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Development of a System of Automatic Change of Working Modes of Group Control Stations

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ABSTRACT

Objective: *Effective management of multiple devices is crucial in modern industrial enterprises and infrastructures. Automating the start and stop of these devices at specific times enhances energy efficiency, optimizes production processes, and ensures safety. This study aims to develop a system that automates the switching of operating modes in group control stations to regulate device operation according to predefined schedules.* ***Methods:*** *The research involves designing and implementing a system that integrates automation technologies for controlling multiple devices. The system is developed to enable automatic switching of operational modes in group control stations based on preset schedules. Key technical aspects, including hardware configuration and software algorithms, are analyzed to ensure seamless operation and adaptability to various industrial environments.* ***Results:*** *The developed system successfully automates the start and stop functions of multiple devices according to predefined time settings. It enhances energy efficiency by minimizing idle device operation and optimizing production workflows. Additionally, the system improves safety by ensuring that critical processes follow scheduled operations, reducing human intervention and potential operational errors.* ***Novelty****: This study introduces an innovative approach to automating group control station operations by integrating time-based scheduling mechanisms. Unlike conventional manual or semi-automatic control methods, this system ensures precise and reliable device management, leading to enhanced efficiency, safety, and sustainability in industrial environments.*

INTRODUCTION

In many industrial enterprises, the control of devices is still done manually, which can lead to human errors, increase energy consumption and reduce production efficiency. Also, managing a large number of devices separately takes time and resources. To solve these problems, an automatic system is needed, which allows the devices to start and stop at the specified time [1,2].

Software: Real-time software includes timers, calendar and logic modules for device control. This software allows you to set the operating time, operating mode and other parameters of the devices.

It includes the interfaces needed to communicate with devices (eg RS-485, Modbus, Ethernet) and analog-to-digital conversion equipment to receive data from sensors. It is shown in [3] that the linear dimensions of pumping units grow much slower than their power and supply. As is known, the volumes (dimensions) of machines (electric motors, pumps, etc.) are proportional to the nominal values of their torque:

$$V = kM \quad (1)$$

where M – is the torque; k – is the coefficient of proportionality.

If we express the moment in terms of the operating parameters of the pumping unit and extract the cubic root from both parts of the equation (1), we get the dependence of the linear dimensions of the unit on its main parameters:

$$L = \sqrt[3]{kM} = \sqrt[3]{k} * \sqrt[3]{\frac{QH}{\eta n}}, \quad (2)$$

where Q – is the pump unit feed; H – is the pump unit head; n – is the pump unit rotation speed; η – is the unit efficiency.

RESEARCH METHOD

The research methodology involves the development and implementation of a real-time automatic control system for industrial devices. The system consists of software equipped with timers, calendar functions, and logic modules to control device operations based on predefined schedules. It integrates communication interfaces such as RS-485, Modbus, and Ethernet to facilitate data exchange between devices and the central control unit. Additionally, analog-to-digital conversion equipment is used to collect real-time sensor data for analysis and decision-making. The study also employs mathematical modeling to determine the relationship between the linear dimensions of pumping units and their operational parameters. By deriving equations based on torque and pump efficiency, the research provides a framework for optimizing unit capacity and minimizing resource consumption.

RESULT AND DISCUSSION

We believe that for the specific installation under consideration, the head values of the compared units are approximately the same. We take the parameters of the smallest of the compared aggregates as the basic ones. For these conditions, after some transformations, we obtain an expression for determining the relative linear dimensions of the compared aggregates

$$L^* = \sqrt[3]{\frac{Q_l / \eta_l n_l}{Q_b / \eta_b n_b}}, \quad (3)$$

where Q_l, η_l, n_l – are the nominal parameters of the larger unit; Q_b, η_b, n_b –are the nominal parameters of the base unit;

From the expression (3), it follows that the linear dimensions of the enlarged unit in comparison with the basic unit increase to a lesser extent than its feed increases. This pattern has been tested on common domestic pumping units of the D series. Based on the actual dimensions of the D-series units taken from the catalog [4], the relative linear dimensions of six standard sizes of pumps in this series are calculated using the equation

$$L^*_{actual} = \sqrt[3]{\frac{l_l b_l h_l}{l_b b_b h_b}}, \quad (4)$$

where l_l, b_l, h_l – dimensions (length, width, height) of the larger unit; l_b, b_b, h_b – dimensions (length, width, height) of the base unit.

