BIOGAS PRODUCTION IN BIOTECHNOLOGICAL FACILITIES

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Abstract. *The article discusses the method of physical and technical functional analogy for the mathematical description of the functioning of biological organs and systems, and provides mathematical models of biotechnological objects. These models were used to obtain new information in the scientific and industrial spheres, to study a biological object without exerting strong (and even more destructive) energy effects on it using neuro-fuzzy systems and intelligent technologies for automation, including for controlling objects in applied biotechnology for biogas production.*

Keywords: *biogas; mathematical model; biological object; computational experiment; neuro-fuzzy system.*

In the world, direct consumption of biogas in 2018 amounted to 35 million tons, when it was produced almost in oil equivalent, more than 60% of the production capacity of this biogas corresponds to the share of Europe and North America. As the leading biogas production region, there are around 20,000 biogas plants in Europe, many of which are being implemented in Germany. Their installed capacity exceeds 7 thousand MW. At present, there are a number of problems in their production and use, along with the widespread use of renewable energy sources produced in the world, and in particular, the low combustion rate of biogas produced in the process of biogas production from biomass, the long-term production of biogas, the low methane content in the extracted biogas, the complete absence of methane from biomass, improper biomass selection,

In Uzbekistan, bioenergy is one of the alternative types of energy in the world, innovations are becoming an unconditional factor of development, in particular, it leads to the formation of a new technological base for the production of electricity and heat, creates new jobs, and improves the quality of life of people.

In accordance with the development strategy of the Republic of Uzbekistan, it is envisaged that by 2025 the production of electricity using renewable and alternative sources will increase by more than 20% in the long term, according to the task plan, it is planned to bring the production of electricity from renewable sources to 120 billion kWh by 2030, as well as to develop and increase alternative and renewable energy sources·

Energy by direct absorption of biological waste can be obtained biogas, biogas is a product that is formed as a result of fermentation-fermentation of bioproducts in an airless environment.

Biogas is a mixture of gases. Its main components are: methane (SN_4) - 55-70%, carbon dioxide ($_{SO2}$) - 28-43% and in small quantities, for example, 500 ppm - hydrogen sulfide (N2S) and other gases. On average, 70% of biological decomposition is 0.18 kg of methane, 0.32 kg of carbon dioxide, which is divided into 0.2 kg of water and 0.3 kg of insoluble residue.

The process of biogas production. Let's consider some thermophysical properties of the material under study. We use animal waste as biomass. By fermenting waste in special devices, we obtain biogas. The emitted gas contains mainly CO, CO_2, H_2O, H_2, CH_4 and other hydrocarbons. Gasification can be carried out by oxidizing agents such as air, oxygen, steam, CO_2.

Methane is produced by the decomposition of biomass on livestock and poultry farms during storage or processing in systems that promote anaerobic conditions.

$$2(CH_2O) \rightarrow CH_2 + CO_2$$

The end product of methane fermentation is biogas, which consists of an average of 65–70% methane and 25–30% carbon dioxide with small impurities of hydrogen sulfide, hydrogen, and nitrogen. The calorific value of biogas is in the range of 20.0 – 34 MJ/m^3 depending on the CO_2 content

Temperature is a good indicator of the composting process. The temperature in the compost heap begins to rise a few hours after the substrate is laid and varies depending on the stages of composting. At the beginning of the process, the waste is at ambient temperature. In the initial, mesophilic stage, the microorganisms present in the waste begin to multiply rapidly, the temperature rises to 42°C.

When the temperature rises above 40 °C, the original mesophylls die, and they are replaced by thermophiles. This raises the temperature to 60 °C, at which point the fungi lose their activity. After 62 °C, the process is continued by spore-forming bacteria and actinomycetes. During the thermophilic phase, the rate of heat release becomes equal to the rate of heat loss, which corresponds to the achievement of the temperature maximum.

Humidity in batch units is one of the main factors that complicates the technological process: the moisture content continuously changes depending on the degree of fuel burnup. Moisture is released during the volatile release phase, and the moisture content decreases depending on the degree of fuel burnup. Therefore, the negative impact of humidity levels on the combustion process can be significant in the early stages of the volatile release phase, which can lead to an increase in emissions from incomplete combustion of fuel.

