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DEVELOPMENT OF INTELLIGENT CONTROLLERS FOR PYROLYSIS REACTORS CONTROL SYSTEMS BASED ON THEIR MATHEMATICAL MODELS

РОЗРОБКА ІНТЕЛЕКТУАЛЬНИХ РЕГУЛЯТОРІВ ДЛЯ СИСТЕМ КЕРУВАННЯ ПІРОЛІЗНИМИ РЕАКТОРАМИ НА ОСНОВІ ЇХ МАТЕМАТИЧНИХ МОДЕЛЕЙ

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Abstract. This paper presents the development and research of intelligent controllers for pyrolysis reactors control systems on the basis of its mathematical models. The functional structure and mathematical model of the pyrolysis reactor control system are presented. The reactor heating temperature control system is developed with the fuzzy PD-controllers of Mamdani and Sugeno types. The adjustment procedures of the fuzzy controllers, simulation and quality indicators comparative analysis of the control systems with fuzzy and traditional PD-controllers are carried out. Simulation results confirm the efficiency of the developed control systems, based on intelligent controllers. The PLC based realization of most efficient fuzzy controller is then considered.

Keywords: pyrolysis reactor; mathematical model; control system; intelligent controller.

Анотація. Наведено розробку та дослідження інтелектуальних регуляторів для систем керування піролізними реакторами на основі їх математичних моделей. Проведено процедури налаштування нечітких регуляторів типу Мамдані та Сугено, моделювання та порівняльний аналіз показників якості систем керування з нечіткими та традиційним ПД-регуляторами. Розглянуто реалізацію найбільш ефективного нечіткого регулятора на базі ПЛК.

Ключові слова: піролізний реактор; математична модель; система керування; інтелектуальний регулятор.

Аннотация. Приведены разработка и исследование интеллектуальных регуляторов для систем управления пиролизными реакторами на основе их математических моделей. Проведены процедуры настройки нечетких регуляторов типа Мамдани и Сугено, моделирование и сравнительный анализ показателей качества систем управления с нечеткими и традиционным ПД-регуляторами. Рассмотрена реализация наиболее эффективного нечеткого регулятора на базе ПЛК.

Ключевые слова: пиролизный реактор; математическая модель; система управления; интеллектуальный регулятор.

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STATEMENT OF THE PROBLEM

The control of pyrolysis plants and their reactors is one of the most complicated and important tasks of heat power technological processes and pyrolysis technological complexes automation. In particular, the fact that multiloop pyrolysis plant (MPP) reactor's temperature is incessantly changing under the influence of disturbances, such as: reactor heat exchange with multiloop circulating system (MCS) and ambient, and influence of physical and chemical processes that take place inside reactor and MCS, must be considered during the development of MPP reactor heating temperature control system [2]. The temperature control system must compensate that influences of disturbances to provide constant reactor heating temperature value that corresponds to the MPP steady operating mode. As the disturbances values are changing indeterminately, the temperature control system must provide certain power regulation of MPP reactor heating device.

The analysis of algorithms and circuit solutions for the MPP reactor heating temperature control system design and implementation shows the feasibility of use of the intelligent control principles, based on the fuzzy logic, artificial neural networks etc. [4, 12].

ANALYSIS OF LASTEST RESEARCH AND PUBLICATIONS

Systems, developed on the basis of intelligent technologies are successfully implemented in such fields as: technological processes control, transport control, medical diagnostics, technical diagnostics, financial management, stock exchanges prediction, pattern recognition [3, 7]. So the method, named «Neuro & Fuzzy logic» [6], is used in the number of air conditioners models of Mitsubishi Heavy Industries group for the most favorable climate creation. Another example of intelligent control system usage is the computerized control system for the pyrolysis reactor load level [8], in which the different types of neural network controllers are used for the level stabilization. Also known are: the control system of electric drives with slippage, which is based on neural-fuzzy controller [1]; caterpillar control system based on neural network identifier for the calculation of adaptive controller coefficients [10]; fuzzy control system of an autonomous wind power system [5]; variety of trucks parking systems based on fuzzy and neural network controllers [4] et al.

THE ARTICLE AIM is to develop and research the intelligent fuzzy controllers for pyrolysis reactors control systems on the basis of its mathematical models.