Since the linear dimensions of pumping units increase more slowly than their supply increases, increasing the unit capacity of the units allows you to reduce their total number and reduce the size of buildings, simplify the hydraulic scheme of the station, reduce the number of pipe fittings and the number of cells in the electrical switchgear, etc.

Thanks to the equipment of pumping units with a frequency-controlled drive, reducing the number of units at pumping stations does not reduce the operational possibilities for changing their operating modes caused by changes in water consumption.

Thus, the use of a frequency-controlled electric drive under certain conditions not only does not increase the capital investment, but also reduces it somewhat (by a certain amount of dK).

Calculations have shown that the use of a frequency-controlled electric drive in combination with the enlargement of the unit power, depending on the purpose of the station and other specific conditions, can reduce the specified costs by 20-50 % [5].

The feasibility study of the use of a frequency-controlled electric drive in pumping units is carried out in the following sequence:

a. Make up hydraulic and electric circuit diagrams compare the pumping systems;
b. Determine the composition of the main equipment of the compared pumping units: pumping units, valves, valves, check valves, cells of switchgears, control devices (frequency converters, etc.);
c. They assemble the main equipment of the compared pumping units;
d. Determine the capital costs for the basic and new options for electrical equipment Kel, pumping equipment Kpum, hydro-mechanical equipment Khm, and construction part Kcon. The cost of electrical and hydro-mechanical equipment is determined in accordance with the price lists of companies and equipment manufacturers. For a preliminary estimate of the cost of a frequency-controlled electric drive and additional capital costs associated with the use of a frequency-controlled electric drive, the graphs shown in fig. 1. and 2. can be used. The cost of the construction part can be determined by the aggregated specific indicators of the cost of construction of pumping stations, contained, for example, in [6], taking into account the current inflationary coefficients of the cost of construction.

   Determine the depreciation deductions A from the cost:

a. electrical equipment $A_{el} = A_{rel.un} K_{el};$
b. pumping equipment $A_{pum} = A_{rel.un} K_{pum};$
c. hydro-mechanical equipment $A_{hm} = A_{rel.un} K_{hm};$
d. construction part of the pumping station $A_{con} = A_{rel.un} K_{con};$

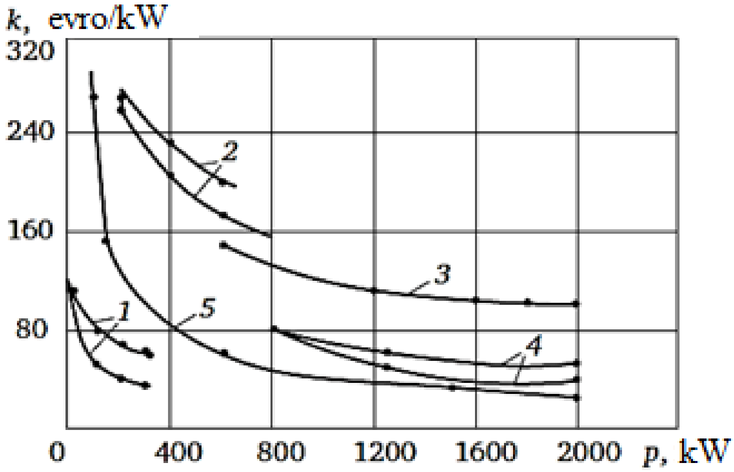

Figure 1. Specific cost of converters and control devices of various types of adjustable electric drive: 1 — low-voltage frequency converters; 2 — high-voltage frequency converters with dual voltage; 3 — high-voltage frequency converters; 4 — high-voltage transformer-free converters according to the valve motor system; 5 — hydraulic variator "Twin-Disk".

