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The Neuro-Fuzzy Controller of Reactor Installation Management of Butanol Hydrogenation

Alexander I. Koldaev,
North Caucasus Federal University,
NCFU,
Stavropol, Russia Federation,

***Abstract*—The possibility of applying the fuzzy logic apparatus for non-fully described systems with unknown dynamics is considered in the article on the example of the problem of defining the condition of management object under the date of different nature. The model of microcontroller for managing a reactor installation of butanol hydrogenation is suggested.The suggested neuro-fuzzy model of the reactor installation management system is proved to be adequate to real data. The designed controller model can be applied for solving the problem of managing any technological process with non-linear dependence/**

***Keywords*—** *fuzzy logic, multicoherent systems, a neural network*

I. Introduction

Management of many real objects is difficult because of the nonlinear characteristics, uncontrolled interference and noise, the set of feedbacks, etc. In practice, control algorithms should be simple enough to implement. They must have the ability to learn, stability, nonlinearity. Thus, traditional methods of management for them are inapplicable. In case of bad formalizability the systems constructed on base of intellectual principles (fuzzy logic, expert systems, artificial neural networks) give good results [1-3].

In paper the problem of the controller construction of management reactor installation of butanol hydrogenation by means of fuzzy logic methods is considered.

Fig.1 presents the block-scheme of investigated reactor installation of butanol hydrogenation. Butanol by means of the pump through a heater moves in the top part of a reactor. Hydrogen also moves in a reactor through a heater where under action of the catalyst there is a process of butanol hydrogenation. From the bottom part of a reactor the butanol enters in a separator where it separates from the hydrogen which has not reacted.

The norms of rules of technological process of butanol hydrogenation are the basis for management of the reactor installation (tab. 1).

Table 1. Norms of technological process Table Styles

Controllable parameters	Norms and technical parameters
1. Temperature in a reactor	120-150 °C
2. Pressure of hydrogen in a reactor	Not less than 1.9 MPa

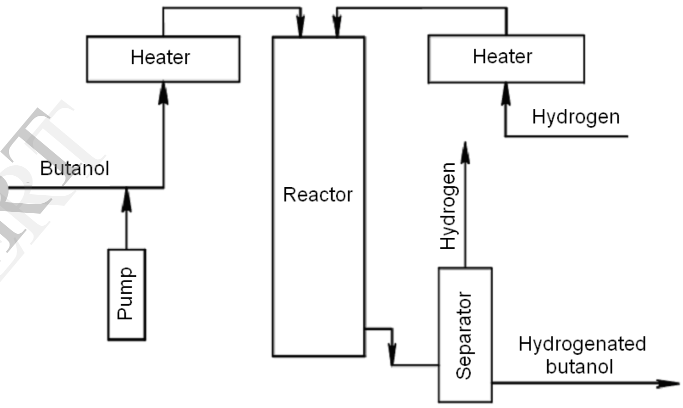

Fig. 1. The Block diagram of installation of butanol hydrogenation

The deviation of any parameter from norm leads to the failure of technological process. Excess of temperature in a reactor more 150 °C leads to destruction of the catalyst. Pressure decrease in a reactor below 1.9 MPa is caused by malfunctions in system of submission of hydrogen. Thus, the problem is the definition of object condition at entrance influences of the different nature (temperature, pressure), that is to define the parameter on which deviations are available. According to condition object the operating influences directed on elimination of the arisen deviation will be formed.

As the parameters of a object are defined by wide range of values, and any value from this range will depend on operating conditions, so in this case it is expedient to apply fuzzy logic method which allow to unite separate entrance values in subsets.

II. Fuzzy-Logic Algorithm

As a whole, it is possible to divide processing of fuzzy logic algorithm into five stages [3, 4]: 1) fuzzification of input variables; 2) application of the fuzzy operator (And or OR) in the precondition; 3) implication of the precondition and consequence; 4) aggregation of consequences through rules; 5) defuzzification. Simultaneous calculation of rules is one of most prominent aspects of fuzzy logic systems.

The first stage is fuzzification of inputs. On this stage the initial information is transformed to a kind convenient for the further application in fuzzy logic. The degree of appurtenance of input parameter to fuzzy set by means of member functions is defined. The input is the numerical value limited by space of preconditions, and the output is a degree of appurtenance to fuzzy set (always an interval between 0 and 1) [5].

At the second stage application of the fuzzy operators is carried out. On an output of the operator there is the unique value which is the result of performance of fuzzy operation.

At the third stage the application of the implication operator is carried out. The output of each rule is fuzzy set.

At the fourth stage the aggregation of all outputs is carried out. Aggregation is process by means of which the fuzzy sets representing outputs of each rule are united in unique fuzzy set.

The fifth stage. Defuzzification. The purpose of defuzzification consists in transformation of the aggregated fuzzy set to precise number.

There are some algorithms of defuzzification. One of them is Sugeno algorithm.