BASIC MATERIAL

Functional structure and mathematical models of the main components of the MPP reactor temperature automatic control system. Functional structure of the MPP reactor heating temperature control system is presented in the Fig. 1 [9]. The set value of the reactor heating temperature T_{SR} is determined on the industrial computer IC. The signal from the industrial computer u_{IC} which corresponds to the set value of the reactor heating temperature T_{SR} is supplied to the PLC. The PLC includes: a summator for comparing signals u_{IC} and u_{TS} which are transferred from the IC and the temperature sensor TS (the summator forms the value of the temperature control error $\varepsilon = u_{IC} - u_{TS}$); a temperature controller TC which forms the control signal u_{TC} according to the error ε and transmits it to the AOM.

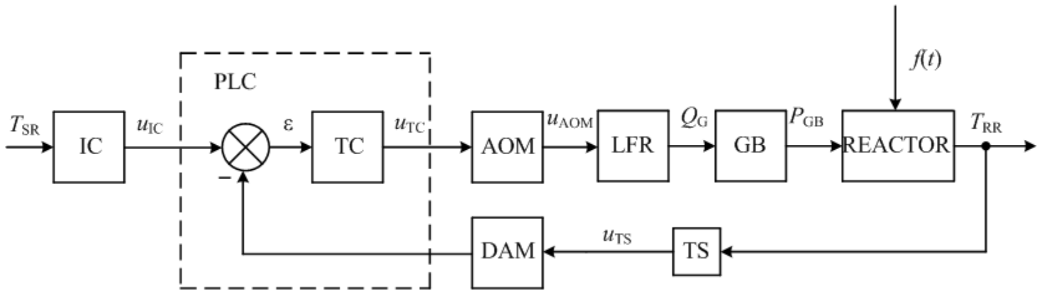

Fig. 1. Functional structure of the MPP reactor heating temperature control system

The analog output module AOM converts the digital signal from the PLC u_{TC} into the analog control signal u_{AOM} that goes to the linear flow regulator LFR.

The linear flow regulator is a gas control valve with a DC servo drive, which has linear characteristics of the gas flow depending on the input voltage. The gas flow rate value Q_G, that corresponds to LFR input DC voltage signal (from 0 to 10 V), goes to the gas burner GB [9]. The gas burner power P_{GB} is used to heat the reactor, with is also influenced by the disturbances $f(t)$.

Data acquisition module DAM convert analog signals u_{TS} from the temperature sensor into the digital signal which is transmitted to the PLC.

If the real value of reactor heating temperature T_{RR} deviates from the set value T_{SR}, the temperature controller produces the control signal u_{TC}, according to the control law, that change the gas flow rate and corresponding gas burner power, that provides the corresponding heating of the reactor.

Certainly, the mathematical model of the MPP reactor temperature automatic control system has a significant influence upon the process of the controller synthesis.

Let us consider the mathematical models of the main components of the MPP reactor temperature automatic control system in detail.

The well tested mathematical model of the MPP reactor, developed and presented in [11], is described by the equations (1)–(15):

$$\begin{aligned} P = P_{GB} - \sum P_l = P_{GB} - \left(P_{fg} + P_{ifl} + P_s\right) = \\ = P_{GB} - \left(B_{fg} c_{fg} T_{fg} + B_{ifl} Q_1^s + P_s\right); \end{aligned} \qquad (1)$$

$$P = \frac{\lambda_e}{\delta} \Delta T F; \qquad (2)$$

$$P_{1x} = P_{1inx} - P_{1outx} = \frac{\lambda_1 F_1}{S_1}\left(T_{11} - T_{12}\right); \qquad (3)$$

$$P_{2r} = P_{2inr} - P_{2outr} = \frac{2\pi\lambda_2 F_2 \left(T_{21} - T_{22}\right)}{\ln\left(R_2 / r_2\right)}; \qquad (4)$$

$$P_{3x} = P_{3inx} - P_{3outx} = \frac{\lambda_3 F_{3x}}{S_3}\left(T_{12} - T_{32}\right); \qquad (5)$$

$$P_{3r} = P_{3inr} = \frac{2\pi\lambda_3 F_{3r} \left(T_{22} - T_{32}\right)}{\ln\left(R_3 / r_3\right)}; \qquad (6)$$

$$P_{4x} = \frac{\lambda_e}{\delta_v}\left(T_{32} - T_{51}\right) F_4; \qquad (7)$$

$$P_{5x} = P_{5inx} - P_{5outx} = \frac{\lambda_5 F_5}{S_5}\left(T_{51} - T_{52}\right); \qquad (8)$$

