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The Effect of Automated Control and Data Processing on Efficiency in D630-80 Brand Pump Systems

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Annotation: *Currently, increasing attention is being paid to the automation of pump unit operations in irrigation pump stations. Automation frees workers from monotonous and heavy labor. Additionally, the implementation of automated control systems in irrigation systems significantly enhances labor productivity and efficiency, while also reducing the management of human factors in technological processes.*

Keywords: *D630-80 pump, measurement algorithm, control algorithm, water flow, pressure sensor, PID controller, mathematical modeling, Simulink, closed loop, automation, transient process, stability.*

Introduction: This article is dedicated to the issues of automating the measurement and control systems of the D630-80 pump. The article discusses the algorithm for collecting pressure measurements at the pump's output, as well as the design of a closed-loop system for controlling water flow and the processes of mathematical modeling. The settings of the PID controller and the results of modeling in the Simulink software environment are analyzed to ensure the system's stability and efficiency.

Developing algorithms that ensure the reliable and efficient operation of the pump system and analyzing their practical application using the MATLAB program.

The system must support and control specified technological process regimes, issue commands to actuators, and visually display information about the state of technological equipment [1]. The complex of technical means, together with software, must ensure the implementation of all functions specified in this technical task. These are achieved through software-technical data processing, remote control, transmission, and storage tools.

Measurement Data Collection Algorithm. As the measurement channel, we select the pressure sensor at the output of the D630-80 pump unit. An algorithm for collecting data from the pressure sensor measurement channel is developed. The algorithm for collecting data from the measurement channel is presented in Figure 1 [2].

