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Gas Pressure and Flow Control Algorithm in Main Gas Pipelines Using the Fuzzy Logic Apparatus

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ABSTRACT: A new approach to the development of a valve control system - a high pressure regulator using a fuzzy logic apparatus is proposed. To solve this problem, a hybrid use of methods of the theory of automatic control and intelligent technologies is proposed. A mathematical model of the process of controlling pressure and gas flow in a gas main is developed taking into account the operation mode of the facility and using a fuzzy controller. The gas pressure control process is mathematically formalized using fuzzy logic algebra.

Application of the proposed approach to solving the problem of controlling the pressure and gas flow in pipelines allows taking into account the accumulated experience of specialists, which allows better process control, unlike the classical PID control, and, as a result, does not require constant adjustment of the PID coefficients regulator.

KEYWORDS: pressure, flow rate, phasing, dephasing, algorithm, control, fuzzy logic.

I.INTRODUCTION

There is a steady increase in demand for natural gas in world markets. This trend leads to accelerated development and implementation of energy saving and gas consumption optimization programs.

As in other countries, and in Uzbekistan, gas demand is characterized by seasonal unevenness. The decrease in natural gas consumption in the industrial and socio-economic sectors of the economy of the countries of the world community is mainly observed in the spring-summer periods. In this aspect, the tasks of optimizing gas storage in gas storages, providing for the most efficient use of underground reservoirs as in the construction of underground gas storage (UGS), deserve attention.

The objects of control in the technological processes of gas injection and extraction are pumping and compressor units, auxiliary equipment, as well as linear sections of gas pipelines, gas distribution stations, wells, etc. Parameters control, signaling deviations and discrete control of valves are characteristic of linear sections [1].

UGS as an object has parameters that vary over time, that is, it is an unsteady control. To solve the problem of controlling such objects, the construction of non-stationary control systems, and hence the design of dynamic controllers, is required. In practice, at present, proportional-integral-differential (PID) controllers are widely used as corrective devices in automatic control systems (ACS).

II. PROBLEM DEFINITION

Operational experience shows that tuning PID controllers is usually very complex and time-consuming. Due to the variable operation mode of the gas pipeline, constant adjustment of the PID controller coefficients is required, and therefore, maintenance personnel are required at the facility. All this leads to self-oscillation, overshoot in the system and, as a result, pressure deviation from the set value, as well as to rapid wear of the mechanical moving parts of the regulating body (valve), such as valve seat, seals, rods, piston, etc. d. [2].

Recently, however, more and more attention in science and practice has been paid to the new principle of constructing controllers, based on the fuzzy logic rules, which allow one to take into account various uncertainties that

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arise in the control process. In this case, the gain in the proportional, integrating and differentiating circuits of the controller, PID controller with a controller based on fuzzy logic are not static, i.e. depend on the state of the system at the current time. This allows you to make the management process more adaptive. To implement the controller based on fuzzy logic, it is necessary to determine the input linguistic variables, the linguistic variable that must be obtained, as well as the rules for the formation of the resulting effect from the input variables[3-4].

Consider the process control process parameters of the pipeline.

The parameters of the state of the pipeline are the gas pressure Pi, j and its flow rate Qi, j at the point of the pipe. All other physical parameters of gas, pipes are accepted by constants at the current moment of calculation.

To calculate the state of a gas during its unsteady motion from the theory of gas dynamics, the following system of nonlinear differential equations is used [1]:

$$\begin{cases} \frac{\partial P}{\partial t} + \frac{\partial Q}{\partial x} = 0 \\ \frac{\partial P^2}{\partial t} + K * Q^2 = 0 \end{cases}$$

where P is the gas pressure;
P_{zad}, Q is the gas flow rate;
K is the coefficient of the physical parameters of the pipe and the environment [5].

The process of controlling the technological parameters of the gas of the main gas pipeline is carried out by a control valve, which is installed on the gas metering unit, which serves to measure the flow rate and control the pressure in the gas pipeline.

III. SOLUTION TO THE PROBLEM

To solve this problem, the inclusion of a microprocessor in the control loop is proposed. Taking into account the operating principle of the facility, as well as the technological regulations, an algorithm and a base of fuzzy logic rules have been developed that will allow regulating the pressure in the gas pipeline (Fig. 1).