In Sugeno algorithm the set of linguistic rules in the following form is used

$$\textbf{If}\ (x_1 = d_1^1)\ \textbf{and}\ (x_2 = d_2^1), (y_c = c_1);$$

$$\textbf{If}\ (x_1 = d_1^2)\ \textbf{and}\ (x_2 = d_2^2), (y_c = c_2);\ \text{etc.},$$

Where d_j^i – linguistic estimations of input variables; c_i – precise values of individual conclusions.

Precise values of individual conclusions are:

c_1 = 0 – an operating conditions without deviations;

c_2 = 1 – a deviation from norm on a input 1 (temperature in a reactor);

c_3 = 2 – a deviation from norm on a input 2 (pressure of hydrogen in a reactor) ;

c_4 = 3 – a deviation from norm on input 1 and input 2 simultaneously;

Precise value of a output variable in Sugeno algorithm is defined under the formula

$$y = \sum_{i=1}^{n} a_i c_i \Big/ \sum_{i=1}^{n} a_i \,, \qquad (1)$$

Where a_i – degrees of the validity for preconditions or conditions of each rules;

c_i – precise values of individual conclusions.

For increase of accuracy of output result it is necessary fine tuning of membership functions is required. This fine tuning is enough labour-intensive process. Therefore for simplification of process of fine tuning of membership functions the linguistic information on object can be presented in the form of special neuro-fuzzy networks.

III. STRUCTURE OF NEURO-FUZZY NETWORK

Generated by means of appendix ANFISedit [6] neuro-fuzzy the network consists of five layers (fig. 2)

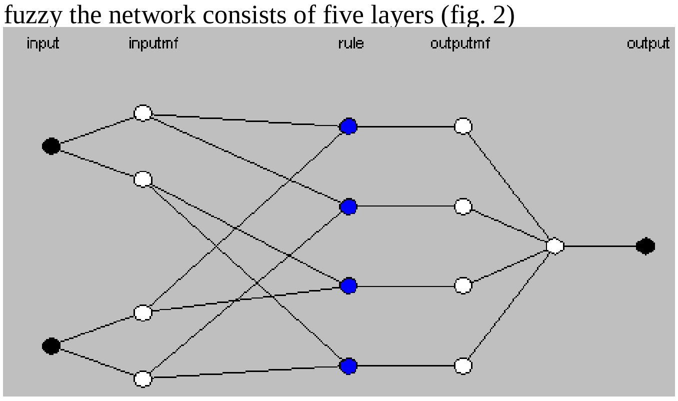

Fig. 2. Structure of neuro-fuzzy network

Layers neuro-fuzzy networks ANFIS carry out following functions.

Layer 1 *(input)* – inputs of object of identification. For investigated object two input parameters (temperature, pressure) are considered.

The layer 2 (inputmf) is presented by basic neurons. This layer produces member functions.

The layer 3 *(rule)* is a layer *And*-neurons which produce a logic connection *And* by production $w_i = \mu^1(x_1) \cdot \mu^2(x_2)$.

The layer 4 *(outputmf)* forms value of a target variable:

$$y(x_1, x_2) = \omega_i \cdot y_i = \omega_i (c_{i1} \cdot x_1 + c_{i2} \cdot x_2).$$

The layer 5 (output) carries out operation of a finding of an average. It carries out transformation of results of an fuzzy logic conclusion to precise number on Sugeno algorithm:

$$y = \sum_{i=1}^{n} w_i y_i \Big/ \sum_{i=1}^{n} w_i$$

The modelling result in graph of a mistake of a network depending on number of the lead training cycles is presented on fig. 3.

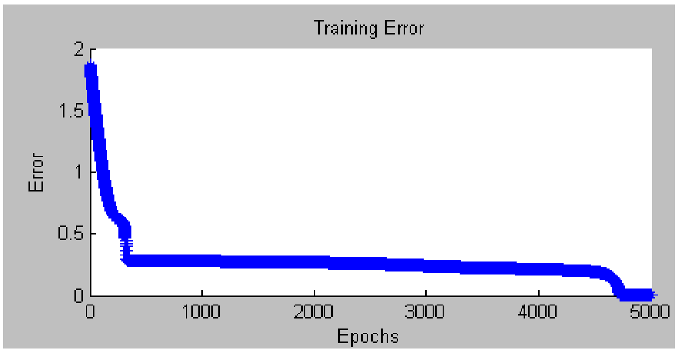

Fig. 3. The graph of dependence of a mistake of training from quantity of cycles of training

TABLE 2. OUTPUT VALUES NEURO-FUZZY NETWORK AFTER TRAINING TABLE STYLES

Input 1 (Temperature, °C)	**Input 2 (Pressure, MPa)**	**Output (non-dimensional)**
139	1.96	-0.00287
133	2.0	-0.00287
151 (deviation)	1.92	1.01
167 (deviation)	1.95	1.01
143	1.89 (deviation)	2.00
138	1.8 (deviation)	2.00
159 (deviation)	1.83 (deviation)	3.01
165 (deviation)	1.76 (deviation)	3.01

For training the neuro-fuzzy network needed 4800 epochs. The mistake of training has made 0.0042 or 0.42 %. In Table 2 output values of neuro-fuzzy network after training are resulted at various of values of input parameters.