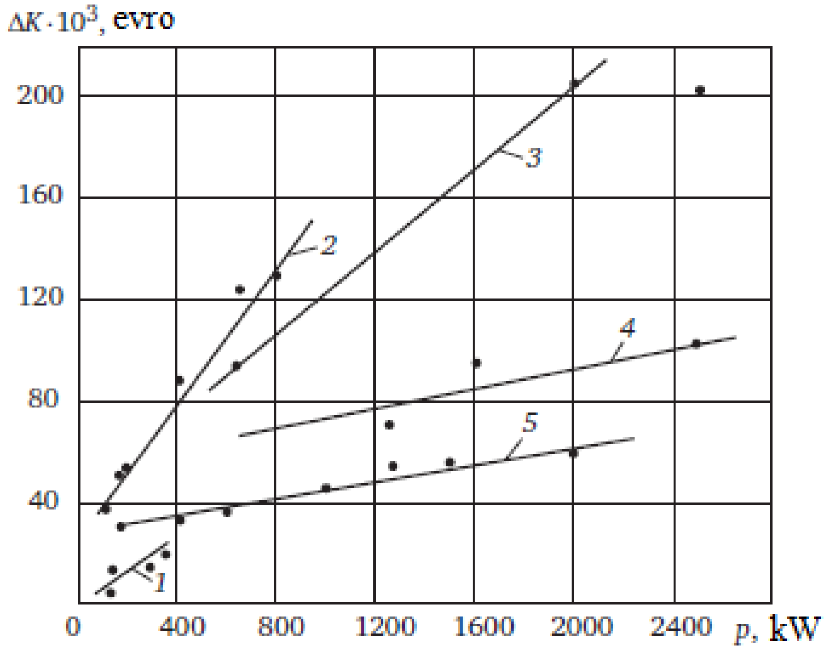

Figure 2. Additional costs associated with the use of converters and various types of controlled electric drive control devices: 1—5 — the same as in figure 1.

Approximate values of depreciation rates for various types of equipment are given in table 3.

Table 1. Depreciation rates by type of main equipment.

Serial number	Equipment types	Amortization rate	
		A, %	$A_{rel.un}$
1	Pump equipment	19	0,19
2	Gate valves, gates, valves	21.3	0.213
3	Electrical equipment	8.3	0.083
4	Building part	2.6	0.026

Determine the energy consumption W_{reg} in use frequency-controlled drive (FCD) in the automatic control system of the pumping unit, kWh, $W_{reg} = 0.25\frac{N_b T_{cal}\left(1+\lambda\right)}{\eta}\left[\left(1+H_{b.p}^{*}\right)+\lambda^{2}\left(1-H_{b.p}^{*}\right)\right]$

Determine the energy savings W_{reg} , obtained as a result of a decrease in overpressure when using the FCD in the ACS of the pumping unit.

Determine the energy savings ΔW_{η} obtained as a result of the use of large capacity pumping units with a higher efficiency η_{big}, in comparison with the units of the basic version η_b, kWh,

$$\Delta W_{\eta} = W_{reg}\left(1-\frac{\eta_b}{\eta_{big}}\right)$$

where $\eta_{big} > \eta_b$.

Determine the energy consumption $W_{n.reg}$, kWh, of the pumping unit when the units are operating according to the basic version, without a frequency-controlled electric drive:

$$W_{n.reg} = W_{reg} + W_{rec} + W.$$

Determine the amount of water lost due to non-productive costs when operating in the basic mode. This volume of water corresponds to the volume of water saved when using a variable frequency drive in the ACS of the pumping unit $V_{sav.year}$.

