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Mathematical Modeling Taking Into Account Features Of Different Drive States Of Pump Station Electric Drive Systems

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ABSTRACT

The article is based on the construction of mathematical models based on the calculation of losses from errors in the operation of pumps used in pumping stations. Recommendations on improvement of electric drive systems used in power management of pumping stations and application of energy-saving methods based on mathematical models have been developed.

KEYWORDS

Electric drives, pumps, fluid flow rate, frequency converter, mathematical model, MATLAB simulator, algorithmic unit and pump unit.

INTRODUCTION

Currently, electric drive systems and automated systems at pumping stations are widely used. Based on this, self-tuning and automatic optimization of systems and control systems are significantly expanded. A newly created pump stations, frequency-controlled electric drives are increasingly used in all pump units. The efficiency of pump stations equipped with modern electric drive and automatic control systems is reflected in the following main components:

- Arbitrary change of fluid flow rate in the mainline from the specified values of static and dynamic pressure,
- Minimization of high pressure and hydraulic shock events;

MATERIALS AND METHODS

The development of pump station control systems and performance assessment in the application of these technologies are the main manifestations and are described on the basis of their mathematical models. In the section of mathematical modelling, a database of mathematical models of pump units and components of pump stations is being developed in order to assemble complex units used in structural and parametric synthesis and optimize control systems for units and stations.[1-3] Components of automated automatic control systems of electric drives of pump stations will consist of a complex of systems controlling continuous operation. Pumps, motors, frequency converters, data measurement and monitoring devices. Components of pump stations are process components of connection of units with a mainline, ratio of variable units to variable control components. Change of rotation speed of pump models (modules H1, H2) in pump stations leads to change of all its operating parameters.[4-5] In this case, we can recalculate the characteristics of the pump according to the actual speed using similar conditions.

$$p_i = k_p \omega_i^2; \; Q_i = k_Q \omega_i;$$

$$M_i = k_p \omega_i^2; \;\; P_i = k_p \omega_i^3;$$

where p_i Q_i, M_i, P_i, ω_i pressure, power, static resistance and load moment, power consumption and pump speed. You can use the following pressure formula for ease of calculation.

$$p_i = H_i \cdot \rho \cdot g;$$

The pressure characteristic of the variable speed pump is described by the square parabolic equation:

$$p_i = p_0 \left(\frac{\omega_i}{\omega_{nom}} \right)^2 - R_{nas} \cdot Q_i^2;$$

where p_o is the pump pressure at zero fluid flow; Q_i - current flow rate of the pump; R_{nas} - hydraulic resistance of this pump, determined by nominal data and idling pressure according to the following formula.

$$R_{nas} = \frac{p_0 - p_{nom}}{Q_{nom}^2}; \; p_{nom} \text{ and } Q_{nom}$$

According to the nominal speed pressure p_o, the pressure is zero for any shaft speed.

$$p_{0i} = \frac{p_0}{\omega_{nom}^2} \omega_i^2, \text{ or } \; p_{0i} = k_{p_0} \omega_i^2,$$

