Accounting for the energy efficiency of the operation of pumping equipment in the monitoring system of large pumping stations of the Republic of Uzbekistan

Farrukh Shaazizov[1*]

[1] National Research University "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers", Department "Pumping Stations and Hydroelectric Power Plants", 100000, Kary Niyaziy Street, 39, Uzbekistan

Abstract. An analysis of the works devoted to the study of the technical condition of the pumping stations of the republic shows that at present there is no comprehensive system for monitoring the technical condition of large pumping stations of the republic. The works of the authors are devoted to the study of individual energy parameters, indicators of the technical condition and the level of safety of equipment and structures of pumping stations. The purpose of the research is the development and software of the module "Accounting for the energy efficiency of the operation of pumping equipment" in the system for monitoring the efficient operation of large pumping stations in the Republic of Uzbekistan. The set goal was to solve the following problems: development of a methodology for determining the energy consumption standards of pumps and pumping stations, taking into account the aging of equipment; development of an algorithm for calculating the main indicators of energy consumption of pumping equipment and pumping stations; compiling a program in the algorithmic language Turbo Pascal; creation of forms in the form of spreadsheets for calculating the energy indicators of pumping stations based on the compiled program in MS Excell 2010 and MS Access 2010. According to the developed methodology, the software in the Turbo Pascal algorithmic language, as well as the created spreadsheet forms on the MS Excell 2010 and MS Access 2010 platforms, the energy efficiency of pumping equipment of 12 pumping stations was calculated and evaluated.

1 Introduction

The President of Uzbekistan, by his decree dated February 7, 2017, approved the Action Strategy for the five priority areas of the country's development in 2017-2021.
One of the directions for the development of the Republic of Uzbekistan in the "Strategy ...": "III. Priority directions for the development and liberalization of the economy",

* Corresponding author: shosfarruh@mail.ru

paragraph 3.3. “Modernization and intensive development of agriculture”, which provides for:

- further improvement of the reclamation state of irrigated lands, development of a network of reclamation and irrigation facilities, widespread introduction of intensive methods into agricultural production, primarily modern water- and resource-saving agricultural technologies, and the use of high-performance agricultural machinery.

Currently, out of 4.3 million hectares of irrigated land, 2.4 million hectares are provided with water supplied by pumping stations. Mechanical irrigation is one of the key sectors of the country's water management in terms of capital costs, power supply and infrastructure development. At more than 1,600 pumping stations, which are on the balance of the Ministry of Water Resources of the Republic of Uzbekistan (Ministry of Water Resources), more than 5,000 units of pumping units have been installed. With a total capacity of 3.8 million kW, the total capacity of these pumping stations is about 7000 m3/s.

The share of pumping stations accounts for a significant part of the electricity consumed for the needs of agriculture. In 2012, pumping stations pumped 59 billion m3 of water, of which 27 billion m3 was supplied by head pumping stations, and 32 billion m3 fell on the second and subsequent stages of lifting.

At the same time, the total energy consumption of pumping stations amounted to 8.0 billion kWh, or about 15% of the annual electricity generation of the entire energy sector of Uzbekistan. If we additionally take into account the pumping stations that are on the balance sheet of farms and collective farms, then the energy consumption figures become even more significant.

One of the conditions for the sustainable operation of pumping stations is to ensure technical reliability and safe operation. The need for special attention to these facilities, on the one hand, is due to the fact that interruptions in water supply caused by a prolonged shutdown of even one pumping station can lead to consequences comparable in damage to a natural disaster, up to a large-scale drought.

On the other hand, most of the operating pumping stations have been in operation for more than 30 years, and world statistics show that it is during this period of operation of facilities that the likelihood of damage and accidents increases sharply.

An analysis of the works devoted to the study of the technical condition of the pumping stations of the republic shows that at present there is no comprehensive system for monitoring the technical condition of large pumping stations of the republic. The works of the authors [1–8] are devoted to the study of individual energy parameters, indicators of the technical condition and the level of safety of equipment and structures of pumping stations[9–15][16–18].