$$T_{11} = \frac{P_{1x} S_1}{2\lambda_1 F_1}\left[\frac{2a_1 t}{S_1^2} + \frac{2}{3} + \sum_{l=1}^{\infty} \frac{4(-1)^{l+1}}{\varepsilon_l^2} \cos\varepsilon_l \exp\left(-\varepsilon_l^2 \frac{a_1 t}{S_1^2}\right)\right]; \qquad (9)$$

$$T_{12} = \frac{P_{1x} S_1}{2\lambda_1 F_1}\left[\frac{2a_1 t}{S_1^2} - \frac{1}{3}\right]; \qquad (10)$$

$$T_{21} = \frac{P_{2r} R_2}{2\lambda_2 F_2}\left[\frac{4a_2 t}{R_2^2} + \frac{1}{2}\right]; \qquad (11)$$

$$T_{22} = \frac{P_{2r} R_2}{2\lambda_2 F_2}\left[\frac{4a_2 t}{R_2^2} + \left(\frac{r_2}{R_2}\right)^2 - \frac{1}{2}\right]; \qquad (12)$$

$$T_{32} = \frac{P_{3x} S_3}{2\lambda_3 F_{3x}}\left[\frac{2a_3 t}{S_3^2} - \frac{1}{3}\right] + \frac{P_{3r} R_3}{2\lambda_3 F_{3r}}\left[\frac{4a_3 t}{R_3^2} + \frac{1}{2}\right]; \qquad (13)$$

$$T_{51} = \frac{P_{5x} S_5}{2\lambda_5 F_5}\left[\frac{2a_5 t}{S_5^2} + \frac{2}{3} + \sum_{l=1}^{\infty} \frac{4(-1)^{l+1}}{\varepsilon_l^2} \cos\varepsilon_l \exp\left(-\varepsilon_l^2 \frac{a_5 t}{S_5^2}\right)\right]; \qquad (14)$$

$$T_{52} = \frac{P_{5x} S_5}{2\lambda_5 F_5}\left[\frac{2a_5 t}{S_5^2} - \frac{1}{3}\right], \qquad (15)$$

where P – net power that goes directly to the reactor heating; P_{GB} – power, released by the GB; ΣP_l – total losses of the heat power, which usually consists of losses, taken by the waste flue gases P_{fg}, losses because of the chemical incomplete combustion of fuel P_{icf} and heat power losses P_s, which is sent for heating of the reactor heating system, its closure, pipe for flue gases discharge etc; B_{fg}, c_{fg}, T_{fg} – consumption, specific heat capacity and temperature of discharge flue gases relatively; B_{icf} – consumption of the unburnt gaseous fuel; λ_e – equivalent coefficient of heat conductivity flue gases between the reactor wall and closure in the reactor heating system; δ – thickness of the layer between the reactor wall and closure in the reactor heating system, which takes part in the heat exchange; ΔT – temperature difference between flue gases and the reactor wall; F_i – area of the corresponding reactor component surface, being heated [11]; λ_i – coefficient of thermal conductivity of the corresponding reactor component; S_i – thickness of the corresponding reactor component; r_{2i} and r_{1i} – external and internal radii of the corresponding reactor component; a_i – thermal conductivity coefficient of the corresponding reactor component; ε_l – correcting coefficient, $\varepsilon_l = \pi l$ ($l = 1, 2, 3, \ldots$); l – normal number sequence; t – heating time; P_{1x}, P_{2r}, P_{3x}, P_{3r}, P_{4x}, P_{5x} – values of heat flows which are provided for heating of the correspondent reactor parts; P_{in} and P_{out} – values of the delivered and diverted specific heat flows to different reactor components; δ_v – thickness of the void between wastes and reactor upper closure; T_{11}, T_{12}, T_{21}, T_{22}, T_{32}, T_{51}, T_{52} – current values of the temperature of the outer and inner surfaces of the corresponding reactor components; $P_{5\text{out}x}$ – value of the heat flow which is diverted from the upper closure of the reactor to the environment.

$$P_{1\text{in}x} = P_{2\text{in}r} = P;\ P_{3\text{in}x} = P_{1\text{out}x};\ P_{3\text{in}r} = P_{2\text{out}r};$$
$$P_{5\text{in}x} = P_{4x} = P_{3\text{out}x}\ [11].$$

The gas burner has a transfer function described by the equation [9]

$$W_{\text{GB}}(p) = \frac{k_{\text{GB}}}{T_{\text{GB}}p + 1},$$

where k_{GB} – gain of the gas burner, which is stipulated by the lower specific heat of the gas combustion Q_1^{s}, which is used as fuel (in this case $k_{\text{GB}} = Q_1^{\text{s}}$); T_{GB} – time constant of GB, which is stipulated by the speed of the gas ignition.