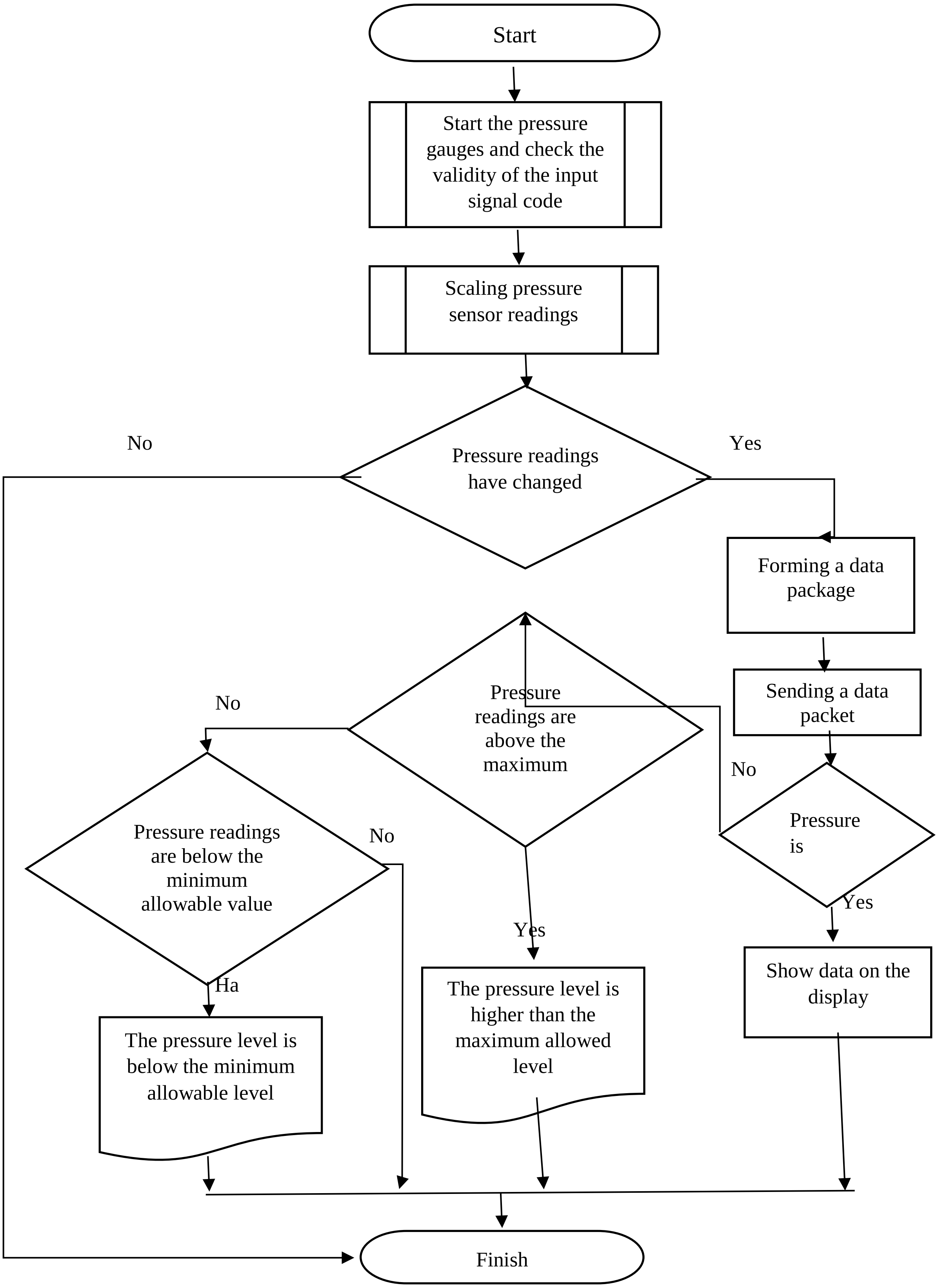

Figure 1. Algorithm for collecting data from the pressure sensor of the D630-80 pump.

Algorithm for Automatic Control of the Technological Process. A control loop for managing the water flow at the inlet of the D630-80 pump station is developed. A valve at the inlet of the pump pipeline is used to control the water flow. The control law for the valve is determined. Mathematical modeling of the control object is performed. The transfer function for the water flow is defined, represented as an aperiodic element with a delay:

$$W(p) = \frac{1}{Tp+1} \cdot e^{-\tau_0 p}; \ (1)$$

$$T = \frac{2 \cdot L \cdot f \cdot c^2}{Q}; \ \tau_0 = \frac{L \cdot f}{Q}; \ c = \frac{Q}{f} \cdot \sqrt{\frac{\rho}{2 \cdot \Delta P \cdot g}}. \ (2)$$

Here: L – the length of the pipe between the measurement point and the control point;

ρ – the density of water;

d – pipe diameter;

f – cross-sectional area of the pipe;

ΔP – pressure difference in the pipe;

τ_0 – delay;

T – time constant.

We take the following values for the object parameters:

L=25 m;

Q=630 m^3/soat = 0,175 m^3/s;

ΔP=1MPa;

$f = \frac{\pi d^2}{4} = \frac{3{,}14*(0{,}325^2)}{4} = 0{,}0829;$

ρ=1000 kg/m^3.

We substitute the numerical values into the (2) formulas and obtain the following:

$$c = \frac{0{,}175}{0{,}0829} \cdot \sqrt{\frac{1000}{2 \cdot 10^6 \cdot 10}} = 0{,}01493 \ s;$$

$$\tau_0 = \frac{25 \cdot 0{,}0829}{0{,}175} = 11{,}843 \ s$$

$$T = \frac{2 \cdot 25 \cdot 0{,}0829 \cdot 0{,}01493^2}{0{,}175} = 0{,}00528 \ s.$$

As a result, the mathematical model of the control object takes the following form:

$W(p) = \frac{1}{0{,}00528p+1} \cdot e^{-11{,}843p}.$

We determine the ratio of delay time and time constant:

$$\frac{\tau_0}{T} = \frac{11{,}843}{0{,}00528} > 1.$$

This ratio is greater than one, indicating that this object has a large transport delay and is difficult to control [3].

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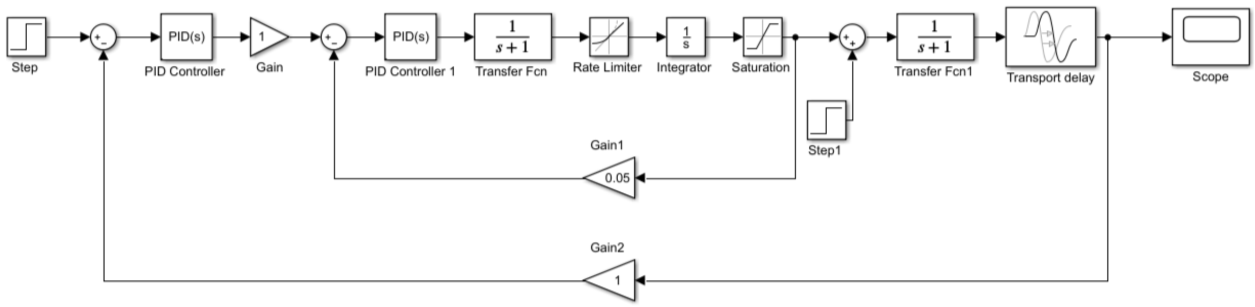
We construct an initial system. The initial system is shown in Figure 2.