This, in turn, will lead to a low-quality gas composition, which means incomplete combustion of the fuel. To solve these problems, let's analyze the process of biogas production: the waste enters the receiving tank for grinding large inclusions. In it, their preliminary accumulation, homogenization, mixing, precipitation and removal of heavy fractions take place. The main unit of the biogas plant is the digester, in which anaerobic digestion of biomass takes place, its disinfection and the formation of biogas. In practice, the duration of the fermentation process is chosen to be equal to the decomposition time of up to 40–50% of organic matter (from 8 to 20 days).

Biogas production can be carried out in a wide temperature range. Depending on the temperature regime maintained by the bioreactor during operation, there are three modes of digestion: psychrophilic (10 – 20 ºC), mesophilic (30 – 45 ºC), thermophilic (50 – 65 ºC). Of the above options, the thermophilic mode is used for our studies [1].

At low humidity (<86%), it is difficult to move the substrate along the utilities, and at high humidity (> 96%), gas emission is sharply reduced due to the insufficient content of organic matter in the raw material. Most experts consider the optimal concentration of dry matter in manure to be 8–10% [2]. According to our research, the optimal moisture content of manure during digestion in the thermophilic mode (50–65 ºC) and a loading dose of 14% is in the range of 92–94 % [3].

The required thermal power is determined by the heat loss of the bioreactor and is described by the equations of thermodynamics. In particular, in order to determine the amount of heat passing through the volume of a bioreactor, as follows from Fourier's law, it is necessary to know the internal temperature field of the bioreactor, and finding the temperature field is the main task of the theory of thermal conduction in relation to the processes occurring in the bioreactor of the facility [4].

Heat transfer is described by the equation relating the heat transferred per unit time from one phase to another (in this case, between the internal volume of the bioreactor and the environment, or between this volume and the heat exchange system) with the surface area of the heat exchange and the interfacial temperature difference

$$T = f(X, Y, Z, \tau.....)$$

The synthesis of active pharmaceutical ingredients is a complex multi-stage batch process and is one of the most complex stages in the production of biogas. Therefore, the most effective algorithm for the operation of such facilities, along with the implementation of the most delicate, as a rule, terminal chemical stages, is the implementation of automated production at all stages of biogas synthesis [5], which will allow achieving an optimal ratio between the cost and quality of the finished product, solving the extremely important task of saving energy resources by optimizing all stages of the process.

As noted above, the production of biogas is a complex process. The difficulty lies in the fact that in the fermentation process, various factors affect the yield of biogas, as a result, the concentration of methane decreases, which loses energy and reduces the calorific value of the resulting gas.

In order to solve this problem, anaerobic processing of animal waste makes it possible to reduce the cost of electricity for the process, but also to take out an excessive amount of it. The resulting energy, for example, biogas is comfortable for the user. Such energy can be changed into thermal, electrical and mechanical. In the process of processing, the sludge is devoid of unpleasant odor and is convenient to apply to the soil. The process of anaerobic treatment of manure includes four interrelated stages carried out by different groups of bacteria, including the stage of enzymatic hydrolysis, the stage of acid formation (acidogenic), the acetatogenic stage, and the methanogenic stage [6].

For these purposes, we will consider the process of forming a mathematical model for a part of the bioreactor, which will facilitate the study of thermal processes occurring in the bioreactor.

Mathematical modeling is an important stage of scientific research, as it allows you to imagine the physics of the process taking place in a particular object. The most accurate and complete model helps to simplify the process of analyzing the dynamic characteristics of a physical phenomenon or a process occurring in the object of study, provided that it is verified for adequacy to the real process.

A mathematical model is a system of ordinary differential equations, of the thirtieth order and higher, by the Runge-Kut method, solved on a computer at each step of the process discretization (on the order of 0.01...0.001s), fitting the results to the previous value, and solving the next step, and etc.