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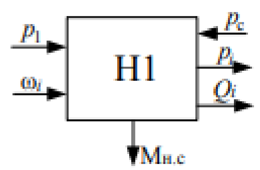
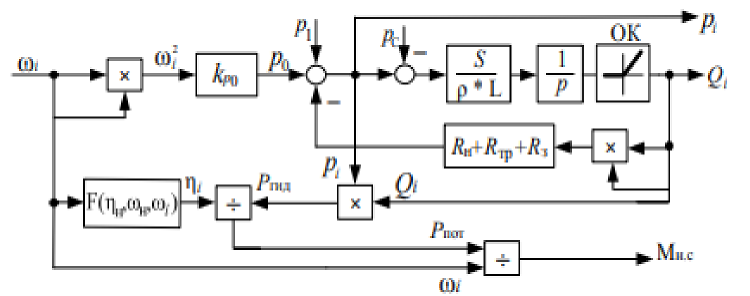
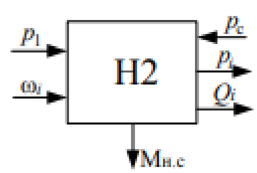
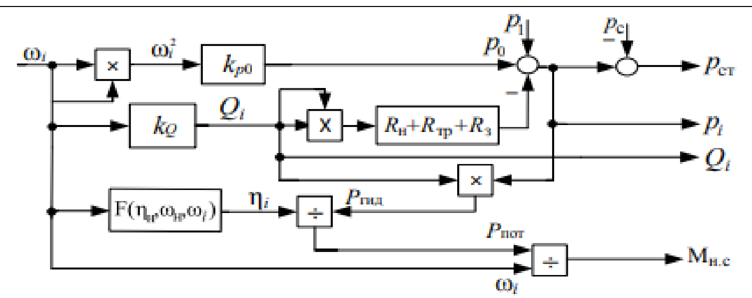
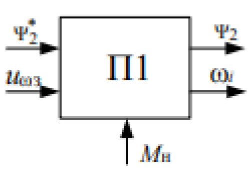
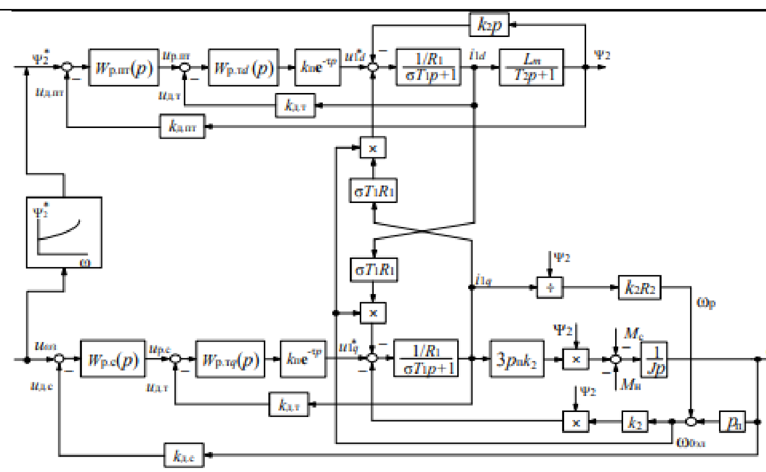
From the above input, you can create mathematical models of pump units used in pump stations. Let us consider the analysis of mathematical models of pump unit and pump station elements based on Table 1.[6-8]

Table 1. Analysis of mathematical models of the pump unit and pump station elements

Nasos birligi	
Komponent modulining diagrammasi	Algorithmic block diagram
Nasos	
Centrifugal pump taking into account the dynamic processes of fluid movement 	
Centrifugal pump without taking into account the dynamic processes of fluid movement 	
Variable frequency	
Vector control 	