Linear flow regulator of gas has the following transfer function [9]

$$W_{\text{LFR}}(p) = \frac{k_{\text{LFR}}}{T_{\text{LFR}}^2 p^2 + 2\zeta T_{\text{LFR}} p + 1},$$

where k_{LFR}, T_{LFR}, ζ – transfer coefficient, time constant and damping coefficient of the linear flow regulator, which is stipulated by the parameters of the servodrive and gas valve, which belong to LFR. By its turn, $k_{\text{LFR}} = k_{\text{S}} k_{\text{GV}}$; $k_{\text{S}} = \dfrac{\alpha_{\text{S}}}{u_{\text{SD}}}$; $k_{\text{GV}} = \dfrac{Q_{\text{G}}}{\alpha_{\text{S}}}$, where k_{S} and k_{GV} – transfer coefficients of servodrive and gas valve, respectively; α_{S} – servodrive rotation angle [9].

The temperature sensor is considered to be a noninertial link with the following transfer function [9]

$$W_{\text{TS}}(p) = k_{\text{TS}},$$

where k_{TS} – the temperature sensor gain.

Synthesis of the fuzzy PD-controllers of Mamdani and Sugeno types for the MPP reactor heating temperature control system. The functional structure of the MPP reactor heating temperature control system with fuzzy PD-controller is presented in the Fig. 2 [9].

The control error ε and it's derivative $d\varepsilon/dt$ go to the fuzzy controller input. The control signal u_{TC} is formed on it's output and goes to the linear gas flow regulator input.

Let's consider the synthesis procedure of Mamdani type [7] fuzzy PD-controller in details.

The main stages of the Mamdani type fuzzy logic inference are: fuzzification, aggregation, activation, accumulation and defuzzification [3, 4]. The according linguistic meaning and degree of fuzzy set membership are determined for each input variable on the fuzzification stage [12]. 5 linguistic terms are chosen for the first and for the second input variables ε and $d\varepsilon/dt$, and 7 linguistic terms are chosen for the output variable u_{TC}. The linguistic terms parameters are presented in the Table 1.

Let's form the knowledge base for the fuzzy logic inference implementation. The rules of the knowledge base according to the Mamdani algorithm are the linguistic statements in the form

$$\text{IF «}\varepsilon = x\text{» AND «}\frac{d\varepsilon}{dt} = y\text{» THEN «}u_{\text{TC}} = z\text{»},$$

where x, y, z – corresponding values of the linguistic terms.

In this case the knowledge base consists of 25 rules, which correspond to all combinations of two input fuzzy variables. The knowledge base is presented in the Table 2.

The truth degree is determined for every rule of the fuzzy inference system at the next stage (aggregation), and truth degree finding procedure for each fuzzy output rule subconclusion is implemented on the activation stage.

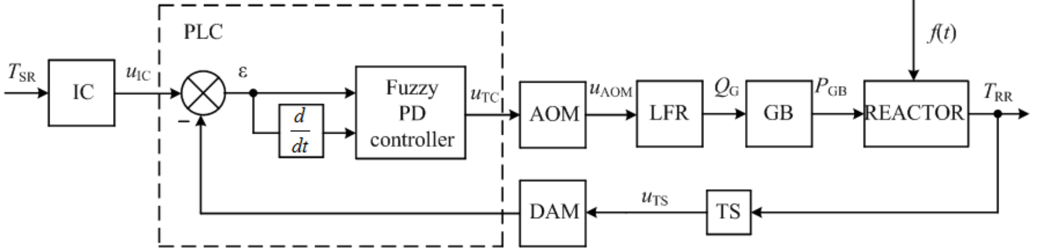

Fig. 2. Functional structure of the MPP reactor heating temperature control system with fuzzy PD-controller