Therefore, a new paradigm (example, sample) of knowledge in the field of physiology is needed to solve the problem of measurement efficiency. It should be based on theoretical models abstracted to the level of the basic functions of each system. For example, biotechnology requires a model that explains the energy processes of fermentation. Such models should acquire the status of axioms, without which it is impossible to construct theoretical concepts, i.e. the solution to this problem has not yet been determined. However, "Any model must begin with the development of a theorem. The main task in the creation of the theorem is to identify the characteristic features of the phenomenon under study in the results of the experiment. This process is the abstraction of the general to the level of the properties characteristic of its constituent parts. The selected properties should clearly fit into the context of the description of the general properties of the phenomenon. By differentiating in this way, the result is a theoretical construction, or more precisely, a model that reflects the main properties of the phenomenon under study. However, such a theoretical model requires a large number of practical experiments" [7].

Consider the fermentation process in a bioreactor to produce biogas, which is used today in all sectors of the economy. The main task of fermentation in a bioreactor depends on temperature and humidity. Solutions to this problem need to start with a model of self-regulating temperature in a continuous bioreactor. The analysis of the mathematical model used in this article is presented for the first time, but similar models have been described in different works [8]. Previously, it was used for the analysis of periodic regimes, but it can be used to study the continuous modes of operation of a bioreactor. The model looks like this:

$$\frac{dT}{dt} = \mu_r \frac{XH}{c\rho} - \frac{kp(T - T_{ext})}{cpV} + Q_r \qquad (1)$$

$$\frac{dX}{dt} = \mu_r X + Q_{X.} \qquad (2)$$

$$\frac{dS}{dt} = -\frac{\mu_r}{Y} X + Q_s. \qquad (3)$$

$$\frac{d\mu_m'}{dt} = \begin{Bmatrix} [\mu_m(T) - \mu_m']/\ \theta_1, d\mu_m'/dt \geq 0 \\ [\mu_r(T) - \mu_m']/\ \theta_2, d\mu_m'/dt < 0 \end{Bmatrix} \qquad (4)$$

$$\frac{dC}{dt} = K_L a) C^* - C) - qo_2 + Q_c. \qquad (5)$$

With initial conditions:

$T(O) = T_0$, X S (6)$(O) = X_0, (O) = S_0,$

$$\mu_m'(0) = \mu_{m0}', C(0) = C_0. \qquad (7)$$

$$\mu_r = \frac{\mu_m' SC}{(S + K_S)(C + K_C)}. \qquad (8)$$

$$qo_2 = X(\mu_r \beta + a). \qquad (9)$$

$$\mu_m(T) = 1{,}4765 - 0{,}02353)T - 273{,}15). \qquad (10)$$

$$C^*(T) = 14{,}438 - 0{,}34755 \cdot T + 4{,}6557 \cdot 10^{-3} \cdot T^2 - 2{,}62965 \cdot 10^{-5} \cdot T^3. \quad (11)$$

$$Q_T = \frac{F(T_{in} - T)}{V} = D(T_{in} - T). \quad (12)$$

$$Q_X = \frac{F(X_{in} - X)}{V} = D(X_{in} - X). \quad (13)$$

$$Q_S = \frac{F(S_{in} - S)}{V} = D(S_{in} - S. \quad (14)$$

$$Q_C = \frac{F(C_{in} - C)}{V} = D(C_{in} - C). \quad (15)$$

Published by Jehovah's Witnesses but also published by Jehovah's Witnesses. and Kristapson M.G. 1993, A.A. 1996) on the most commonly held research (Rylkin S.S. and others 1973).

In the most prosperous language: T_0 = 32ºC, X_0 = 15 g/l, S_0 = 50 g/l, μ_0' = 0 $^{ch-1}$, C_0 = 7.22 mg/l and conscienties of the cylinders and the cylinders of the cylinders in the cylinders: X_{in}= 0 cylinders, C_{in}= 0 mg/l. The mathematical model is implemented as a program in the Borland Delphi language. The Runge–Kutta method of the fourth order with a constant step was used to solve the system of differential equations. The step was chosen for reasons of the necessary error in solving differential equations. Thus, it can be concluded that with fairly significant temperature changes in the input flow – from 0 to 50 ºC, the biological object has the ability to spontaneously equalize various factors.