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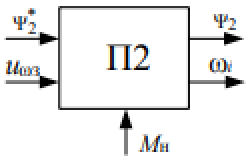
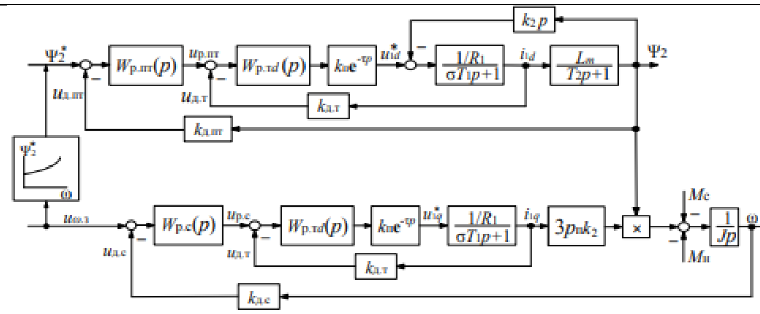
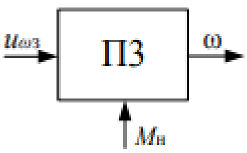
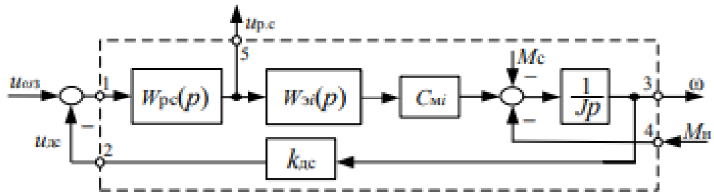
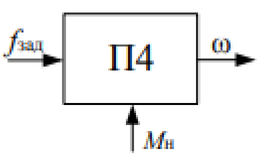
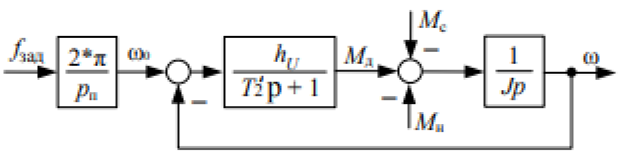
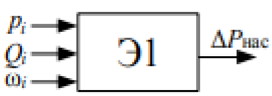
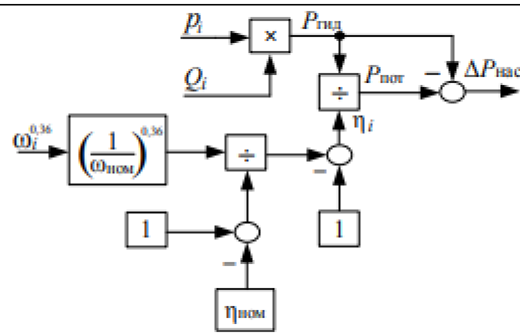
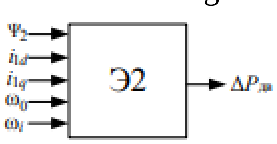
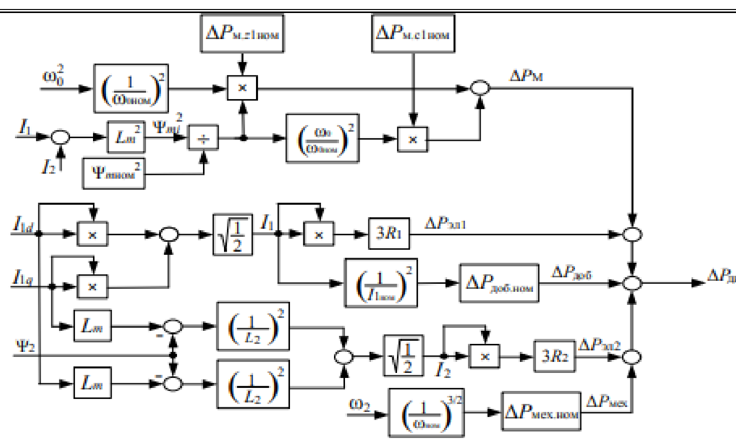
<table>
<tr><th></th><th></th></tr>
<tr><td>Vector control without regard to the interdependence of variables
</td><td></td></tr>
<tr><td>Constant vector control
</td><td></td></tr>
<tr><td>Scalar control
</td><td></td></tr>
<tr><td colspan="2">Models of energy processes</td></tr>
<tr><td>Estimation of power losses in the pump
</td><td></td></tr>
<tr><td>Calculation of engine loss
</td><td></td></tr>
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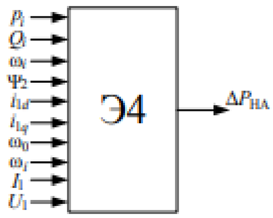
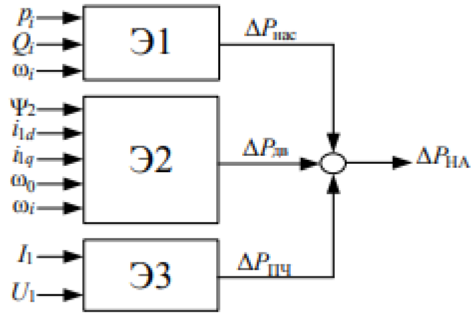
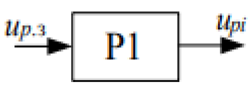
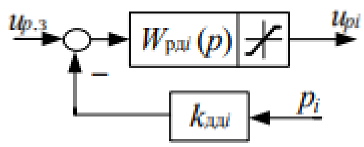
Calculation of power losses in the pump block 	
Pressure regulation 	

