta V_{2(100)}=\Delta_2 V=0{,}003\cdot 634\cdot 10^3=1902 \text{ m3};\ \Delta V_2=\frac{\Delta V_{2(100)}}{S}=\frac{1902}{100}=19.2 \text{ m3/ha}$$

where $\Delta V_{2(100)}$ – volume of water for irrigated land by 100 hectares;

Δ_2 – measurement error of a multifunctional intelligent sensor;

S – irrigated land area.

According to the decision of the Cabinet of Ministers of the Republic of Uzbekistan No. 475 dated September 15, 2023 "On additional measures to introduce market mechanisms in the fuel and energy sector", starting from October 1, 2023, the cost of 1 kWh of electricity for agricultural enterprises is 331 soums and 1 m3 570.96 soums for irrigation water.

The economic efficiency (for 1 hectare) obtained as a result of the reduction of the volume of water consumption and the amount of electricity produced is as follows.

$$E_1=E_{CC}+E_{EE}=T_{CC}\cdot(\Delta V_1-\Delta V_2)+0.004\cdot(\Delta V_1-\Delta V_2)\cdot T_{EE}\cdot H=570.96\cdot(114.12-19.2)+$$
$$+0.004\cdot(114.12-19.2)\cdot 331\cdot 2=54298.296+251.8248=54550.1208 \text{ soum.}$$

for 100 ha: $E_{1(100)}=E_1\cdot 100=54550.1208\cdot 100=5455012.08$ soum.

where T_{CC} is the price of 1 m3 of water flow, T_{EE} is the price of 1 kWh of electricity, H is the height of the water level, 0.004 is the relative consumption of electricity used to remove 1 m3 of water, kWh/m3.

In the distribution of water resources in open channels, hydrotechnical gates perform one of the important tasks [10,13]. A large amount of electricity is required to automatically control and control the opening and closing of hydraulic valves. Energy consumption of vertically and horizontally moving hydraulic valves is calculated using the following formula [13].

$$P=\frac{F_{total}\cdot v}{\eta}, \tag{2}$$

where F_{total} the total force acting on the valve, η - the total F.I.K. of the lifting mechanism, v - the speed of lifting up. Usually, the speed of lifting up $v=0.25-0.3$ m/min and the overall F.I.K. of the upward mechanism depends on what mechanism is used. For example, if a screw mechanism is used for lifting, its F.I.K. is equal to $\eta=0.63-0.85$ [13].

Analyzing the energy consumption in the movement of hydraulic valves along the coordinates, we can conclude the following: the average power required under the same conditions is equal to 236.69 W for vertically moving valves and 139.88 W for horizontal valves.

We determine the power difference:

$$\Delta P_m=P_{1m}-P_{2m}=236.69-139.88=96.81 \text{ W}=0.09681 \text{ kW}.$$

where P_{1m} is the average power in vertically moving hydraulic valves;

P_{2m} is the average force in horizontally opening and closing hydraulic valves.

We calculate the annual economic efficiency of the electric motor.

$$E_m=\Delta P_m\cdot t\cdot S=0.09681\cdot 2400\cdot 331=76905.864 \text{ soum.}$$

where t=4 months×20=4×30×20=2400 is the working time of the electric motor in one season, i.e. for 4 months. S – the price of electricity is 331 soums.

It can also be calculated as:

$E_{1m}=P_{1m}\cdot t\cdot S=0,23669\cdot 2400\cdot 331=188026.536$ soum.

$E_{2m}=P_{2m}\cdot t\cdot S=0,13988\cdot 2400\cdot 331=111120.672$ soum.

$E_{m}=E_{1m}-E_{2m}=188026,536-111120,672=76905.864$ soum.

These counts were calculated for one prison. If we use 10 gates to irrigate 100 hectares of land, the annual economic efficiency of the electric motor will be as follows:

$E_{m(10)}=E_{m}\cdot 10=769058.64$ soum.

The calculation results are shown in the following table

Table 2. Economic efficiency in terms of electrical energy used in the control of hydraulic valves.