In [9] there are descriptions of specially created experimental systems for fermentation with automatic control of the substrate feed rate based on complex mathematical models. Despite this, commercially available bioreactor controllers provide little more than the ability for the operator to set simple time-based make-up profiles, or the ability to automatically control the substrate feed rate as a function of pO2.

It is known [10] that a nonlinear regulator based on sigmoid functions is robust to perturbations in the specific growth rate of the microbial population μ_m. However, it is impossible to take into account all the processes taking place in the BTS and compensate for the influence of all perturbing influences on the process. In this regard, we will construct a neuro-fuzzy system in automatic control of substrate supply and product selection during continuous fermentation based on fuzzy logic and neural network technology [11].

The analysis of [12-15] studies shows that the use of intelligent methods for the synthesis of control systems for industrial fermentation processes is insignificant. With the advent of similar developments for technological processes, the expansion of the field of application of intelligent technologies for automation, including for object control in applied biotechnology, can be considered promising [16]. Therefore, a promising way of industrial automation of fermentation processes in biotechnological production is the creation of algorithmic support for automated control systems (ACS) based on intelligent methods.

In order to develop perfect automatic control systems without significantly complicating the laws of regulation and the structures (schemes) of these systems, it is necessary to use the technology of robust control, fuzzy and neural network regulators. This direction of research and development of systems in the development of these industries is economically justified [17].

Figure 1 shows a functional diagram of a continuous fermentation process for the production of biogas from various organic wastes.

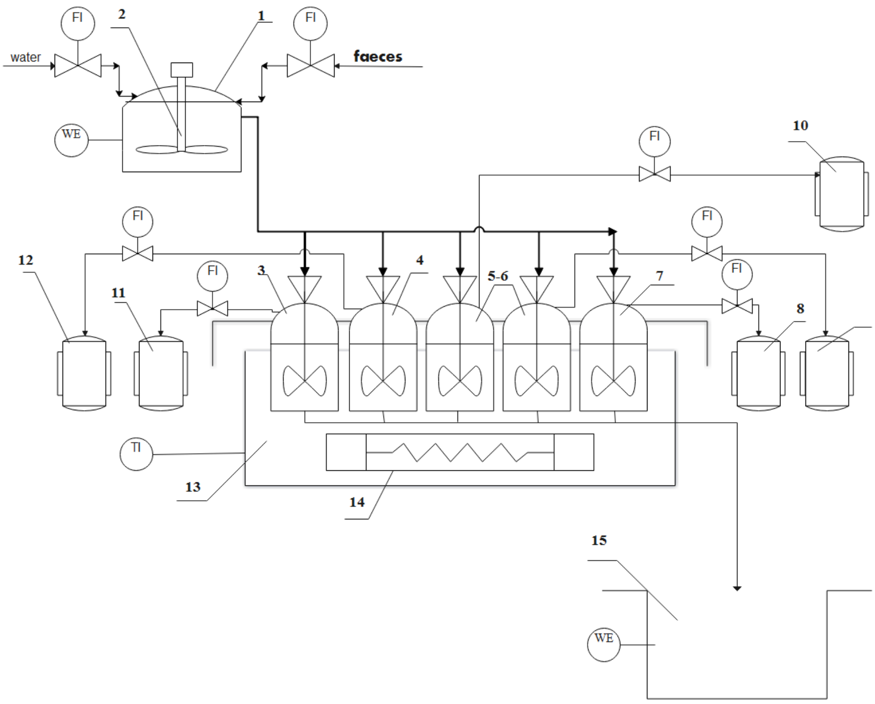

Fig.1. Functional diagram of a continuous fermentation process

At the same time, the combination of the methods of the theory of fuzzy systems and the theory of neural networks makes it possible to implement neuro-fuzzy control of complex biotechnological processes [18]. However, the joint use of the basic provisions of the theory of intelligent control in the development of neuro-fuzzy control devices raises many problems [19] and, first of all, requires consideration of the influence of physical and biological processes on the characteristics of fuzzy controllers [20].

