Modelling and Identification of Crude Oil Heating Block at the Primary Distillation Units with Using Dynamic Neural Network

A. O. Kolykhmatov[1], A. G. Shumikhin[2], O. A. Andrievsky[3]
Perm National Research Polytechnic University
[1]kolykhmatovao@gmail.com, [2]atp@pstu.ru, [3]kafedra@at.pstu.ru

***Abstract*— The paper presents the results of identification of information transfer channels for the crude oil preheating unit of the ADU/VDU plant of a refinery, which is a system of heat exchangers using a dynamic neural network. The trained neural network allows to simulate dynamics of technological object (trends of change of technological parameters) and to identify it with application of methods of active experiment on a neural network by transfer functions.**

The transfer functions of transmission channels “the crude oil temperature – the controlled oil flows rate” and “the crude oil temperature – the disturbance influences” that found during identification of heat exchange block were get. These functions were used for development the mathematical model block of heating. That model is used to solve the optimization problem of dynamic modes of heat exchange system.

The results of the problem of identification and modelling of the block for heating the crude oil unit of the ADU/VDU are considered in the report.

Keywords*— *oil refinin; ADU/VDU; heat exchange system; control; modeling; identification; neural network

I. INTRODUCTION

As a rule, the modern primary distillation units are a complex, expensive and high-tech production complex. At these units an essential role is played by the heat transfer unit for heating crude oil, which allows to recover the heat of the products. One of the activities carried out at unit ADU/VDU is the modernization of the heat exchange unit and the improvement of the control system.

Modeling and computer experiments with mathematical model of the block of heat exchange are the effective remedy of development of the system of control allowing to estimate alternative structures and laws of management, to consider behavior of the operated object in non-staff situations. It turn, it demands development of techniques of modeling of the dynamic modes of system of heat exchange taking into account delay in "channels" of the disturbance and operating influences [1–3]. An important role for the system of heat exchange is played by management of distribution of streams of crude oil. The creation of an effective control system is carried out on the basis of results of modeling of dynamics of the system of heat exchange described in the form of the equations of space of states.

II. COMPUTING EXPERIMENT

The object of a study is the block of heat exchange of units of primary oil refining of the oil processing enterprise [4–5]. The block of heat exchange includes 3 regulated streams of crude oil, 10 streams of the heat carriers and 25 heat exchangers connected among themselves both in parallel and is consecutive. The block diagram of the block of heat exchange is shown in the Fig. 1.

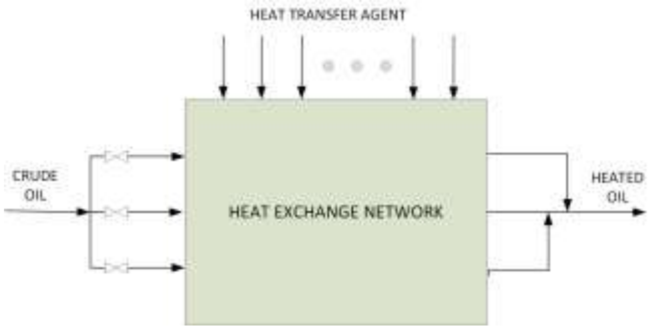

Fig. 1. The block diagram of the heat exchange unit

For identification of system of heat exchange, the dynamic neural network (NN) has been built. The model of nonlinear autoregression with external entrances is used [6–7]. The neural network has 23 external inputs and 3 outputs. At the entrance of the neural network is also given its outputs on the previous bars in a quantity equal to 10 bars. The number of neurons in the hidden layer is six. The outputs of the neural network are the temperature of the crude oil flows at the exit of the Heat exchange unit. The correlation coefficient between the data "unloaded" from the automated control system of the real unit and the data obtained on the trained neural network makes it possible to estimate the accuracy of predicting the temperature of the streams at the output of the heat exchange unit. The correlation value lies in the 0,954-0,983 range.

Computing experiment was conducted to assess the accuracy of the received NN. To do this, a new sample of data is taken from a real unit (Fig. 2), based on which the experiment on NN was conducted. The result of calculations is comparable with the data from the unloaded samples. Fig. 3 shows the results of testing the NN. With the same accuracy,

978-1-5386-5824-6/18/$31.00 ©2018 IEEE

the results are obtained for other input-output channels of the control object.

To identify the object on the trained neural network, an experiment was conducted to determine the frequency characteristics

of the input-output channels. The input sinusoidal signal is realized in the frequency range ω, equal to 0,002-0,065 sec-1, in increments of 0,005. The obtained complex frequency characteristic (CFC) for the channel flow rate of the 1st flow of oil – the temperature at the output of the 1st stream of oil is presented in Fig. 4.