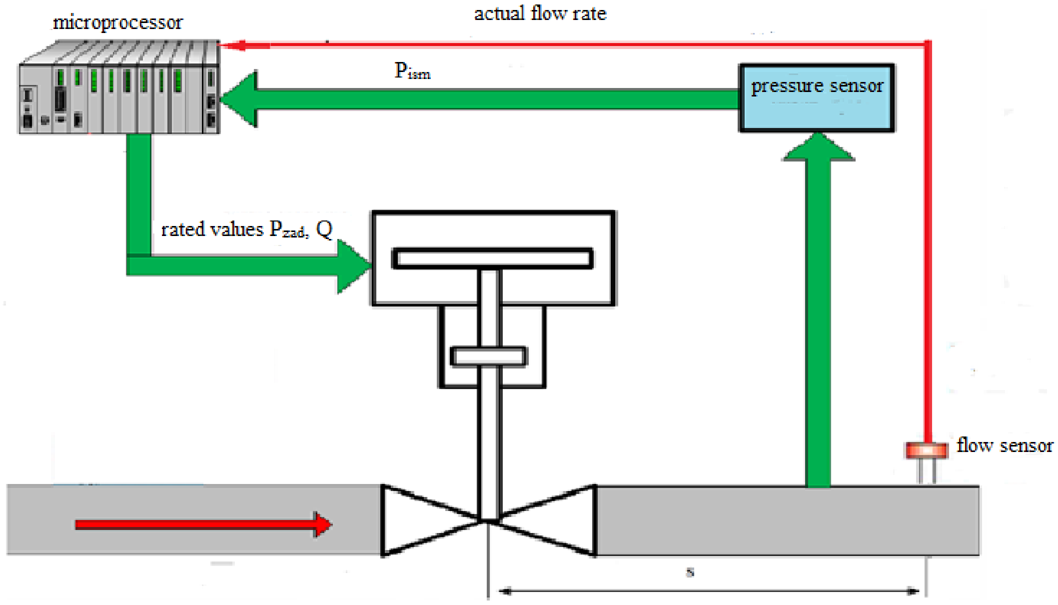

Fig. 1. The technological scheme of pressure and flow control.

The pressure value P_{ism} is determined by the sensor, which is installed after the control valve, with a measuring range from 0 to 100 kg / cm2.

For phasing, according to the deviation of gas pressure in the pipeline, we will take the triangular shape of the membership functions of the three terms (Fig. 2).

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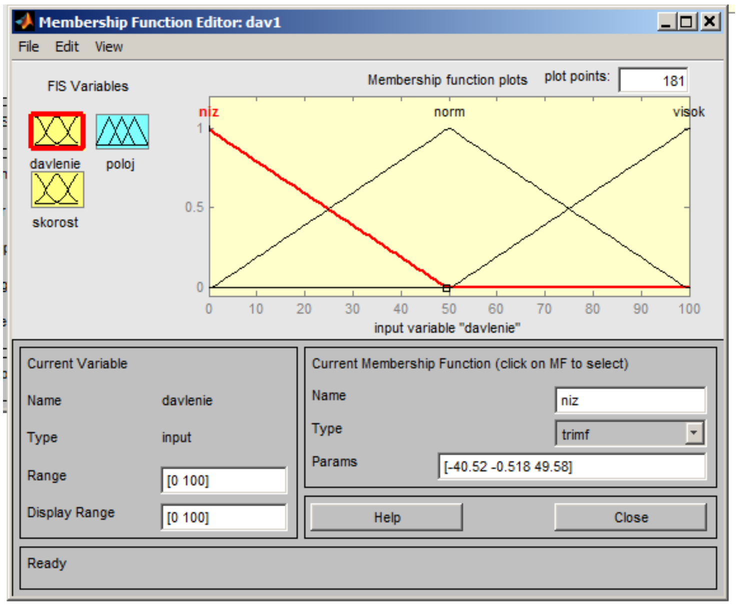

Fig. 2. The form of the pressure change membership function.

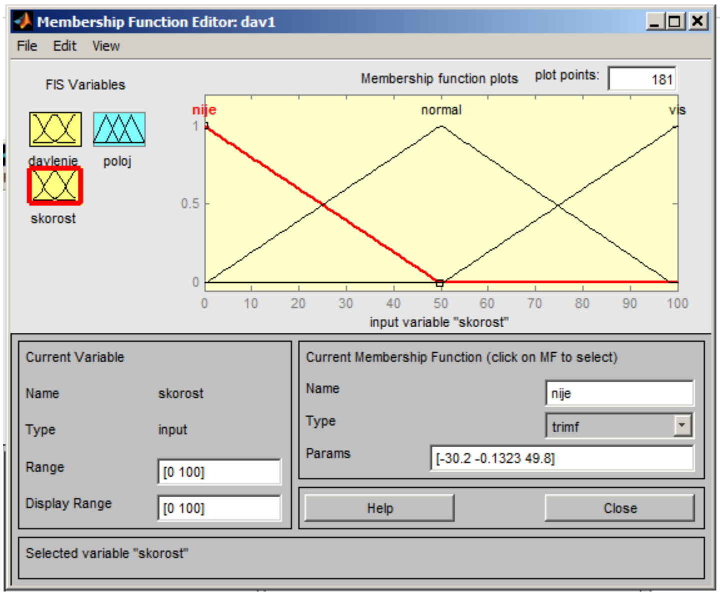

Fig. 3. The membership functions of the change in pressure velocity.