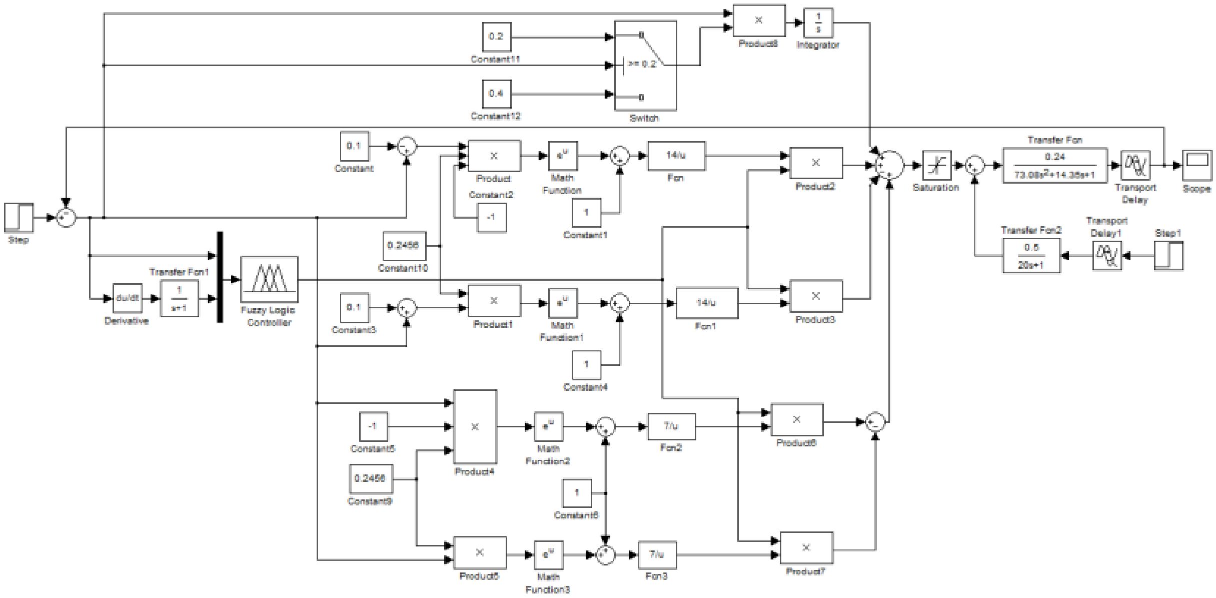

Fig.2 – The state of the WORLD in the former Matlab Simulink

To verify the validity of the rules using the Fuzzy Logic Toolbox package, which is part of the Matlab system, with two input and one output signals, a three-dimensional surface was constructed, which is a graphical representation of the relationship between the error e and the rate of change of the error de/dt on one side (the input side) and the correction value of the coefficient M of the ANF controller of the system controls on the other side (exit side).

The neuro-fuzzy structure of the hybrid model of the object under study is shown in Figure 3 (see Figure 3). It reflects multiple sets of input data for a single output and reflects a system of linear ost models in the form of separate nonlinear rules. The first input level of the model is nonparametric, reflecting the distribution of input signals, and is characterized by a y-vector:

$$y = f_y(x_1, x_2, x_3). \quad (16)$$

Expression (1) at the top contains the number of control values of object π and the number of outputs n_y entered into the vector $p = 1..., P$ values (i.e. the input number) are defined in the basic structure of the modeling object. A large number of vector elements leads to more accurate modeling, but as the number of fuzzy rules and the calculation of training parameters increases, the order of correspondence becomes more complex.