Determine the decrease in the volume of non-productive water consumption, dumped into the sewer, when operating in the basic mode.

$$V_{dec.dum.year} = \left(0,80 \div 0,85\right)V_{sav.year}$$

Determine the electricity costs for the base case.

$$C_{el.b} = W_{n.reg}P_{el}$$

where P_{el} – electricity tariff

Determine the electricity costs for the new option (with the use of aggregates of enlarged capacity and FCD in the automatic control system of the pumping unit)

$$C_{el.n} = W_{reg}P_{el}$$

Determine the costs of covering the non-productive flow of clean water during the operation of the pumping unit without FCD

$\Delta C_Q = P_Q P_{sav.year},$

where P_Q — cost of 1m3 of clean water

Determine the costs of processing and transporting waste water in the wastewater system (sewers)

$\Delta C_q = P_q P_{dec.dum.year},$

where P_q — the cost of pumping and processing $1m^3$ of wastewater

Determine the amount of capital costs for the basic $K\Sigma b$ and new $K\Sigma n$ options for electrical, hydraulic and construction parts

$K_{\Sigma b} = K_{el.b} + K_{pum.b} + K_{hm.b} + K_{con.b}$

$K_{\Sigma n} = K_{el.n} + K_{pum.n} + K_{hm.n} + K_{con.n}$

Determine the amount of depreciation for the base $A_{\Sigma b}$ and new $A_{\Sigma n}$ options

$A_{\Sigma b} = A_{el.b} + A_{pum.b} + A_{hm.b} + A_{con.b}$

$A_{\Sigma n} = A_{el.n} + A_{pum.n} + A_{hm.n} + A_{con.n}$

Determine the amount of operating costs for both options $C_{\Sigma b}$ and $C_{\Sigma n}$, taking into account energy consumption, saving clean water, reducing the discharge of effluents into the sewage system and depreciation deductions

$C_{\Sigma b} = C_{el.b} + \Delta C_Q + C_q - A_{\Sigma b};$

$C_{\Sigma n} = C_{el.n} - A_{\Sigma n}$

Determine the reduced costs for both options

$З_b = C_{\Sigma b} + EK_b;$

$З_n = C_{\Sigma n} + EK_n;$

where E—is the coefficient of efficiency of capital investments, depending on the adopted payback period for additional capital investments:

$E = 1/T_{pb}$

Payback period Tpb, year.	2	3	4	5	6
Coefficient E .	0,5	0,33	0,25	0,2	0,166

The reduction of the reduced costs $\Delta З$,%, is calculated according to the new variant $З_n$ in comparison with the basic variant $З_b$,%

$$\Delta З = \frac{З_b - З_n}{З_b} 100.$$

The payback period of an ACS equipped with an adjustable electric drive, taking into account the saving of clean water, a decrease in the discharge of effluents into the sewage system, an increase in the unit capacity of pumping units is determined by the expression

$$T_{pb} = \frac{\Delta K - dK}{\Delta C_{el} + \Delta C_{n.w} + \Delta C_{w.w} - A_{el}\Delta K + A_c dK},$$

where $\Delta K = K_{fcd} + K_{acs}$ – additional capital costs associated with the creation of an energy-saving ACS based on FCD; $dK = K_{\Sigma b} + K_{\Sigma n}$ – reduction of capital costs due to the enlargement of the unit capacity of pumping units and a decrease in their number.

$\Delta C_{el} = C_{el.b} - C_{el.n}$ – reduction in operating costs due to the use of a variable frequency drive in the ACS of a pumping unit and an increase in the efficiency of pumping units due to the enlargement of their unit capacity.

$\Delta C_{n.w} = \Delta C_Q$ – reduction in operating costs due to a decrease in excess pressure in the network and a reduction in non-productive water consumption due to the use of a variable frequency drive in the ACS of a pumping unit.

$\Delta C_{w.w} = \Delta C_q$ – reduction in operating costs due to a decrease in excess pressure in the network and a reduction in wastewater discharge into the sewage system due to the use of a frequency-controlled electric drive in the ACS of the pumping unit.

$A_{el} = 0,083$ – depreciation rate for electrical equipment.

$A_c = 0,026$ – depreciation rate for the construction part.