To improve the accuracy and quality of process control, we calculate the rate of change in pressure in the pipeline dV. To phaseify the rate of change in pressure in the gas pipeline, we will take a similar form of membership functions (Fig. 3). To regulate using the open-close valve-regulator, we use the signal for setting the valve position L back, which comes from the output of the microprocessor control module. The formation of the control signal provides a change in the position of the valve of the regulator L, which is determined by the range from 0 to 100%. The control of the position of the valve in linguistic variables of fuzzy logic can be represented by five terms (Fig. 4). If the pressure is less than the set point and its value does not change, then the valve is partially open. Using fuzzy variables, we write this rule as follows:

ifdP = M and anddV = H, then L = B.

If the pressure is less than the set point and its value decreases, the valve is fully open. Through fuzzy variables, this rule can be represented as follows:

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ifdP = M and dV = M, then L = CB.

If the pressure is greater than the set point and its value does not change, then the valve is partially closed. Using fuzzy variables, we represent this rule as follows:

ifdP = B and dV = H, then L = H.

If the pressure is greater than the set point and its value increases, then the valve is completely closed. Through fuzzy variables, this rule can be represented as follows:

ifdP = B and dV = B, then L = CB.

Similarly, we compose the rest of the rules. If you analyze all the possible states of the above conditions, then for this case, you can make nine rules.

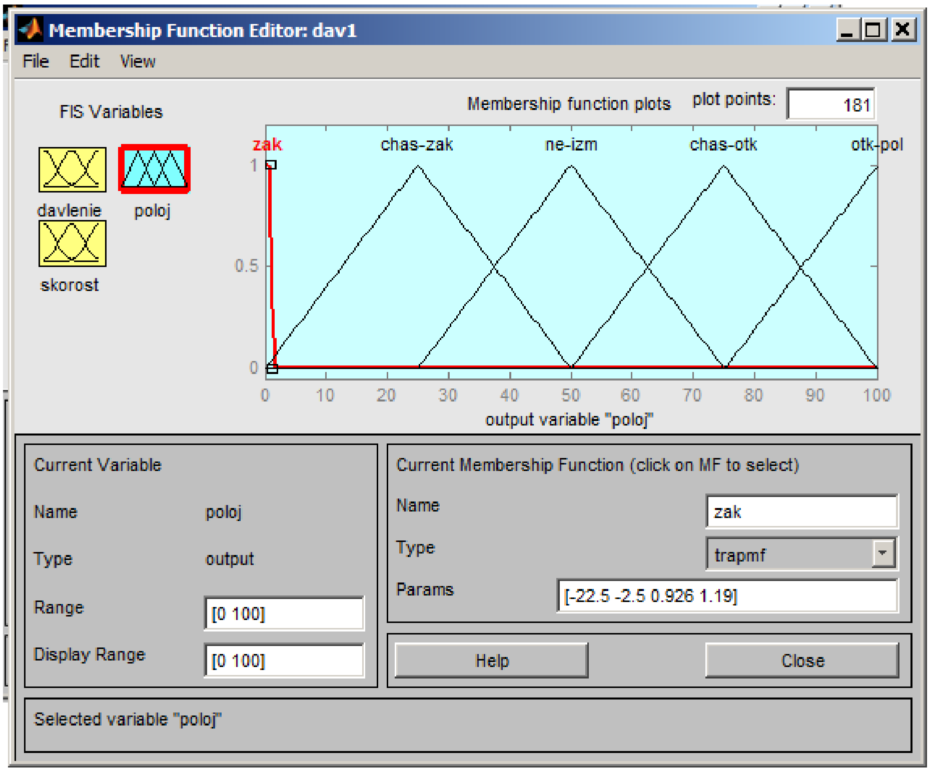

Fig. 4. Linguistic variables of valve opening.

