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MODEL OF THE CONTROLLER FOR OUTPUT STREAM CONCENTRATION IN THE MIXER OF A STEAM UNIT

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ABSTRACT

There is an actuality validation for the development and research of hybrid intelligent system synthesis methods in this paper. We considered the model of the output stream concentration control for lighting-up equipment of steam unit boiler. The control of the electric motor of the mixer from the lighting-up equipment is carried out by a hybrid controller application. Fuzzy Logic Toolbox was used for simulation. The synthesis of the control model of the mixer output stream has been done. A conventional control method and the fuzzy control method were used for the system synthesis. We used Mamdani algorithm to implement the fuzzy control model of the mixer output stream concentration. There is a description of the procedure of the fuzzy system model integration in Simulink interactive system by means of the graphic editor FIS in this paper. The results of this work are meant for the experimental researches of intelligence hybrid control system parameters.

Keywords: control, steam unit, hybrid intelligence, simulation, lightning equipment, mixer stream, electric motor, fuzzy system.

1. INTRODUCTION

Development and research of the synthesis methods of hybrid intelligence control systems, development of the algorithms for objects control with hybrid systems, and extension of the application area of these methods are the topic problems [1-4]. Classic automatic control theory cannot offer a qualitative control action for the objects with incomplete data. However, modern plants control takes place precisely in the uncertainty conditions. The electric motor controlling throttle position for fuel supply in the boiler of the steam unit SGU-50/6M can be rated as such object. The control of the output stream concentration of the lightning equipment ensures desired quality for the boiler operation. Structural block diagram of the lightning equipment is shown in Figure-1. The control of the electric motor is implemented by the hybrid controller usage [5]. A hybrid approach uses the classic control theory integrated with fuzzy logic, as a tool. The application of hybrid modeling methods and hybrid control systems allows the significant improvement of main quality indexes of automatic control systems operation [3-8]. For example, we can affect the form of control curve by creating it separately at each time interval during the fuzzy controller parameters tuning. It is possible to constrain the influence of neighbor parts of the control curve during the controller design and the tuning of coefficients.
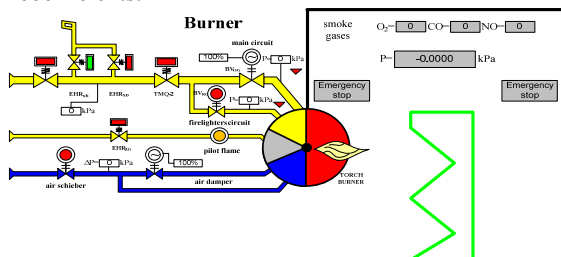

Figure-1. Lightning equipment.

Hybrid control system synthesis and research were carried out in Matlab with SIMULINK interactive system for Windows. Fuzzy Logic Toolbox was used in modeling [9].

2. OUTPUT STREAM CONCENTRATION CONTROL MODEL

The features and results of conventional and fuzzy model without disturbances and with them and control object (DC motor) parameters changing were considered in [10]. This motor is used in the control system of the technological process of the steam unit USG-50/6M applied in the oil industry. The fuzzy system implementing PI controller was developed with Fuzzy Logic Toolbox graphic interface**.**

We used the classic (method 1) and the fuzzy control (method 2) methods for the synthesis of the control system for output stream concentration regulation. Classic control method was implemented with a control theory [1] usage. Use of different methods can be explained by high quality standards of chemical and alimentary industries to control in such systems.

The algorithm of synthesis of the output stream concentration control model has the following structure.

The variables identification:

Method 1 (conventional logic) execution corresponds to I=1;

Method 1 (conventional logic) non-fulfillment corresponds to I=0;

Method 2 (conventional logic) execution corresponds to J=1;

Method 2 (conventional logic) non-fulfillment corresponds to J=0;

Method 1 (fuzzy logic) execution corresponds to L=1;

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Method 1 (fuzzy logic) non-fulfillment corresponds to L=0;

Method 2 (fuzzy logic with changed rule base) execution corresponds to S=1;

Method 2 (fuzzy logic with changed rule base) non-fulfillment corresponds to S=0.

Step-1. Calculation of the classic controller and the control object parameters by the method 1.

Step-2. Synthesis of the conventional control system.

Step-3. Creation of the special file for the conventional system simulation results writing, the setting of file parameters.

Step-4. Simulation of the conventional control system.

Step-5. Recording of the simulation results to the created file

Step-6. Calculation of the ADC capacity and the DAC sampling step.

Step-7. Analysis of simulation results. If the condition I=1 is fulfilled, then the algorithm goes to **step-21**, else (I=0) the algorithm goes to **step-8.**

Step-8. Calculation the classic controller and control object parameters by the method 2.

Step-9. Simulation of the conventional control system.