If there is backpressure, the characteristic of the network (trunk) is determined by the following formula.

$$p_c = p_n + R_c \cdot Q_c^2;$$

where pc is the current pressure in the network; Qc - current flow rate of fluid in the network; pp is the peak point of liquid supply and backpressure due to the difference in the geodetic marking of the pump installation place; Rc is the hydraulic resistance of the network determined by this formula.

$$R_c = \frac{p_{nom} - p_n}{Q_{nom}^2},$$

A combined solution of the pump and current supply network equations Qi provides that the change in the pump supply depends on its angular velocity in the presence of a rotary pressure. In describing the dynamic processes of fluid movement in the hydraulic part of the pumping device, the constant surface S and the length L are considered to be an inconspicuous dense body occupying a volume in a certain pipeline. Control device consists of a neural network model of the controlled process and optimization unit. The optimization unit determines those values that minimize the control quality criterion, and the corresponding control signal controls the process.

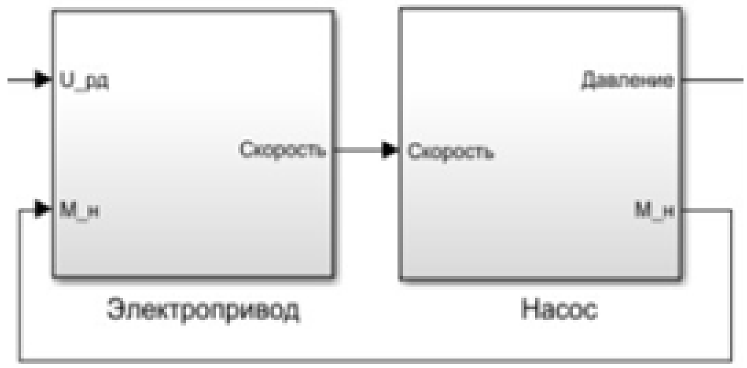


Figure 1. block diagram of the network control system for the pump unit

For the pump unit developed in the Matlab simulation system, a block diagram of the network management system is shown. This structure includes a controlled object unit and a pump control unit, as well as a step signaling unit and a graphic unit.