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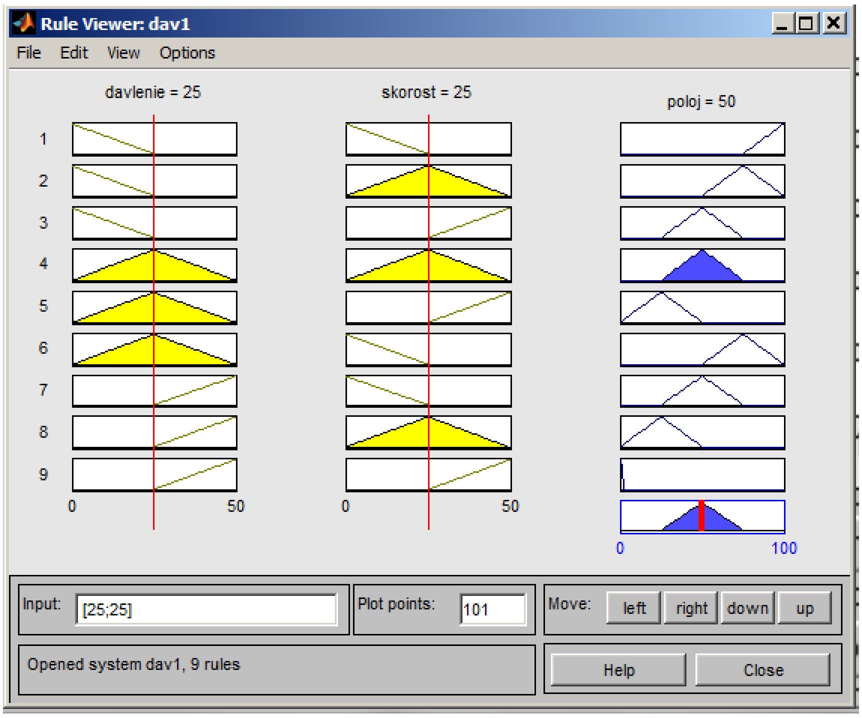

Fig. 5. Rule Viewer control window.

Let us consider how the control action is calculated at an arbitrary point in the motion of the system.

Let the pressure deviation be 30 kg / cm^2 and it continues to decrease with a speed of 10 kg / cm^2. In this case, the terms M and H of the pressure deviation have a degree of belonging of 0.6 and 0.4, respectively (Fig. 2), and the terms M and H of the rate of change of pressure are 0.8 and 0.2, respectively (Fig. 3) The degree of belonging to other terms is 0. For the accepted form of writing rules, the degree of belonging of the antecedent of each rule is determined by the minimum of all conditions, i.e. for the conclusion, the rules containing conditions with nonzero degrees of membership are significant:

1. If dP = M and dV = M, then L = CB.
2. If dP = M and dV = H, then L = B.
3. If dP = H and dV = M, then L = B.
4. If dP = H and dV = H, then L = H.

Each of these rules gives the degree of belonging to the conclusion to a minimum:

1. M_{CB} (L) = min {m_m (dP); m_m (dV)} = min {0.6; 0.8} = 0.6.
2. M_B (L) = min {m_m (dP); m_H (dV)} = min {0.6; 0.2} = 0.2.
3. M_B (L) = min {m_H (dP); m_H (dV)} = min {0.4; 0.8} = 0.4.
4. M_H (L) = min {m_H (dP); m_H (dV)} = min {0.4; 0.2} = 0.2.

At the second stage of the formation of fuzzy inference, we determine the degree of membership of the terms of the output variable by the maximum value.

For example, the expressions of paragraphs 2 and 3 give different values of the degree of belonging for the term MB, but the maximum of them is taken:

1. M_B (L) = max {m_B (L); m_B(L)} = max {0.2; 0.4} = 0.4.

Thus, for a given state of the input signals, the degree of membership of the terms of the output variable have values (Fig. 4):

{m_{cm}, m_m, m_H, m_B, m_{CB}} = {0; 0; 0.2; 0.4; 0.6}.

To move from fuzzy conclusions to a control action onthe valve we use the dephasification formula according to the center of gravity method:

$L_{set} = (L_{cm}m_{cm} + L_m m_m + L_H m_H + L_B m_B + L_{CB} m_{CB}) / (m_{cm} + m_m + m_H + m_B + m_{CB})$

Substituting the numerical values in the formula, we obtain thus, in order to maintain the required pressure setting, the valve must be opened by 83.3%, therefore L_{set} = (83.3 • 16) / 100 + 4 = 17.33 mA.

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IV. CONCLUSION

The use of this control algorithm based on fuzzy logic, allows better control of the regulatory process, in contrast to the traditional PID regulation. Firstly, the algorithm allows you to better adapt to the variable mode of the gas pipeline and does not require constant selection of the PID controller coefficients. Secondly, it increases the service life of the valve due to the minimal impact on its mechanical part, and most importantly, minimizes the occurrence of emergency situations at the facility.

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