Step-10. Recording of the simulation results to the created file

Step-11. Analysis of simulation results. If the condition J=1 is fulfilled, then the algorithm goes to **step-21**, else (J=0) the algorithm goes to **step-12.**

Step-12. Extraction of numerical values from the file.

Step-13. Design of the fuzzy control system with FUZZY LOGIC TOOLBOX on the basis of received values. The type of used fuzzy system, linguistic variables with appropriate term-sets, and methods necessary for fuzzy inference are determined at this step. The appropriate set of production rules and a fuzzy inference surface are created.

Step-14. Integration of the developed fuzzy system into interactive SIMULINK system by using of FUZZY LOGIC TOOLBOX.

Step-15. Simulation of the conventional (method 2) and the fuzzy (method 1) control systems.

Step-16. Comparison of the simulation results. If the condition L=1 is fulfilled, then the algorithm goes to **step-21**, else (L=0) the algorithm goes to **step-17**.

Step-17. Correction (the method 2 for fuzzy system creation) of the rule base of the "Fuzzy controller" system and/or changing of the fuzzy inference methods to increase the control efficiency.

Step-18. Simulation of the conventional (method 2) and the fuzzy (method 1) control systems.

Step-19. Comparison of the simulation results. If the condition S=1 is fulfilled, then the algorithm goes to **step-21**, else (S=0) the algorithm goes to **step-20**.

Step-20. Improvement of the fuzzy model by changing and/or correction of the main fuzzy inference stages.

Step-21. The end of algorithm, and issue of conclusions.

The desired parameters of the control object and the controller have been calculated with the data presented in Table-1.

Table-1. The data for the calculation of the control object and the controller.

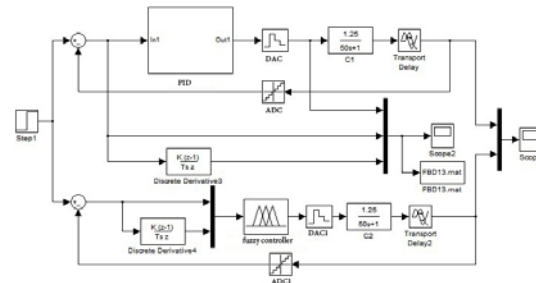| K_{co}	T_{co}	τ_{co}	T_i	T_d	K_p
1,25	50	5	$2{,}5\,\tau_{co}$	$0{,}4\tau_{co}$	$0{,}95T_{co}/k_{co}\tau_{co}$

The transfer function of the control object has a form

$$W_{co}(p) = \frac{1,25e^{-5p}}{1+50p}. \qquad (1)$$

The transfer function of the PID controller has a form

$$W_{PID}(p) = 7,6\left(1+\frac{1}{12p}+2p\right). \qquad (2)$$

We showed the model of the digital integrated control system made in SIMULINK system in Figure-2.

Figure-2. Digital integrated control system model.

The ADC capacity is chosen according to a quantum rate (the value of lower order bit). The DAC capacity is chosen according to the range of output variable $y(t)$ and the allowable error Δy of amplitude quantization. The sampling step is determined from the inequality $T_0 \le (0{,}1 \div 0{,}3)T_{co}$ and it is equal to 1,5 s, the quantum rate is equal to $\Delta y = 2{,}4109e\text{-}005$.

The signals of error θ, error rate $\dot{\theta}$, and control action U are recorded in the special file FBD13.mat during the system simulation.

Data record in the file FBD13.mat was implemented with the discreteness equal to 1 in the investigated model. The "PID-controller" subsystem model with calculated parameters is shown on Figure-3.

The Mamdani algorithm is used for the implementation of the fuzzy model of the output stream concentration control in the mixer. The new file is created using FIS editor graphic interface with a name of fuzzy inference system «PIDbezvozm», the Mamdani fuzzy inference algorithm, and chosen methods of activation, aggregation, accumulation, and defuzzification.
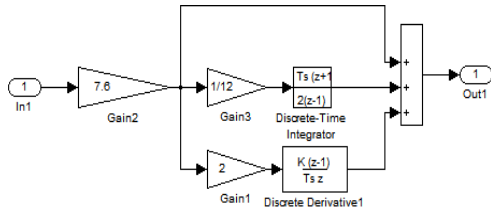
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Figure-3. The "PID-controller" subsystem model.

The terms and the membership functions, which have been developed in the editor of membership functions, for the input and output variables of the fuzzy inference system are presented in Figure-4-6.
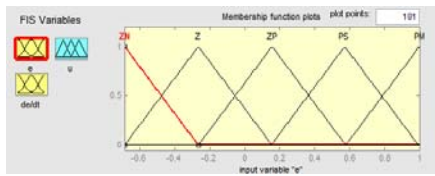

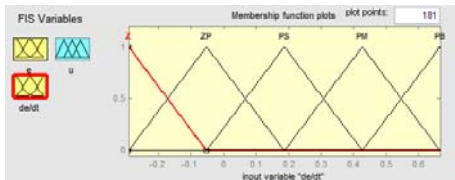**Figure-4.** Terms of linguistic variable "error".