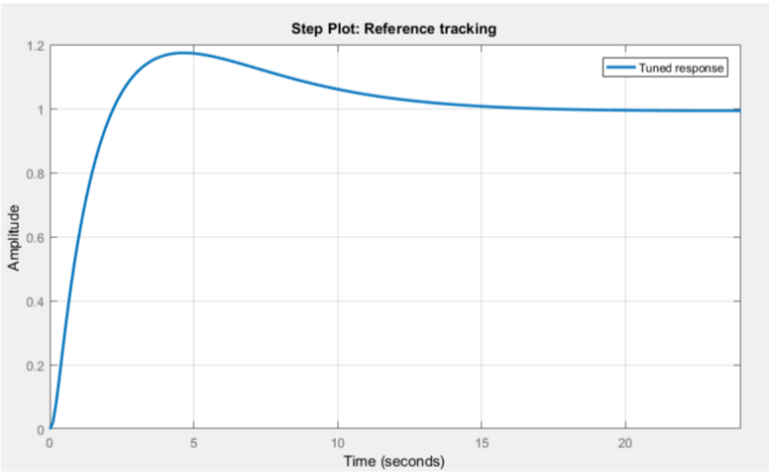
2 – Fig. Scheme of the D630-80 pump model in Simulink

The control unit is represented as a closed loop. In the direct circuit of this loop, there is a first-order aperiodic loop (electromechanical part), a RateLimiter loop that limits the signal rate of change, an integrator that converts angular velocity into an angle of movement, and a Saturation loop that limits angular movement.

The system has two loops: a closed loop of the electric drive and a direct external control loop.

External influences also have a negative effect on the system, which can occur due to environmental changes or mechanical effects on the object.

For the internal loop, we tune the PID controller using the Simulink auto-tuning function (Fig. 14).



3 - Picture. Characteristics of the PID regulator after auto-tuning.

In the graph, time (in seconds) is on the horizontal axis and amplitude is on the vertical axis. The system starts from 0 and reaches an amplitude of 1.2 quickly (in about 2-3 seconds) and then the amplitude decreases slightly, approaches 1 and remains stable at this level for 20 seconds. This graph shows the stabilization and flexibility of the system after a step signal.

The following PID controller values were obtained using autotuning:

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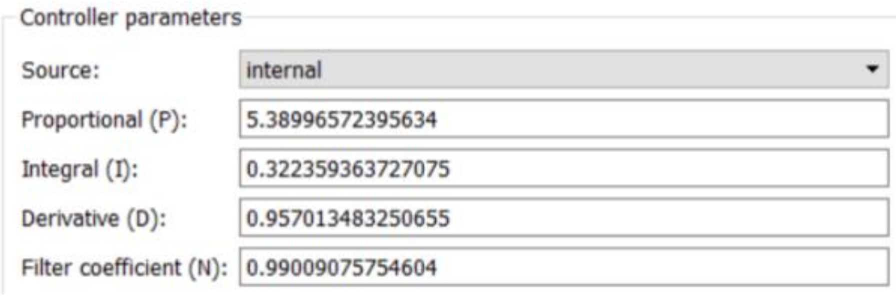

Figure 5. PID-regulator values.