The second level of the layer model is parametric, which acts as a chaplain using Gaussian functions described by the following relations:

$$\mu_{X_p,m}^{(n)} = exp\frac{-(x_p - c_{Xp,m})^2}{2\sigma_{Xp,m}^2}. \quad (17)$$

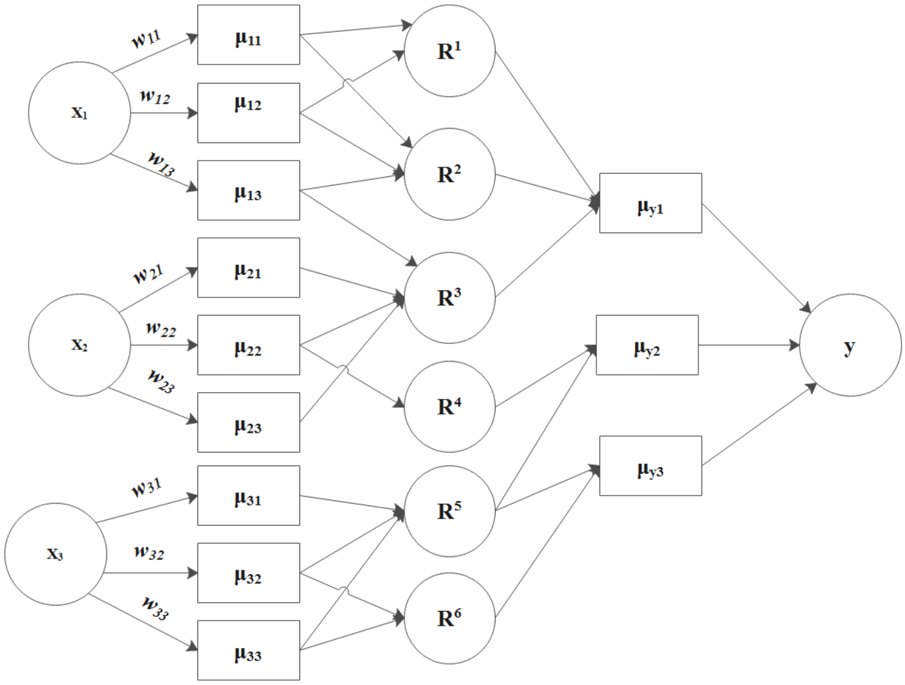

Fig. 3. In the thys of the thyrrow, in the thys of the thyred of the thyyrrhea,

The hotel is located in μ the heart of the historic μ of the city, close to the historic centre of the city, close to the historic centre of the city. a - the place and the cylinder in the cylinder.$c_{Xp,m}$ *and* $\sigma_{Xp,m}$

In the process of biogas production, it was expressed by various factors. They are necessary to build a forecast of the criminogenic situation based on factors X_1-X_{15}. In the course of the experiment, it was observed that when the number of input variables increased by more than 3, the time for conducting the experiment significantly increased. Therefore, it was decided to select variables from the entire set using the seqsrch function, the algorithm of which consists of the following.

On the prophet's conscienties *y(k)* in the form of biogas in the 1st 5 procene prosths: x $_1$ -; x_2 -; x_3 -; x_4 -; x_5 -; x_6 -; x_7- ... x_{15}.

For the 10th year-in-a-year-in-law MatLAB (sequential forward search) is a multi-indudumation of the matlab (sequential forward search). In this search, a single input variable is added to the model at each step, ensuring that the standard deviation error is minimized.

The 3rd century on the 15th of December: x 4; x_{14}; x_{15}, the faculties of the Anfis are in the threshing sphere of the Anfis and in the threshing of the threshing scisses (Fig. 4).