The expression for approximating of the complex frequency characteristic of the second order on channels "input-output" is made

$$W^{Ap}(j\omega_\nu) = \frac{\kappa_{ob}}{(T_1 j\omega_\nu + 1)(T_2 j\omega_\nu + 1)} e^{-j\omega_\nu \tau},$$

reduced to the form:

$$W^{Ap}(j\omega_\nu) = \mathrm{Re}^{Ap}(\omega_\nu) + j\mathrm{Im}^{Ap}(\omega_\nu), \nu = \overline{1, N}. \quad (1)$$

Obtained on the basis of the expression (1) for approximating CFC and coordinates of the points of experimental CFC (Fig. 4)

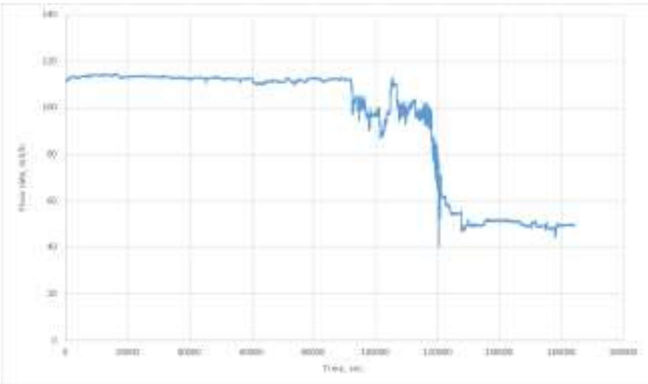

Fig. 2. Change of one oil stream on a real unit

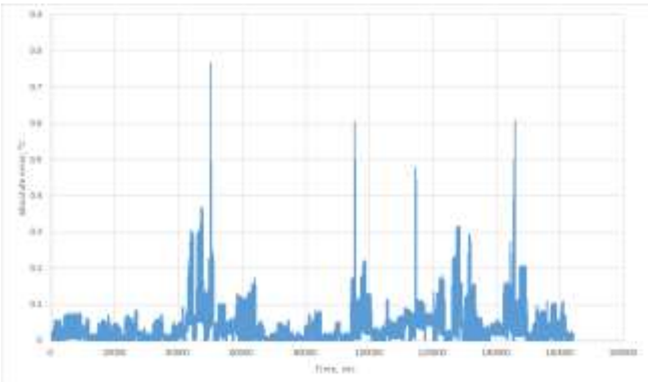

Fig. 3. Absolute error of prediction of the NS temperature of one oil stream

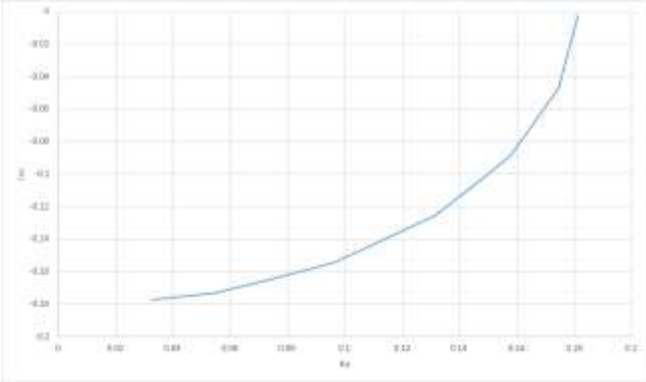

Fig. 4. Experimental CFC flow rate of the 1st stream of oil-the temperature at the output of the 1st stream of oil

transfer function on the channel, the flow rate of the 1st flow of oil – the temperature at the output of the 1st flow of oil, has the form:

$$W_1(s) = \frac{y_1(s)}{u_1(s)} = \frac{0{,}18}{10s^2 + 13.1s + 1} e^{-25s}. \quad (2)$$

The function contains a delay, which makes it difficult to use it directly in the classical algorithms for optimizing dynamic processes. The transfer function for pure delay is approximated by its expansion into a third-order Padé series. As a result, a transfer function approximating the function (2) has the form:

$$W_{1P}(s) = \frac{-0.18s^3 + 0.0864s^2 - 0.01728s + 0.001382}{10s^5 + 17.9s^4 + 8.248s^3 + 1.814s^2 + 0.1966s + 0.00768}. \quad (3)$$

To solve problems of synthesis using a digital computer, it is advisable to present the obtained models in general form in the form of equations of the state-space:

$$\dot{\vec{x}} = A\vec{x} + B\vec{u}, \; \vec{y} = C\vec{x} + D\vec{u} \quad (4)$$

Below in the matrix form the coefficients of the system (4) corresponding to the coefficients of the transfer function (3) are presented:

$$A_1 = \begin{bmatrix} -1.79 & -0.8248 & -0.1814 & -0.0786 & -0.049 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0.25 & 0 & 0 \\ 0 & 0 & 0 & 0.0625 & 0 \end{bmatrix}; \quad (5)$$

$$B_1 = [0.025 \;\; 0 \;\; 0 \;\; 0 \;\; 0];$$

$$C_1 = [0 \; 0 \;\; -0.072 \;\; 0.035 \;\; -0.0276 \;\; 0.0354];$$

$$D_1 = 0.$$

Fig. 5 shows a graph of the transient characteristics on the input-output channel of the object for models (2) - (4). The graphs show that the models almost equally emulate the response of the transmission channels to a stepwise disturbance.