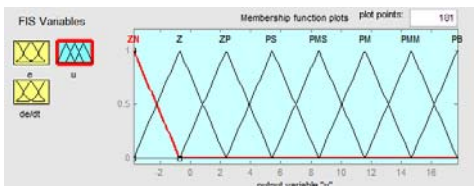**Figure-5.** Terms of linguistic variable "error rate".

Figure-6. Terms of linguistic variable "control action".

The "error" linguistic variable has the term-set T_1={ZN, Z, ZP, PS, PM}. The "error rate" linguistic variable has the term-set T_2={Z, ZP, PS, PM, PB}. The "control action" output linguistic variable has the term-set T_3={ZN, Z, ZP, PS, PMS, PM, PMM, PB}. The terms of input and output variables are intersected for the control efficiency sake. Fuzzy inference rules have been formed by the tools of FIS editor. One can see the program with fuzzy inference rules in Figure-7. This program could be used straight in simulation process. To do that, we should choose other type of fuzzy controller in SIMULINK: «Fuzzy Logic Controller with Rule Viewer». The developed fuzzy inference model is integrated into SIMULINK interactive system after the end of all fuzzy system development stages with means of FIS graphic editor.

The fuzzy controller model in SIMULINK system with the integrated fuzzy inference model is shown in figure 8. This model was developed on the basis of the chosen algorithm and appropriate methods.

There is an opportunity of setting of the certainty coefficients or the weight coefficients for every rule (values in the parentheses opposite to every rule). Theses coefficients can take values from the interval [0,1]. If these weight coefficients are not defined, their values are equal to 1.
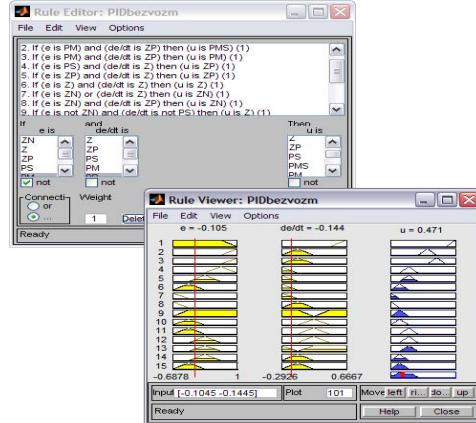

Figure-7. Program of fuzzy rules development and view.

The dialog window for the fuzzy inference system integration into SIMULINK interactive system is shown in Figure-9.

It is necessary to enter the name of file «PIDbezvozm» in the parameters window of block Fuzzy controller (see on Figure-9) and to choose item *Model Properties* in the menu File of the model window. Then it is necessary to choose tab *CallBacks* in the appeared window and to enter the command "*fuzzy* = r*eadfis*('PIDbezvozm')" in the field *Model pre-load function*. This command will place the created file "fuzzy.fis" into the Workspace of MATLAB each time the model file is opened.
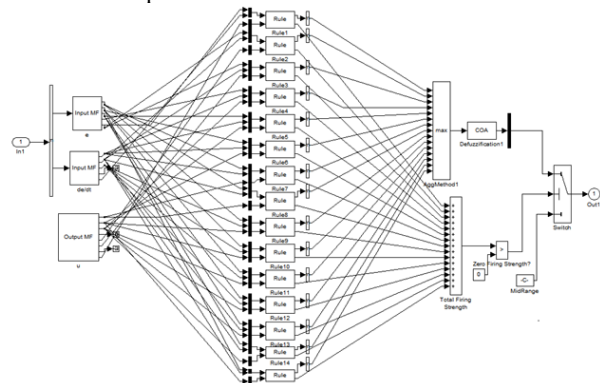

Figure-8. Fuzzy controller model in SIMULINK.

The error and error rate input signals and the output signal of control action with membership functions defined in FIS editor are represented by Input MF (e), Input MF (de/dt) and Output MF (u) subsystems. Input MF (e),

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Input MF (de/dt) and Output MF (u) subsystems are formed in turn by the set of *ZN, Z, ZP, PS, PM*; *Z, ZP, PS, PM, PB*; *ZN, Z, ZP, PS, PMS, PM, PMM, PB* subsystems. The rule base made by FIS editor tools is represented by Rule (Rule 1, Rule 2, …, Rule 11) subsystem. The form of Input MF (e) and Input MF (de/dt) subsystems in the developed model is shown in Figure-10.
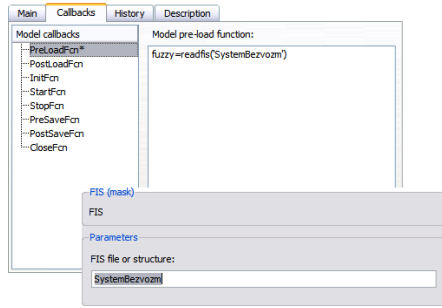

Figure-9. Integration of fuzzy output model with SIMULINK.