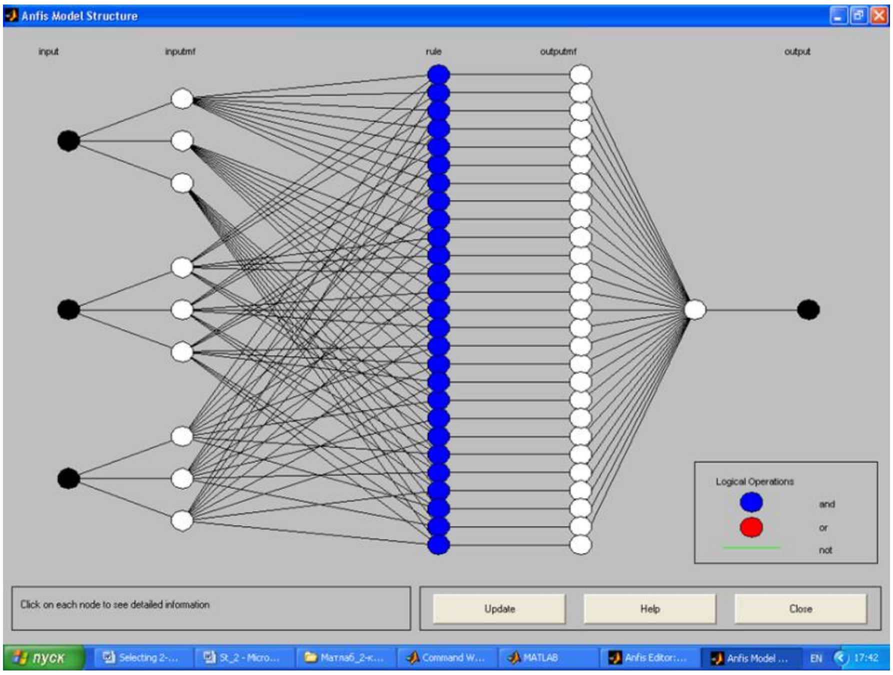

Fig.4. Anfis is a member of the Governing Body of Jehovah's Witnesses.

The time it took to create and train the fuzzy system graph was 11 seconds. A graph of fuzzy system data mapping is shown in Figure 5.

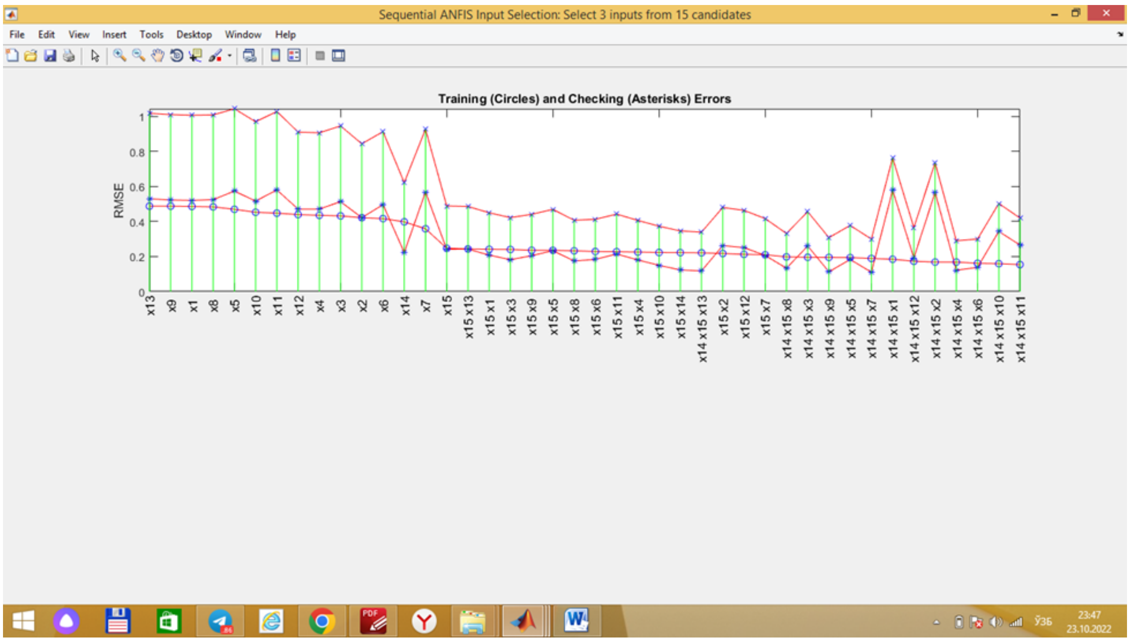

Fig. 5. Selection of input variables of the model by the neuro-fuzzy method of searching for a direct sequence.

As can be seen from the graph, the neuro-neurological system can accurately describe the learning pattern of information entered into a Sugeno-type system. Subsequently, depending on the factors, a forecast of criminogenic situations was made (a criminogenic situation is the occurrence of a sharp change in the entered information).

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