This state of affairs in the field of operation of mechanical irrigation systems led us to the idea of creating a system for monitoring the technical condition of large pumping stations of the republic.

This monitoring system is a very useful information and one of the necessary tools for analyzing the technical condition of pumping stations, and is also a tool for taking the necessary measures to improve the efficiency of pumping stations.

The monitoring system under consideration consists of several modules. One of the main modules in the system for monitoring the technical condition of large pumping stations is the module “Accounting for the energy efficiency of the operation of pumping equipment”.

The main purpose of this article is the development and software of the module "Accounting for the energy efficiency of the operation of pumping equipment" in the system for monitoring the efficient operation of large pumping stations in the Republic of Uzbekistan.

To study the current technical condition, 29 large pumping stations of the Republic of Uzbekistan were selected. According to the grant: REP 1/1 "Energy efficiency monitoring system of operating irrigation pumping stations in Uzbekistan", a working group was organized to visit 8 regional centers of the republic (Andijan, Bukhara, Jizzakh, Navoi, Namangan, Surkhandarya, Fergana regions and the Republic of Karakalpakstan).

When visiting the selected facilities, the energy consumption of each pumping station was preliminarily estimated and a data bank is currently being created to account for the electricity consumption of each pumping station and its performance over the years.

Surveys of pumping stations have shown that at present the general technical condition of most pumping stations and their main equipment is in an unsatisfactory condition.
This combination of circumstances is caused by aging and increased wear of the main equipment, a decrease in their energy performance and energy efficiency. The equipment of many pumping stations is obsolete.

In this regard, at present, the issue of modernization and re-equipment of pumping stations has become urgent, by replacing the existing obsolete and worn-out power and power equipment at pumping stations with more modern models of foreign and local production.

Under these conditions, the most acute problem is energy saving and energy efficiency, careful use of limited water resources and effective management of organizations that distribute energy and water resources.

2 Materials and methods

As noted above, the purpose of the studies was the development and software of the module "Accounting for the energy efficiency of the operation of pumping equipment" in the system for monitoring the efficient operation of large pumping stations in the Republic of Uzbekistan.

The goal was to solve the following tasks:

1. development of a methodology for determining the energy consumption standards of pumps and pumping stations, taking into account the aging of equipment;
2. development of an algorithm for calculating the main indicators of energy consumption of pumping equipment and pumping stations;
3. compiling a program in the algorithmic language Turbo Pascal;
4. creation of forms in the form of spreadsheets for calculating the energy performance of pumping stations based on the compiled program in MS Excell 2010 and MS Access 2010.

To assess the electricity consumption standards, the authors used the method of system analysis, methods of mathematical statistics. On the basis of these methods, a “Methodology for determining the energy consumption standards of pumps and pumping stations, taking into account the aging of equipment”, was developed, which is given in detail in earlier works [19–21].

According to this method, the operation of the PS in steady state (H_g, Q_{ps}, η_{ps} is constant) requires energy costs for every 1000 m3 of pumped water in the amount determined by the following formula:

$$e = \frac{2.72 \cdot H_g}{\eta_{ps}}, \text{ кW×hour/ thousand m}^3 \qquad (1)$$

where: e is the specific cost of electricity per PS for every 1000 m3 of pumped water at the geometric height of the lift H_g.

For a period of time t, the PS pumps W (thousand m3) of water and consumes electricity directly for water lifting, which is determined by the following formula:

$$E_B = e \cdot W, \text{ кW×hour;} \quad (2)$$

where: E_B is the consumption of electricity by the PS for the period t, calculated for water.

"Methodology for determining the energy consumption rates of pumps and pumping stations, taking into account equipment aging" corrects the methodology for determining the energy consumption rates required for calculations. The standards should become a starting point that allows you to determine the actual required amount of energy consumption of each pump or pumping station, knowing which it will be possible to judge the efficiency of their work.