III. Conclusion

Thus, the possibility of application of the neural network for solving the problem of process model identification of the heat exchange unit is investigated in the paper. The results of determination of dynamic characteristics of the heat exchange unit are presented. Transfer functions on channels of expenses of streams of the oil coming to the heat exchange block, and temperatures of the heating oil transformed for synthesis of a control system to a form of the equations of state-space are received.

In the automated control system of the unit ADU/VDU, it is possible to update the parameters of the transfer functions with the minimum period of discreteness of 60 seconds.

This allows, due to the significant inertia of the Heat exchange unit as a control object, by adapting the models to promptly compensate and uncontrollable disturbances in the system, influencing the values of the parameters of transfer functions.

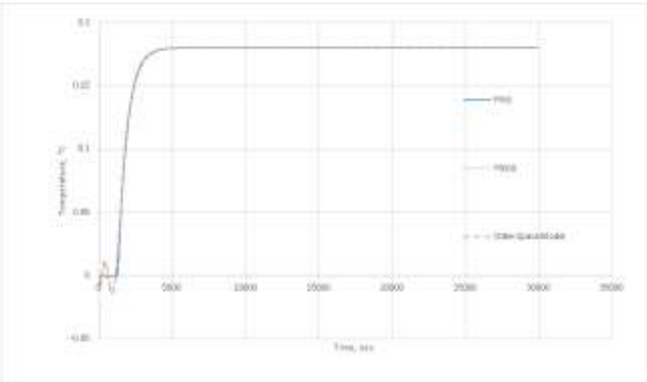

Fig. 5. Example of transient characteristics obtained for 1st stream of oil by means of transfer functions (2), (3) and Equations system solutions (4) with coefficients (5)

The results of the study presented in this paper are intended to solve the problem of synthesis of algorithms for optimal management of crude oil flows. The development will make it possible to increase the efficiency of the unit ADU/VDU operation by increasing the heat recovery from the flow of circulating products leaving the installation, which in turn makes it possible to reduce the consumption of natural gas.

References

[1] Boiarinov A.I., Kafarov V.V. *Metody optimizatsii v khimicheskoi tekhnologii: uchebnoe posobie dlia vuzov* [Methods of optimization in chemical technology: a textbook for high schools]. Moscow. Publ. Khimiia. 1969.

[2] Kafarov V.V., Meshalkin V.P. *Analiz i sintez khimiko-tekhnologicheskikh sistem: uchebnik dlia vuzov* [Analysis and synthesis of chemical-technological systems: a textbook for universities]. Moscow. Publ. Khimiia. 1991.

[3] Gartman T.N., Klushin D.V. *Osnovy komp'iuternogo modelirovaniia khimiko-tekhnologicheskikh protsessov : uchebnoe posobie dlia vuzov* [Fundamentals of computer modeling of chemical and technological processes: a textbook for universities]. Moscow. Publ. Akademkniga. 2006.

[4] Kolykhmatov A.O., Shumikhin A.G. The optimization algorithm in the problem of heating unit of crude oil on the ADU/VDU oil refinery with its actualization in a computer-training complex. *Vestnik Permskogo natsional'nogo issledovatel'skogo politekhnicheskogo universiteta. Khimicheskaia tekhnologiia i biotekhnologiia* [Bulletin of the Perm National Research Polytechnic University. Chemical technology and biotechnology]. 2015, no. 3, pp. 39-48. (in Russian)

[5] Kolykhmatov A.O., Shumikhin A.G. Optimization of crude oil preheating unit at the ADU/VDU in output some heat exchangers to repair. *Vestnik Permskogo natsional'nogo issledovatel'skogo politekhnicheskogo universiteta. Khimicheskaia tekhnologiia i biotekhnologiia* [Bulletin of the Perm National Research Polytechnic University. Chemical technology and biotechnology]. 2016, no. 3, pp. 20-27. (in Russian)

[6] Shumikhin A.G., Boiarshinova A.S. Identification of a complex control object with frequency characteristics obtained experimentally with its dynamic neural network model. *Avtomatika i telemekhanika* [Automation and Remote Control]. 2015, no. 4, pp. 125-134. (in Russian)

[7] Shumikhin A.G., Boiarshinova A.S. Control object parametric identification within execution mode with neural network technology, *Vestnik Permskogo natsional'nogo issledovatel'skogo politekhnicheskogo universiteta. Elektrotekhnika, informatsionnye tekhnologii, sistemy upravleniia* [Bulletin of the Perm National Research Polytechnic University. Electrotechnics, Informational Technologies, Control Systems]. 2016, no. 19, pp. 102-110. (in Russian)