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INTERNATIONAL SCIENTIFIC DISCUSSION: PROBLEMS, TASKS AND PROSPECTS



**BRIGHTON, GREAT BRITAIN
21-22.10.2021**



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DYNAMICS OF ASYNCHRONOUS ELECTRIC DRIVE WITH PID-SIMILAR FUZZY CONTROLLER FOR WATER SUPPLY SYSTEMS

***Abstract.** in presented paper the transient characteristics of an asynchronous electric drive of a pump unit with PID-similar fuzzy controller are investigated. A comparative analysis of control quality in a system with traditional and fuzzy controllers is performed. The use of fuzzy controller in the asynchronous electric drive of the pump unit for water supply system is substantiated and it is proved that the use of fuzzy logic leads to the improvement of the quality of the transient process of the system. The simulation was performed using the Scilab mathematical application package.*

***Keywords:** controller, main-line pump, simulation, fuzzy logic, asynchronous electric drive, transient characteristic.*

The task of the work is to study the dynamics of an asynchronous electric drive in a pump unit with a PID-similar fuzzy controller [1]. To achieve this task in the work we need to solve the following tasks: to build a model of asynchronous electric drive network pump and perform the synthesis of PID-similar fuzzy controller; as well as modeling of the electric drive control system with PID-similar fuzzy controller in Scilab; perform a comparative analysis of the operation of the asynchronous electric drive of the mains pump with traditional and fuzzy controllers.

The probabilistic nature of water consumption requires continuous changes in the mode of operation of pumping units of water supply systems. Changes must be made in such a way as to maintain the required values of the technological parameters in the system as a whole and at the same time to ensure the minimum possible power consumption of the pumping unit. This problem is solved by an automatic control system, which stabilizes the pressure in the network at a given value. It is almost impossible to stabilize the pressure at all points of the complex network, so it is usually about stabilizing the pressure at individual points of the network, which are called dictation [2]. Signals from the pressure sensor installed in the dictation point of the network and from the setting device signal are fed to the pressure controller, where they are compared with each other and processed accordingly, and then transmitted to the control system of the pump drive unit.

From the point of view of energy efficiency, the most effective way to coordinate the modes of supply of pump units and fluid consumption and control the speed of the impellers. The speed can be changed in several different ways, but to build automatic control systems for pumping units, the most convenient and effective today is the use of an adjustable electric drive [3].

The pumping station 3 NKVE 15/8 T, which is designed to increase the water pressure for industrial, civil and agricultural purposes, is considered as a control object in present paper. The pumping station is composed of three vertical multistage centrifugal pumps type NKVE 15, each of which is equipped with an asynchronous motor MDEMA XX 132-2 2. The model consists of standard blocks of the Xcos tool

palette, as well as an additional module sciFLT Toolbox [4]. All parameters of the model in the pressure stabilization system are calculated for the selected control object with the methods given in [3, 5].

In the model of the pump unit it is conditionally possible to allocate electromechanical and mechanical parts. The electromechanical part includes an electric drive, and the mechanical part includes a mains pump [3].

The model of the electromechanical part is shown in Fig.1.