Table 1. **Linguistic terms parameters**

Term	Membership function type	Range of values
For input variable ε		
BN – big negative	Triangular	[–15 –10 –5]
SN – small negative	Triangular	[–10 –5 0]
Z – zero	Triangular	[–5 0 5]
SP – small positive	Triangular	[0 5 10]
BP – big positive	Triangular	[5 10 15]
For input variable *dε/dt*		
BN – big negative	Triangular	[–0,75 –0,5 –0,25]
SN – small negative	Triangular	[–0,5 –0,25 0]
Z – zero	Triangular	[–0,25 0 0,25]
SP – small positive	Triangular	[0 0,25 0,5]
BP – big positive	Triangular	[0,25 0,5 0,75]
For output variable u_{TC}		
VBN – very big negative	Triangular	[–2 0 2]
BN – big negative	Triangular	[0 2 4]
SN – small negative	Triangular	[2 4 6]
Z – zero	Triangular	[4 6 8]
SP – small positive	Triangular	[6 7,5 9]
BP – big positive	Triangular	[8 9 10]
VBP – very big positive	Triangular	[9 10 11]

The further stage of the fuzzy logic inference is accumulation that is the membership function finding procedure for every output linguistic variable [3, 7]. The aim of accumulation is to combine all output linguistic terms with according truth degrees of each rule for the obtaining of output variable membership function. Thus, the resultant membership function for the fuzzy decision is formed at the accumulation stage, which is necessary to be converted to precise output signal value.

Table 2. **Knowledge base**

		Rate of error change, *dε/dt*				
		BN	SN	Z	SP	BP
Error, ε	BN	VBN	VBN	VBN	BN	SN
	SN	VBN	BN	BN	SN	SP
	Z	SN	SN	Z	SP	SP
	SP	SN	SP	BP	BP	VBP
	BP	SP	BP	VBP	VBP	VBP

The procedure of finding of output signal u_{TC} precise numerical value is the defuzzification procedure.

There are several methods of defuzzification: the gravity center method, the square center method, the left modal value method, the right modal value method and the other [3, 4, 12]. In this case the gravity centre method is chosen, according to which the output signal value is calculated by the formula

$$u_{TC} = \frac{\sum_{i=1}^{n} u_i \cdot \mu(u_i)}{\sum_{i=1}^{n} \mu(u_i)},$$

where n – the number of output linguistic variable values; u_i – i-th value of the according output linguistic variable; $\mu(u_i)$ – the number of the resultant membership function for the according value u_i.

Let's consider the synthesis procedure of Sugeno type fuzzy PD-controller in details.

The same linguistic terms for the Sugeno type controller are chosen for the first and for the second input variables ε and $\frac{d\varepsilon}{dt}$ as for the Mamdani type controller (Table 1) at the fuzzification stage.

Let's form the knowledge base for the fuzzy logic inference implementation. The rules of the knowledge base according to the Sugeno algorithm are the linguistic statements in the form

$$\text{IF «}\varepsilon = x\text{» AND «}\frac{d\varepsilon}{dt} = y\text{» THEN «}u_{TC} = k_p\varepsilon + k_D\frac{d\varepsilon}{dt}\text{».}$$

The rule part THEN is, in this case, the linear combination of inputs. Each linear combination is determined by the coefficient vector $mf_i = \left[k_{Pi}, k_{Di}\right]$, where i – the rule number that tares value from 1 to 25; k_P – the proportional term gain; k_D – the derivative term gain. The problem of the all of this gains determination by means of training appears during the PD-controller design process.

All of the found output signal gain values during the training process are summarized in Table 3.

The gravity center method is also chosen for the defuzzification procedure in case of Sugeno type controller.

Table 3. **Output signal gain values**

		№ rules				
		1–5	6–10	11–15	16–20	21–25
Gain values	k_P	0	0	–5,6	15,2	17,2
		0	–1,11	–6,29	15,6	17,54
		0	2,4	14	16,08	18,4
		0	–3,97	14,5	16,76	19,2
		0	–5,23	14,9	43,16	20
	k_D	0	0	–100	368	312
		0	0	–120	358	307,5
		0	–50	250	353,5	300,5
		0	–68	390	340,5	295
		0	–74	380	320	280

Simulation and quality indicators comparative analysis of the control systems with traditional and fuzzy PD-controllers. The traditional PD-controller transfer function has the form

$$W(p) = k_P + k_D p,$$

where k_P and k_D – controller gains, that can be adjusted; p – Laplace operator. The gain values are found with the help of parametric optimization, k_P = 13,6; k_D = 400.