The system analyzes the data in the database before the specified time and sends the necessary signals to start or stop the devices. Various scenarios and conditions can be implemented through logic modules in the software, such as day and night modes, holidays, etc.

The proposed automatic system increases the efficiency of device management, contributes to energy saving and reduces human errors. The main advantages of the system: High efficiency, Energy saving, Reliability, Easy to manage, Flexibility.

Future research can be focused on expanding the functionality of the system, integrating new communication technologies, and further strengthening the security of the system.

CONCLUSION

Fundamental Findings : The study demonstrates that implementing an automatic control system with frequency-controlled electric drives significantly enhances the efficiency of industrial pumping units. By optimizing the start and stop sequences, the system reduces energy consumption, minimizes human errors, and increases the operational reliability of the equipment. The analysis confirms that larger unit capacities contribute to reduced capital costs and simplified infrastructure, further supporting energy-saving initiatives and operational cost reductions. **Implications :** The findings have significant implications for industrial enterprises aiming to optimize energy consumption and operational efficiency. The proposed system not only lowers electricity costs but also minimizes water loss and unnecessary wastewater discharge, contributing to environmental sustainability. Additionally, integrating frequency-controlled electric drives into pumping units enhances system adaptability, allowing businesses to achieve higher levels of automation while maintaining cost-effectiveness. **Limitations :** Despite its advantages, the system has limitations, primarily related to initial capital investment and technical integration challenges. The implementation requires careful planning, including the selection of compatible equipment and software configurations. Moreover, the effectiveness of the system is influenced by the variability in industrial settings, meaning that each installation may require customized adjustments for optimal performance. **Future Research :** Future research should focus on expanding the system's capabilities by incorporating advanced communication protocols, machine learning for predictive maintenance, and enhanced cybersecurity features. Additionally, exploring the integration of renewable energy sources into the system could further improve energy efficiency and sustainability. Investigating real-time data analytics to optimize control strategies will also be beneficial for achieving superior automation and operational performance.

REFERENCES

[1] B. S. Leznov, *Energy Saving and Adjustable Drive in On-Pine and Blower Installations*. Moscow: Energoatomizdat, 2006.

[2] B. S. Leznov, "Characteristics of branched pipelines with intermediate water withdrawals," *Water Supply and Sanitary Technique*, no. 12, 2007.

[3] B. S. Leznov, *Methodology for Evaluating the Effectiveness of the Application Adjustable Electric Drive in Water Supply and Sewerage by Pumping Installations*. Moscow: Mashinostroenie, 2011.

[4] B. S. Leznov, "Technological bases for the use of variable electric drive in pumping units," *Vodoochistka. Water Treatment. Water Supply*, no. 5, 2012.

[5] I. Khafizov, K. Gafforov, S. Muxammedov, and A. Jurakulov, "Energy saving when using a variable frequency drive in pump installations," *Journal of Critical Reviews*, vol. 7, no. 12, pp. 99–102, 2020.

[6] P. Shoyimov, X. Khafizov, B. Murodov, and B. Murodova, "Influence of electric power and other forces on the quality of cotton seeds on the surface of working body," in *International Scientific Conference "Construction Mechanics, Hydraulics and Water Resources Engineering" (CONMECHYDRO-2021)*, Tashkent, Uzbekistan, Apr. 1–3, 2021, *E3S Web of Conferences*, vol. 264, p. 04010, 2021. [Online]. Available: https://doi.org/10.1051/e3sconf/202126404010

[7] I. I. Khafizov, K. Gafforov, S. Atoyev, and M. Jòrakulova, "Economical mode by stabilizing the fluid supply pressure and eliminating energy losses in pumping units," *ResearchJet Journal of Analysis and Inventions*, vol. 2, no. 4, pp. 282–289, Apr. 2021.

[8] I. I. Khafizov, K. Gafforov, and B. Miyliyev, "Advantages of using a variable speed drive in pumping units," *Emergent: Journal of Educational Discoveries and Lifelong Learning (EJEDL)*, vol. 2, no. 5, pp. 134–142, May 2021.

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