The output values of a network adequately define a condition of butanol hydrogenation process at various values of input parameters and correspond to the fuzzy knowledge base. The small error in definition of process condition is caused by a mistake of neuro-fuzzy network training, but essential influence on managerial process does not render. Depending on values of an output of a neuro-fuzzy network the managerial signals directed on elimination of deviations in technological process will be formed.

IV. REALIZATION OF NEURO-FUZZY CONTROLLER

The neuro-fuzzy controller is generated on the basis of neuro-fuzzy network which defines a object condition of management (fig. 4).

The controller has two inputs. These are *input1* and *input2*. They realize a fuzzyfication of input variables. Also the controller structure includes four *blocks Rule1 – Rule4*. These blocks perform linguistic rules. Block *Deffuzzification1* carries out a conclusion of precise value on Sugeno algorithm.

On fig. 5 and 6 the results of control system modelling are presented at influence of a random handicap on the channels of temperature and pressure management in a reactor accordingly.

At influence of handicapes the managerial signals simulated by controller allow to support output parameters within the limits of. On the channel of temperature management (fig. 5) it is necessary to maintain temperature 140°C; but handicapes are directed on increase of parameter from above 150°C. Apparently from graphs (fig. 5) the neuro-fuzzy controller allows to maintain temperature not exceeding 150°C.

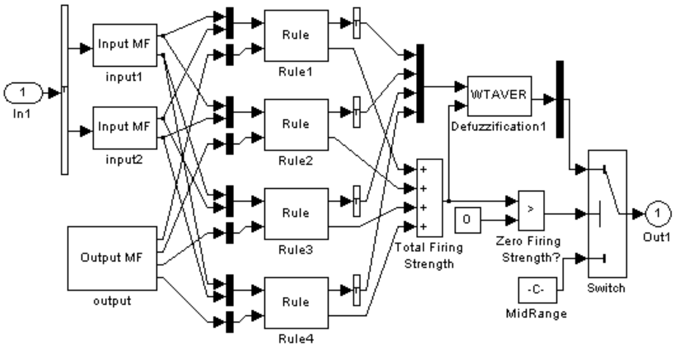

Fig. 4. Internal structure of the neuro-fuzzy controller

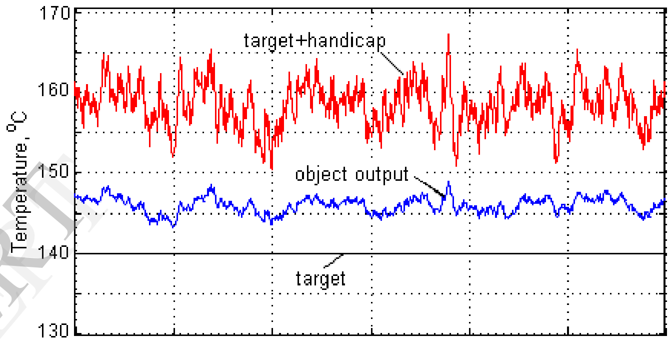

Fig. 5. Results of temperature management in a reactor at influence of handicapes

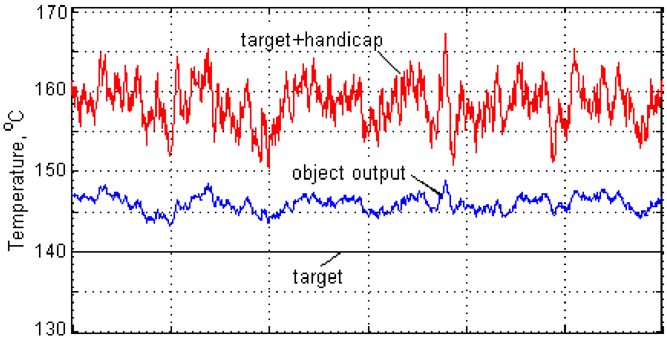

Fig. 6. Results of pressure management in a reactor at influence of handicapes

In the same way the signals of controller support the pressure in a reactor not below demanded 1.9 MPa (fig. 6).

V. CONCLUSIONS

The possibility of applying the fuzzy logic apparatus for non-fully described systems with unknown dynamics is considered in the article on the example of the problem of defining the condition of management object under the date of different nature. The device of fuzzy logic can work with not completely described systems with unknown dynamics, thus the aprioristic mathematical model of object of management is not required. It is shown, that application of a neural network allows to simplify process of fine tuning of membership functions and to raise accuracy of an fuzzy conclusion.

Check of the constructed control system model with neuro-fuzzy controller shows high degree of its adequacy to real initial data. It allows to draw a conclusion that there is an opportunity of its practical application for a problem of any technological process management described by nonlinear dependence.

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