The quality indicators comparative analysis of the control systems with traditional and fuzzy PD-controllers for the different input setting impacts values (T_{SR} = 550, 600, 650 °C) is presented in the Table 4, where σ – overshoot, $\sigma = \frac{T_{MAX} - T_{SR}}{T_{SR}} \cdot 100\ \%$; t_r – regulating time; Δ – static error, $\Delta = \frac{T_{SR} - T_{RR}}{T_{SR}} \cdot 100\%$; μ – oscillation (a number of steady value T_{RR} crossing for the time t_r).

Table 4. **Quality indicators comparative analysis of the control systems with traditional and fuzzy PD-controllers**

Quality indicators	Control system quality indicators values								
	PD-controller			Mamdani controller			Sugeno controller		
	Input impact value T_{SR}, °C								
	550	600	650	550	600	650	550	600	650
σ, %	0	0	0	0	0	0	0	0	0
t_r, s	155	160	165	185	188	192	112	115	117
Δ, %	0,15	0,16	0,165	0,17	0,25	0,3	0,09	0,1	0,11
μ	0	0	0	0	0	0	0	0	0

The control system transient process at zero initial conditions, for T_{SR} = 600 °C, without disturbance is given in the Fig. 3.

The control system with Sugeno type controller for the given input impact has the best quality indicators, specifically regulating time t_r is 115 s, overshoot σ equals 0 %, oscillation μ equals 0 and static error Δ equal 0,09.

The control system with traditional PD-controller also has overshoot 0, but regulating time is 160 s and static error equals 0,16 %.

The control system with Mamdani type controller has the worst indicators in comparison with the previous systems, the output signal of this system has regulating time 188 s, overshoot and oscillation are 0 and static error equals 0,25 %.

The control system transient process with traditional and fuzzy PD-controllers of Sugeno and Mamdani types in the presence of the disturbances *f*(*t*), which have step character, at zero initial conditions, at T_{SR} = 600 °C, are given in the Fig. 4.