The rates of electricity consumption at pumping stations of the Ministry of Water Resources of the Republic of Uzbekistan determine the rate of electricity consumption for lifting 1000 m3 of water per meter of height.

For the convenience of carrying out computational work to determine the main indicators of energy consumption, according to the previously developed methodology, a program was compiled in the Turbo Pascal algorithmic language, in addition, templates and forms in the form of spreadsheets for calculating energy indicators were created based on the developed program on MS Excell 2010 and MS Access 2010 pumping stations.

To calculate and calculate the rate of electricity consumption of the PS, taking into account the aging of the equipment, the primary data are entered into the table: the main passport data and parameters of the main equipment, the energy indicators of pumping units and general indicators for the pumping station, the total volume of pumped water, the total volume of electricity consumed, the amount of waste machine hours for the period under review and from the start of operation.

In the calculation tables is fixed:

1. Power of pumping units ***N***, kW.

2. Lifting height $\boldsymbol{N_g}$, m.

3. Calculation of the specific consumption ***e***, kW per thousand m3.

4. Recommended norms of specific power consumption of PS, taking into account the aging of equipment.

The following values are accepted as permissible deviations from the maximum value of the PS power consumption rate, taking into account the aging of the equipment and the service life of the HC for centrifugal and axial pumps:

For $\eta_o \geq 0.7$, 0.1

For $\eta_o < 0.7$ 0.15

The operational tolerance for the deviation of characteristics from passport data must be determined by technical and economic calculations. Taking into account the aging of equipment, it is recommended to accept the norms of energy consumption of the National Assembly with a minimum increase of 0.1 with an appropriate analysis of operational data.

Then, according to the existing methodology, the norms of electricity consumption of the National Assembly are calculated, taking into account the aging of the equipment according to the table. At the next stage, the calculated rates of power consumption of the PS, taking into account the aging of the equipment, are compared with the recommended rates of power consumption of the PS, taking into account the aging of the equipment. When comparing the above values, depending on the conditions, the operating efficiency of the pumping station is determined (satisfactory or not satisfactory).

Below is a program created in the Turbo Pascal algorithmic language to determine the power consumption of a pumping station.

The following primary data are entered into the developed program to solve the problem:

Total consumed electricity PS, $\boldsymbol{E_B}$
Height of water lifting PS, $\boldsymbol{H_g}$
Total volume of pumped water, $\boldsymbol{W}$
The rate of electricity consumption PS, taking into account the resource PU, $\boldsymbol{N_t}$
Estimated consumption rate of electricity PS, taking into account the resource PU, $\boldsymbol{N_p}$

Further, the program, according to the developed methodology, calculates the main indicators