Indicators	**In a vertically moving valve (10 pcs)**	**In a horizontal opening and closing valve (10 pcs)**
Electricity price, soum	1880265.36	1111206.72
Economic efficiency E, soum	769058.64	

Thus, as a result of the use of the recommended multifunctional intelligent sensor and horizontally opening and closing hydrotechnical valves in the process of water distribution in open channels, the annual savings amounted to $E=E_{1(100)}+E_{m(10)}=$ 5455012.08+769058.64=6224070.72 soums (when the control system is set to 10 valves).

We can also see the electricity consumption of the intelligent control and measurement device from the diagram in Figure 1.

We determine the net benefit of introducing a new system of automatic control of technological processes in open channels as follows [11,12]:

$$S_D = E - I_{o.c.} = 6224070.72 - 525000.92 = 5699069.8 \text{ soum.} \quad (3)$$

in which E-annual savings, soum, $I_{o.c.}=525000.92$ сўм, - operating costs.

We calculate the payback period of capital costs. The payback period of capital costs is such a period of time, that is, during this period, the income generated from investments fully covers the investment costs.

We calculate the cost incurred, i.e. the payback period, with the following expression [15]:

$$T_{p.p} = \frac{S_k}{E} \quad (4)$$

where $S_k=2800831.82$ capital costs, soums; E - annual savings (economic efficiency), soum.

$$T_{p.p} = \frac{S_k}{E} = \frac{2800831.82}{6224070.72} \approx 0.45 \text{ year}$$

Since the payback period is 5 years in practice, it would be appropriate to use a multifunctional intelligent sensor and horizontally opening and closing hydraulic valves for measuring and controlling the water level and flow in open channels.

3 Results and Discussion

In the course of experimental studies, the improved control system for measuring and controlling water consumption in open channels reliably performed the specified technological process and its technical indicators fully met the set requirements.

Table 3. Technical economic indicators describing economic efficiency.

The name of economic indicators	**Values**
Capital costs S_k, soum	*2800831.82*
Operating costs $I_{o.c.}$, soum	*525000.92*

Annual economic effect E, soum	*6224070.72*
Net income S_D, soum	*5699069.8*
Payback period	4.5 month

Energy consumption of smart control and measuring device.

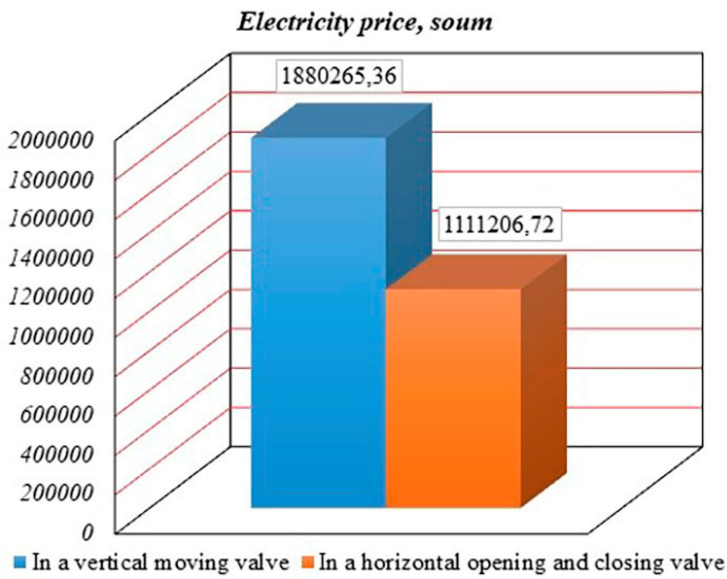

Fig. 1. Electricity consumption cost comparison chart.

4 Conclusion

The use of an improved intelligent system used for the distribution of water resources in hydromelioration systems and hydrotechnical facilities creates the possibility of continuous monitoring and remote automatic control of scattered irrigation facilities.

When using the intelligent system in water distribution systems of open channels, the error in measuring the required quantities was reduced, as a result, the excess water flow was reduced from 114.12 m3/ha to 19.2 m3/ha.

It has been proven that the electricity consumption of an intelligent system consisting of horizontally opening and closing hydraulic valves in the water distribution network of open canals is twice less than that of existing systems.

The widespread introduction of digital sensors with a high measurement accuracy in the irrigation systems of our country allows to save water resources by 10-20%.

As a result of the use of the proposed intelligent system for water distribution networks of open channels, it has been proven that the annual economic net income is 5699069.8 soums due to the reduction of annual water consumption and energy.

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