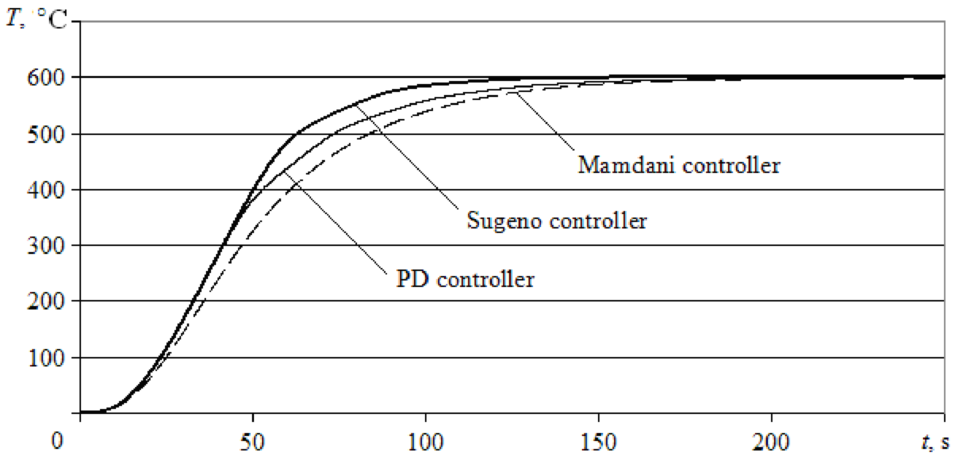

Fig. 3. Control system transient process at T_{SR} = 600 °C

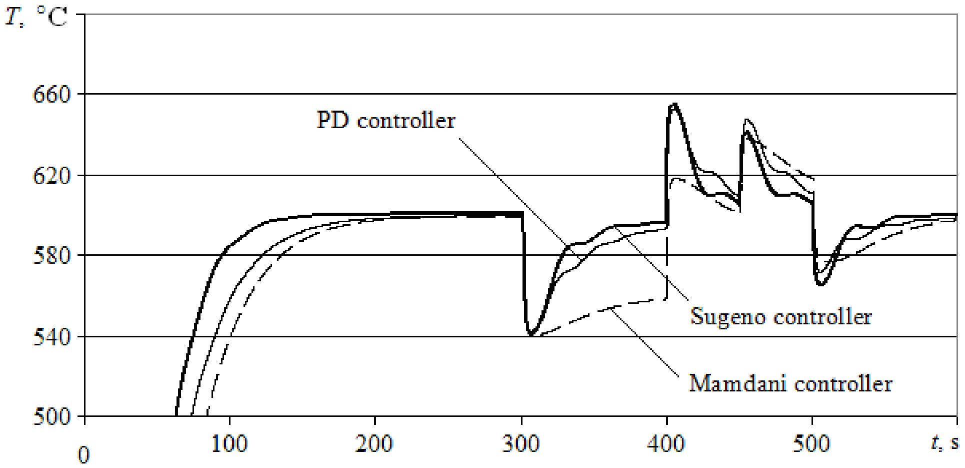

Fig. 4. Control system transient process at T_{SR} = 600 °C with disturbances

The deviations from input signal value at maximum disturbance (Fig. 5) of amplitude –60 °C are about 1,33 % and 0,7 % for the control systems with traditional controller and Sugeno type controller respectively, while 6,7 % – for the control systems with Mamdani type controller, that is much more.

After carrying out the control system simulation in short-term step disturbances (Fig. 5), we can conclude, that the output signal deviations from setting values of the control systems with traditional controller and Sugeno type fuzzy controller are minor, specifically 0,7…1,5 % (that is not more than 10 °C), that has little influence on the MPP reactor processes in terms of temperature regulation.

Concerning the control system with Mamdani type controller, the output signal deviation at short-term step disturbances is rather significant and reaches almost 7 % at maximum disturbance value –60 °C, that is about 40 °C setting temperature dropping, that impact on the technological process.

PLC-based Hardware Realization of Fuzzy PD-Controller. For hardware implementation of the reactor heating temperature control system (Fig. 1) authors used the following configuration: ICP DAS WP-8131 programmable logic controller (PLC), which acts as the main control unit of developed system, ICP DAS I-7018P module that is used for the data acquisition, ICP DAS I-7024 module for the linear flow regulator control and thermo-couple as the feedback sensor. Modules are connected through the RS485 network via built-in controllers and DCON protocol.

The ICP DAS company supplies the libraries package in the set with the controller WP-8131 and it also supplies the documentation which is required for software development with the help of Visual Studio 2005/2008 (later versions of the software package don't support the development which runs on Windows CE).

The PacNet.dll library includes the functions which are required for the peripheral modules control, control of interrupts and controller's timers, data transfer via the Ethernet network, RS232 and RS485 interfaces, etc.

For realization of fuzzy PD-controller authors used the open sourced Fuzzy Logic Library for Microsoft .Net (fuzzynet).

The algorithm of reactor heating temperature control using the described PLC-based system is given in the Fig. 6.

It can be divided into 7 main steps:

Step 1 includes the PacNet.dll based PLC initialization commands, such as tuning of COM port for data exchange with remote modules ICP DAS I-7024 and I-7018P, creation log files, etc.

Step 2 performs the initialization and tuning of Sugeno type of fuzzy PD-controller (Table 3) using the functions of fuzzynet library.

Step 3 initiates the connection between the PLC and remote modules through the pre-set on stage 1 COM-port via the RS485 network. Data exchange is performed using the DCON protocol at 115200 kbps.

Step 4 reads the thermal behavior data of MPP reactor from the I-7018P module.

Step 5 uses the designed Sugeno fuzzy controller to calculate the control system reaction u_{TC} (Fig. 1).

Step 6 transfers the command to I-7024 module for generation of desired analog control signal u_{AOM} that goes to the linear flow regulator.

Step 7 is performed only if the PLC did not received the answer to its request from the remote module. On this step PLC generate alarm report and goes to the Step 3 to perform another attempt of connection.

Described step repeats continuously until the control program in PLC will be terminated.