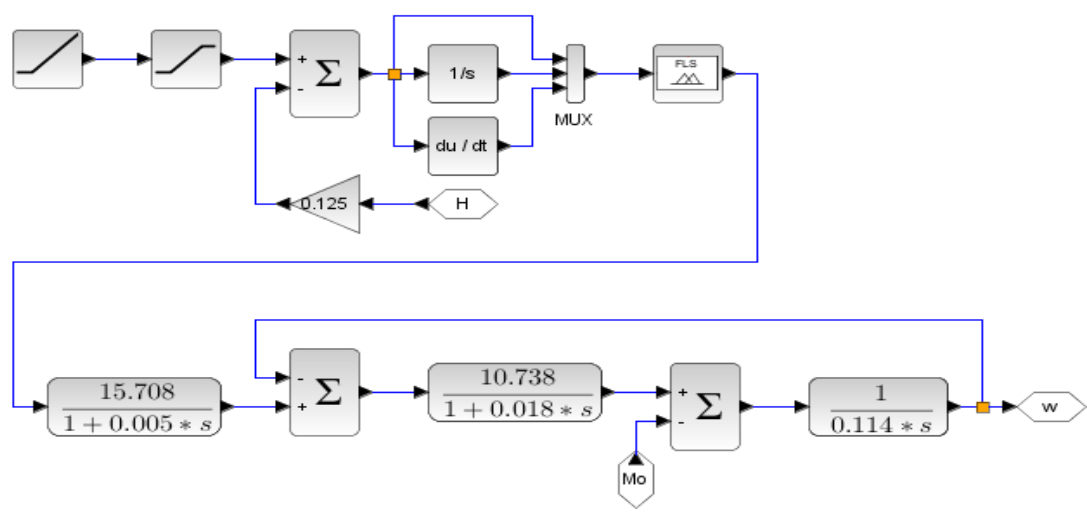


Fig. 1. Model of the electromechanical part of the pump unit

Therefore, the electromechanical part includes: the setting device (blocks Ramp and Saturation); the comparison device of signals of the task on pressure, and also feedback on pressure H (the Summation block); PID-similar fuzzy pressure controller (Integral_f, Deriv, Mux and another block of fuzzy output system scicos_fls); a frequency converter implemented by the aperiodic block Clr; the asynchronous motor is represented in a simplified form as a second-order aperiodic block (Summation, torque block on the first-order aperiodic block Clr, adder of electromagnetic torque of the motor and static resistance torque M_{SR} generated by the pump, motor speed block in the block Clr). The output coordinate of the electric drive is the angular velocity w.

In the presented work, fuzzy logic in the PID-pressure controller is used to organize the automatic adjustment of the coefficients of the traditional PID-

controller. This approach is more convenient due to the ease of use than adaptive control or the use of complex state controllers.

The coefficients of proportional, integral and differential components of the traditional pressure controller are pre-calculated, provided that the pressure stabilization circuit is set to the technical optimum.

The fuzzy output system (scicos_fls block in Fig. 1) is made according to the Mamdani type with three input and one output parameters. Three input parameters (Inputs): for proportional (kP), integral (kI) and differential (kD) components of the pressure controller, and the output parameter (Outputs) is a control signal (y).

The procedure for processing input information in a fuzzy controller can be described as follows: the current values of the input variables kP, kI and kD are converted into linguistic values (fuzzification); on the basis of the received linguistic values with use of base of rules (Rules) fuzzy logical conclusion is carried out therefore linguistic values of an initial variable y are calculated.

To implement the phasing and defuzzification procedures, the membership functions are set for each input and output parameters. Determining the membership function is the most labor-intensive process that determines the quality of the system management process. Therefore, to compile the most appropriate model, you need not only knowledge of the nature of the system's behavior, but also a number of experiments that will identify the shortcomings of the fuzzy model and eliminate them. For all terms, the membership functions are chosen triangular in shape. The use of other forms in such a system has little effect on the result.

Therefore, to build a pump model in the Xcos program, schemes [1] are compiled, which implement the functional dependences of the operating parameters of the network pump: $Q=f(\omega)$, $H=f(\omega)$ and $M_o=f(\omega)$.

In [2], the dependence for calculating flow rate, pressure and static moment of the pump. So dependent flow rate of pump from its angular velocity $Q=f(\omega)$ is:

$$Q = Q_n \cdot \sqrt{\frac{H_f \cdot \left(\frac{\omega}{\omega_n}\right)^2 - H_{st}}{H_f - H_{st}}} \quad (1)$$

where Q_n , ω_n – nominal flow rate and angular velocity of the pump; H_f – fictitious

value of pressure at zero flow; H_{st} – static delivery head; ω is the current value of the angular velocity of the pump.

Static pressure pump varies according to the expression:

$$H_{st} = \frac{H - H_n \cdot \left(\frac{Q_{FR}}{Q_n}\right)^2}{1 - \left(\frac{Q_{FR}}{Q_n}\right)^2}, \quad (2)$$

where H – the pressure created by the pump; H_n – nominal pressure of the pump; Q_{FR} – flow rate in the hydraulic system.

The dependence of the pump pressure on its angular velocity $H=f(\omega)$ is determined by

$$H = H_{st} + \frac{(H_n - H_{st}) \cdot \left(H_f \cdot \left(\frac{\omega}{\omega_n}\right)^2 - H_{st}\right)}{H_f - H_{st}}. \quad (3)$$

The moment of static resistance, which is created the pump $M_{SR}=f(\omega)$:

$$M_{SR} = \frac{\rho \cdot g \cdot Q \cdot H}{\omega \cdot \eta_p}, \quad (4)$$

where ρ – density of the liquid, which is pumped; g – acceleration of free fall; η_p – pump efficiency.