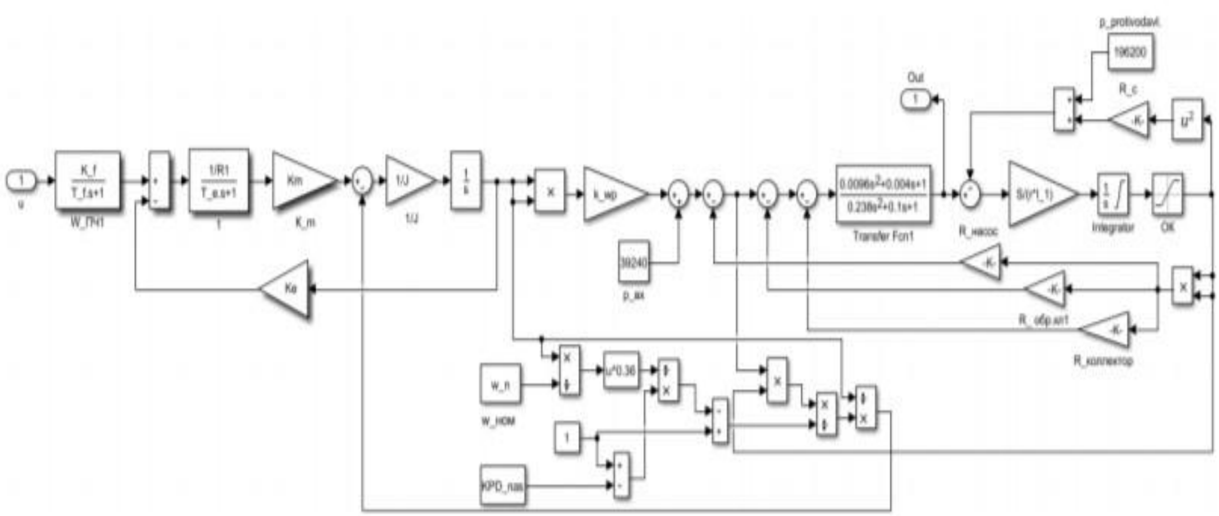


Figure 1. Pump unit subsystem model

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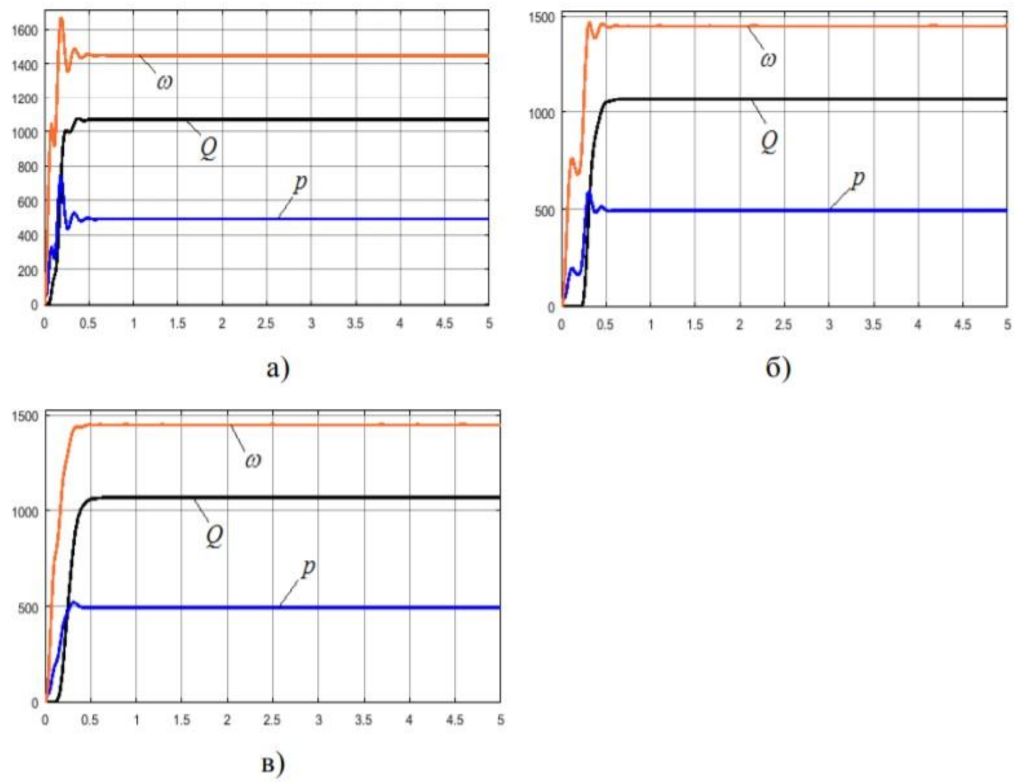

Figure 2. Diagram of parametric change of pump unit

Based on the values obtained in the above pump device, it is possible to observe the change of the parametric values of the pump and the loss of processes in them at a certain stage.

CONCLUSION

Mathematical models of pump units are developed taking into account dynamic and energy processes and various options for their connection and allow evaluating electrical, mechanical and hydraulic variables. Based on the computer models produced, computational and modelling work was carried out. The simulations allowed us to conduct studies that would allow us to assess the reliability of the models developed and determine the optimal version. From typical functional modules of components, block complexes are created that are used in analysis, synthesis and optimization to determine the best version of the control system. On the basis of the mathematical description of components and a combination of different versions of modules included in one module, mathematical descriptions and operation modes of computer models and parallel pumping units in the Matlab Software environment are studied.

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