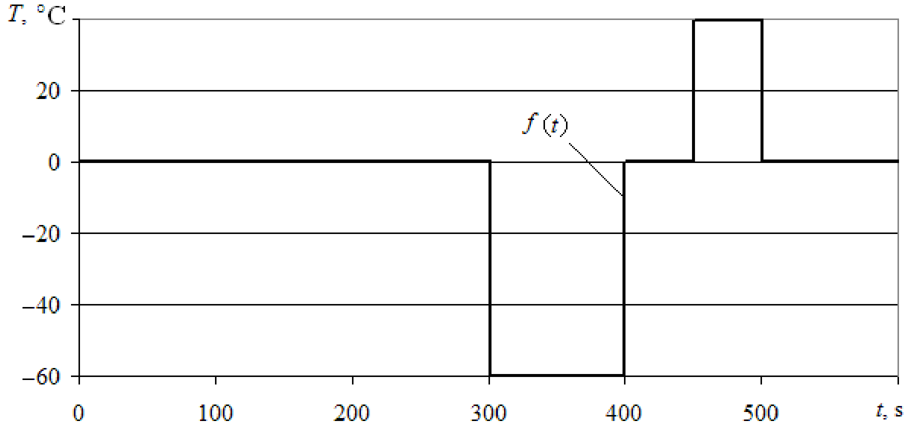

Fig. 5. Character of the disturbances that affect on the MPP reactor

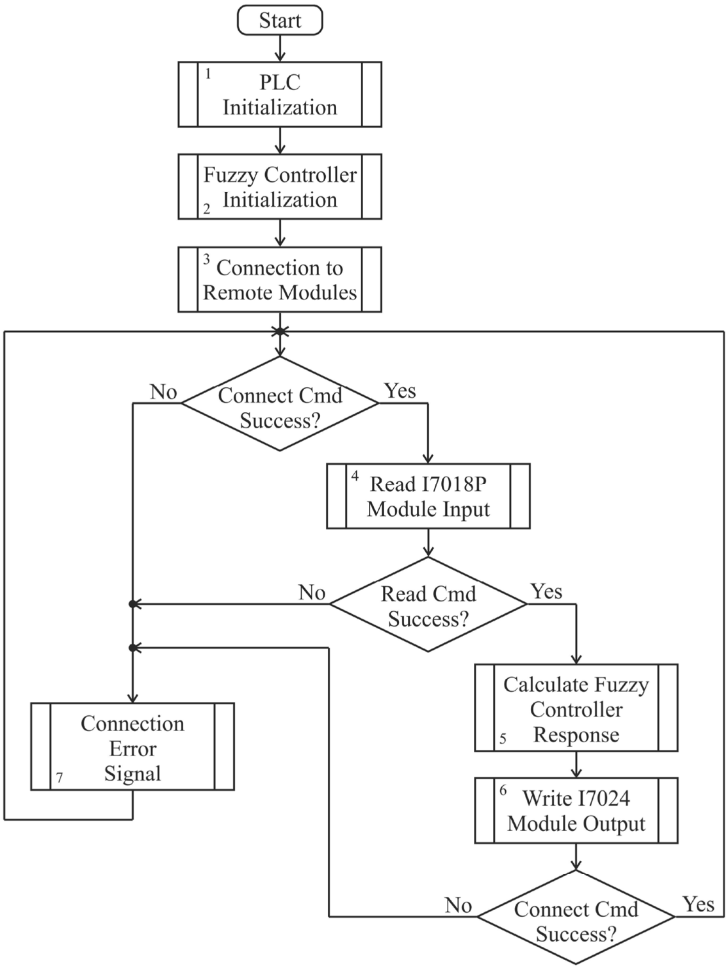

Fig. 6. Block diagram of PLC-based realization of Fuzzy PD-Controller

CONCLUSIONS

The development and research of intelligent controllers for the MPP reactor heating temperature control system based on its mathematical model is presented in this paper.

The presented mathematical models of the main components of the MPP reactor heating temperature control system allows to study it behavior in the steady and transient modes under the condition of different disturbances and to carry out the synthesis procedure of the different types of it controllers.

As a result of the work, we can conclude, that it is advisable to apply the Sugeno type fuzzy controller in the given control system, because the control system with a such kind of controller has better quality indicators in comparison with the control system with the traditional PD-controller. The Mamdani type controller application did not give better results, because the given controller parameters were not optimized previously, as the parameters of the traditional and fuzzy Sugeno PD-controllers. This fact confirms the necessity of the optimization procedure holding for the dynamic properties increasing of any control system.

This paper also presents the PLC-based Hardware Realization of Fuzzy PD-Controller for the MPP reactor heating temperature control system. Designed system uses the ICP DAS WP-8131 programmable logic controller, which acts as the main control unit of developed system, ICP DAS I-7018P module that is used for the data acquisition, ICP DAS I-7024 module for the linear flow regulator control and thermo-couple as the feedback sensor.

Proposed functional structure grants flexibility and diversity to the designed system. All remote modules connects through the RS485 network and thus can be add or replaced at any time with minimal cost and time. Usage of industrial ready components increases the overall dependability of control system.

Realisation of control algorithms for chosen PLC can be performed using different approaches – industrial SCADA software or VB/C# programming using the . Net 2.0 platform and PacNet.dll that are supplied with controller.

The realization of fuzzy control algorithms by the authors was performed using the open-source. Net library (fuzzynet), which was combined with the input/output functions of supplied PacNet.dll.

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