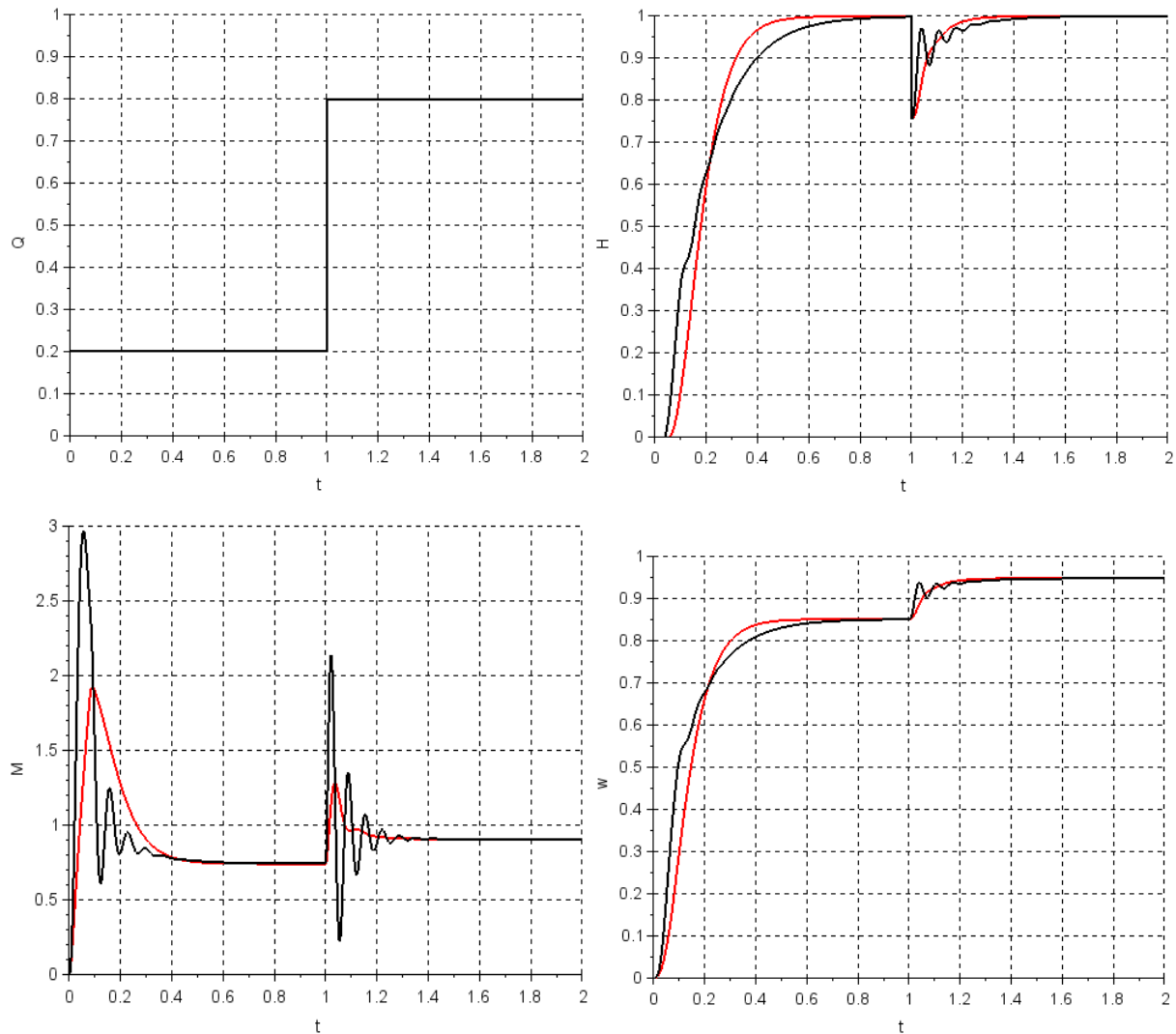
Pump efficiency depending on the angular velocity formula:

$$\eta_p = 1 - \frac{1 - \eta_n}{\left(\frac{\omega}{\omega_n}\right)^{0,36}} \quad (5)$$

where η_p – nominal efficiency of the pump.

The transient characteristics of this model of asynchronous electric drive of a main-line pump with traditional and fuzzy controllers when the flow rate in the hydraulic system is shown in Figure 2.

Therefore, the analysis of control quality by transient characteristics can be concluded traditional PID-controller. The obtained results confirm the expediency and efficiency of application of PID-similar fuzzy pressure controllers in the asynchronous electric drive of water supply systems.



– with a traditional PID controller;

– with PID-similar fuzzy controller

Fig. 2. The transient characteristics of an asynchronous electric drive of a pump unit

Conclusions. In the presented paper a model of asynchronous electric drive with fuzzy controller of water supply system was built, which allows to determine working parameters, as well as to analyze electromechanical, energy processes and to study dynamics of asynchronous electric drive when changing modes of pump unit. The results of simulation modeling in the Scilab application package showed that it is expedient to use fuzzy logic in the structure of traditional PID-controllers of asynchronous electric drive of water supply systems, and also confirmed the prospects of such an approach. The use of methods of fuzzy logic theory in the synthesis of the controller allows to make the control process more adaptive.

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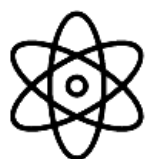
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