We also use the autotuning function of the PID controller to determine the controller coefficients for the external loop. PID-regulator data is presented in Figure

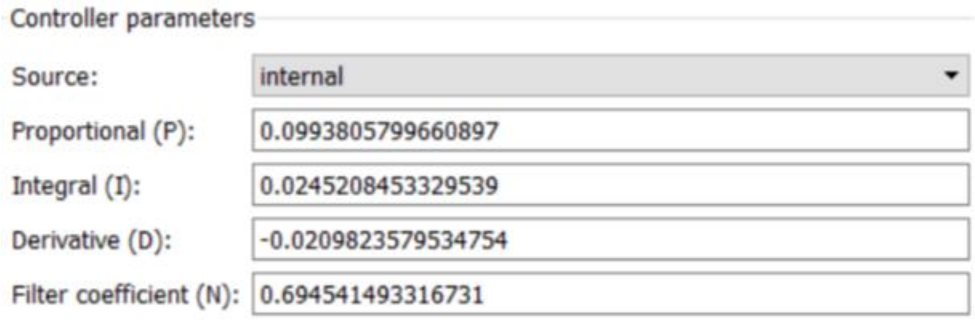

Figure 6. External loop PID controller values.

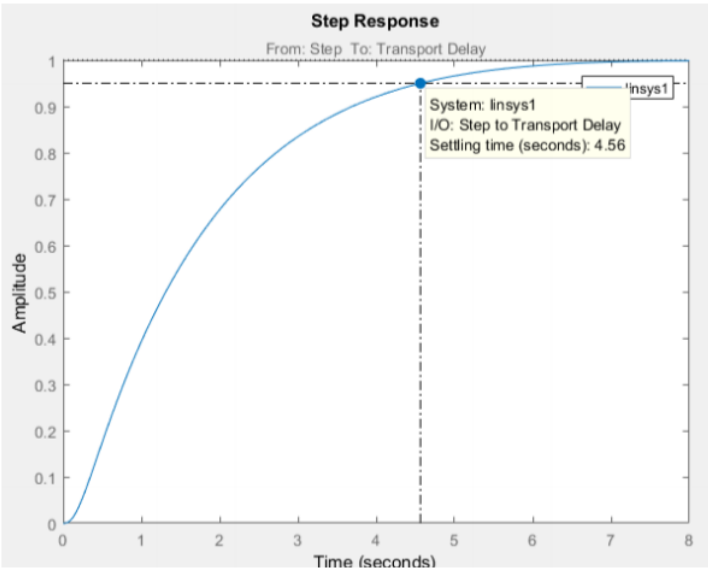

Figure 7. Transfer characteristic graph.

The graph shows time (in seconds) on the horizontal axis and amplitude on the vertical axis. The blue line represents the transfer characteristic of the system, which gradually increases with time, approaching an amplitude of approximately 0.9. In addition to the line, a point is marked where the transport delay and settling time are 4.56 seconds, indicating the dynamic characteristics of this system.

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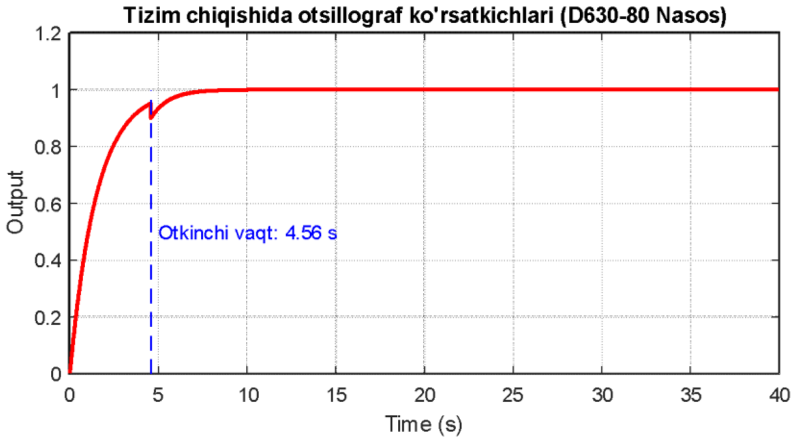

Figure 8. Oscilloscope readings at the system output.

All calculations resulted in a system with 0% overshoot and a transient process time of 4.56 s. As can be seen in Figure 8 , after the initiation of the disturbance, the system slightly deviated from the steady state value and then returned to its initial state. These quality indicators are acceptable for the system.

Conclusion

Measurement and control algorithms for the D630-80 pump have been developed. The algorithm for collecting data from the pressure sensor and a closed-loop system for controlling water flow have been successfully designed. The mathematical model implemented in the Simulink program and the automatic tuning of the PID controller have ensured optimal operation of the system. As a result, a stable system with 0% overshoot and a transient time of 4.56 seconds was obtained. These results confirm the high efficiency and reliability of the system, which allows its use in industrial conditions.

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