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program calculation of electricity consumption ( input, output );
    var E_B, H_g, W, N_m, N_p: real;
    begin read (E_B, H_g, W, N_m, N_p);
N_p : = E_B/( H_g*W);
                if N_p > N_m then write " unsatisfactory "
                                 else write " satisfactory ";
    end.
```

3 Results and Discussion

According to the developed methodology, the software in the Turbo Pascal algorithmic language, as well as the created spreadsheet forms on the MS Excell 2010 and MS Access 2010 platforms, the energy efficiency of pumping equipment of 12 pumping stations was calculated and evaluated.

The results of calculations and logical operations are summarized in a tabular form, presented in Table 1.

As calculations and logical operations to assess the energy efficiency of pumping equipment operation show, out of 12 pumping stations, 2 have unsatisfactory energy consumption (PNS-2 and Dustlik).

In the table, ***s*** is satisfactory technical condition, ***n/s*** is unsatisfactory technical condition.

Table 1. Basic parameters of pumping stations

№	Name of the pumping station	Number of installed units	Total capacity (m3/s)	Substation meter reading, (kW)	Indicators for rails (UWL-BWL), (m)	Volume of pumped water, (million m3)	Total electricity consumption (kWh)	Norm of energy consumption PS	Estimated rate of energy consumption of PS	Technical condition of PS
1	Khamza -1	9	72	45000	50	842.7	157890	4.1	3.7	s
2	Khamza -2	10	150	125000	55	2947.7	623200	4.2	3.8	s
3	Khamza - secondary	30	45	48000	60	35.8	5654	4.2	2.6	s
4	Jondor-1	16	56	20000	21	808.4	52894	4.3	3.1	s
5	Bottom Mozor	6	102	30000	21	1519	116571	3.9	3.7	s
6	PNS-1	6	21	7500	24	201.6	18607	4.7	3.8	s
7	PNS-2	6	21	7500	24	158.6	19929	4.1	5.2	n/s
8	Dustlik	12	18	19200	70	44.3	54614	4.2	17.6	n/s
9	Korovul Bozor	5	22.5	16000	60	288.4	13265	3.4	0.8	s
10	Korovul Tepa-1	4	132	125000	45	1722.4	385931	5.4	5.0	s
11	Korovul Tepa secondary	26	39	52000	80	62.1	23041	4.9	4.6	s
12	Malikobod	6	2.4	9600	11	17.7	1281	8.1	6.6	s
	TOTAL	142	680.9	504800		8648.7	1472877			

Figure 1 shows the results of the calculations performed on the MS Access 2010 platform.

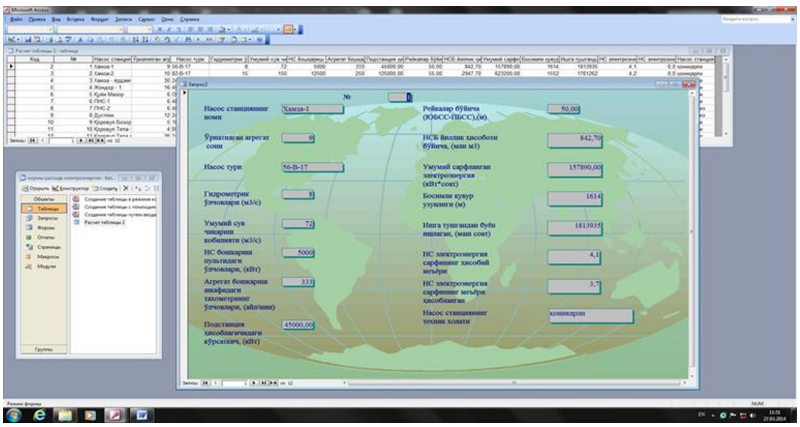

Fig. 1. Forms in the form of spreadsheets for calculating the energy performance of pumping stations on the MS Access 2010 platform.

4 Conclusions

- To study the current technical condition, 29 large pumping stations of the Republic of Uzbekistan were selected. According to the grant: REP 1/1 "Energy efficiency monitoring system of operating irrigation pumping stations in Uzbekistan", a working group was organized to visit 8 regional centers of the republic (Andijan, Bukhara, Jizzakh, Navoi, Namangan, Surkhandarya, Fergana regions and the Republic of Karakalpakstan).
- A technique has been developed for determining the energy consumption rates of pumps and pumping stations, taking into account the aging of equipment for the selected objects of study.
- An algorithm for calculating the main indicators of energy consumption of pumping equipment and pumping stations has been developed and a program has been compiled in the Turbo Pascal algorithmic language.
- Forms were created in the form of spreadsheets for calculating the energy indicators of pumping stations based on the compiled program for MS Excell 2010 and MS Access 2010 for 12 large pumping stations of the republic.
- According to the developed methodology, the software in the Turbo Pascal algorithmic language, as well as the created spreadsheet forms on the MS Excell 2010 and MS Access 2010 platforms, the energy efficiency of pumping equipment of 12 pumping stations was calculated and evaluated.

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