The procedure of truth degree calculation for every rule antecedent is presented by Max block. The procedure of output variables defuzzification (reduction to precise form) is presented by COA subsystem.
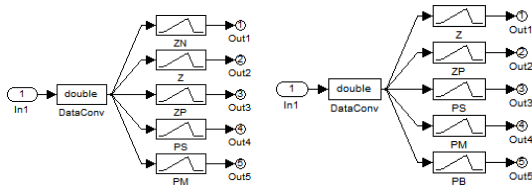

Figure-10. Form of Input MF (e) и Input MF (de/dt) subsystems.

The general algorithm of *ZN, Z, ZP, PS, PM*; *Z, ZP, PS, PM, PB* subsystems is shown in Figure-11.
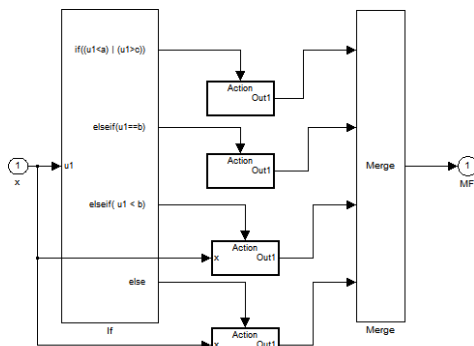

Figure-11. Algorithm of *ZN, Z, ZP, PS, PM*; *Z, ZP, PS, PM, PB* subsystems.

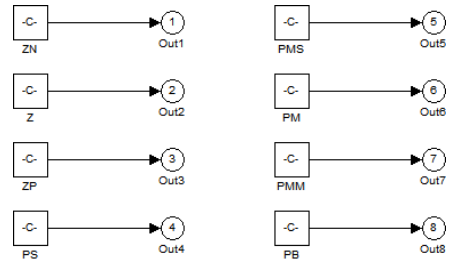The form of Output MF (u) subsystems in the developed model is shown in Figure-12.

Figure-12. Output MF (u) subsystems.

It is necessary to enter the command «trimf (linspace (fis.output (1). range (1), fis.output (1). range (2), 101), fis.output (1).mf(7).params)» for *Z, ZP, PS, PMS, PM, PMM, PB, PMB* subsystems. The designed algorithm for development of fuzzy rules from the set Rule (Rule 1, Rule 2, …, Rule 11) is shown in Figure-13.
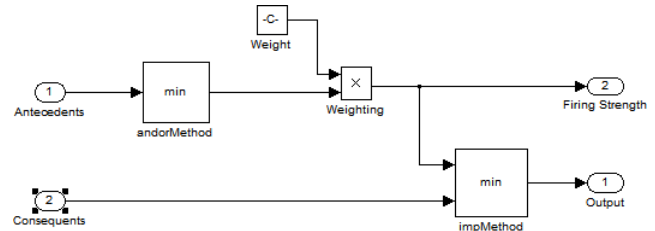

Figure-13. Algorithm of fuzzy rules development.

Developed algorithm of COA subsystem is shown in Figure-14.
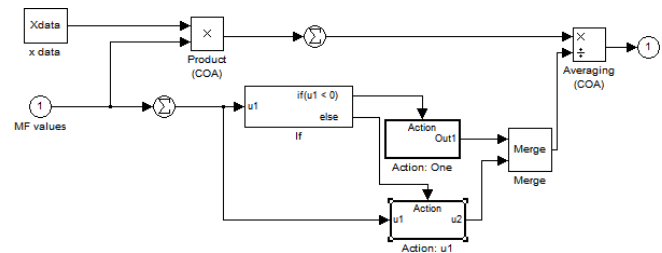

Figure-14. COA subsystem algorithm.

3. CONCLUSIONS

We developed the integrated model of control system on the example of PID control of the output stream concentration in mixer. The transfer functions of control object and controller has been derived.

Fuzzy control model synthesis has been done on the example of PID-FUZZY-controller of the output stream concentration in mixer. The terms and membership functions have been defined for input and output variables of the fuzzy inference system. The set of fuzzy inference rules has been formed. The fuzzy inference system type, the methods of activation, aggregation, accumulation and defuzzification have been chosen.

We showed the procedure of the developed fuzzy system integration into SIMULINK interactive system by

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use FIS graphic editor. The block diagram of the integrated fuzzy inference model and basic subsystems are presented. Obtained results allow the experimental research for the intelligence hybrid control system parameters selection.

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