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PROBLEMS OF MODERN ABSORTION COLUMN CONTROL SYSTEM

Abstract: *mathematical modeling of technological processes has become an integral part of the solution of scientific and technical problems aimed at building automated control systems of technological processes.*

We will consider the possibility of simulating the properties of the absorption column and controlling the process through it, using a radial base function and directly connected neural networks. The input and output results for the training of neural networks are derived from the absorption column model. The results obtained using neural network models are mainly compared with the results obtained from simulation calculations. The result obtained suggests that relatively simple neural network models can be used to model the steady state of the absorption column. The neural network type used in modeling allows the use of modern methods of control.

Key words: *Intelligent control systems, neural network, system logic window, schematic diagram, MATLAB, Simulink.*

Language: *English*

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Introduction

The absorption column is one of the most important and basic devices of the nitric acid production process. In modern industrial plants producing nitric acid, it consists mainly of sieve mesh plates, Fig. 1.

The diameter of the absorption column device used in modern production processes is more than 6 m, and the height of the device is more than 80 m. It is important to create a clear mathematical model of the process in terms of the fact that the maintenance of this device requires large capital expenditures, as well as environmental legislation. It can be used in the operation of the device through a model that predicts changes in the mass flow rate in the device, as well as changes in temperature and pressure. Even in the early stages of the development of nitric acid production technology, the design of the absorption column was carried out using experimental data obtained from industrial enterprises.

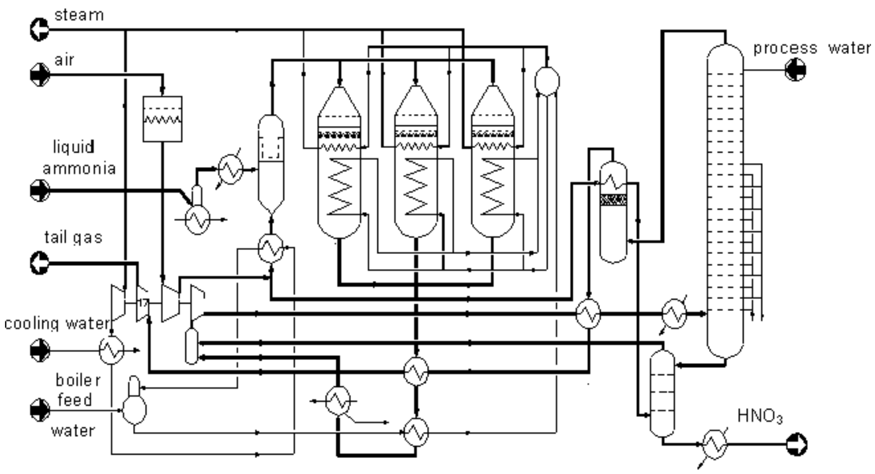

Figure 1. Nitric acid production process device diagram.

As the process of nitric acid production has been mastered, in some literature the process parameters are expressed by the method of graphs. In modern modeling, the possibility of more accurate and faster study of the model of the absorption process by computer is being developed.

MAIN PART

The main stages of the process of obtaining nitric acid without concentration:

- air purification;
- air compression and energy recovery;
- preparation of gaseous ammonia;
- purification of air-ammonia mixture (PAM);
- oxidation of ammonia (contact)
- heat cooling and use of nitrogen gases
- absorption of nitric oxides (production of nitric acid)
- storage and delivery of nitric acid

Thermal decomposition of excess ammonia, transfer for selective purification, formation of elemental nitrogen is formed in the universal combustion chamber of the turbine and in the heat part of the gas channel to the turbine according to the following reactions:

4NH3 = 2N2 + 6H2

6H2+ 3O2 = 6H2O

4NH3+ 3O2=2N2 + 6H2O

In the contact device, ammonia oxidation reaction occurs in the catalyst cells made of platinum alloys in the temperature range 890-910 ^{0}S, pressure 0.617 MPa (6.3 kgf / cm2), production capacity 13, 661 tons / day

4NH3+5O2 = 4NO + 6H2O + 907,3 kJ (216,7 cal) (1)

4NH3+ 3O2 = 2N2 + 6H2O + 1269,1 kJ (303,1cal) (2)

When a mixture of ammonia and air passes through a catalyst plate in a nitric acid production unit, many reactions take place, the most basic of which is as follows:

$$4NH_3 + 5O_2 = 4NO + 6H_2O \quad (3)$$

A mathematical model of the absorption column was developed using the following parameter changes:

- Ideal mixing of gas and liquid phases on the plate;
- Absence of fluid gradients associated with temperature and concentration in the plate pool;
- Gas and liquid phases have sliding properties;
- Low heat loss to the environment;
- To the heat reaction transmitted by the heat exchanger;
- That the temperature of the gas is the same as the liquid coming out of the plate pool;
- The occurrence of chemical reactions in the bushings of the device without heat exchange with the environment;
- HNO2 to HNO3, with the decomposition of NO and H2O by the liquid in the plate pool;

The amount of nitric acid formed in the plate depends on the efficiency of the plate, the theoretical ratio of the NOx reaction and the amount of NOx fall on the plate:

$$X_{HNO_3} = \eta y \sum_{j=NO}^{N_2O_4} G_j^{i-1} \quad (4)$$

$$\eta = 1 - \exp\left(A \frac{\left(1+\frac{C^i_{HNO_3}}{100}\right)^{1.49}}{(w_g^i)^{0.546}(p_{NO}^{i-1})^{0.0483}(T^i)^{1.248}}\right) \quad (5)$$

The composition of the nitric acid solution flowing through the i-plate can be described by the following relations:

$$L_{HNO_3}^{i} = L_{HNO_3}^{i+1} + X_{HNO_3} \quad (6)$$

$$L_{H_2O}^{i} = L_{H_2O}^{i+1} + y_{H_2O} - 0.5X_{HNO_3} \quad (7)$$

$$y_{H_2O} = G_{H_2O}^{i-1} - \frac{p_{H_2O}^{i}\left(\sum_{j=NO}^{N_2O_4} G_j^i + \sum_{j=O_2}^{Ar} G_j^i\right)}{p^i - p_{H_2O}^{i}} \quad (8)$$

The composition of the condensate solution flowing between the plates can be calculated on the basis of the following values:

$$L_{HNO_3}^{i} = L_{HNO_3}^{i+1} + X_{HNO_3} + L_{HNO_3}^{k} \quad (9)$$

$$L_{H_2O}^{i} = L_{H_2O}^{i+1} + L_{H_2O}^{k} + y_{H_2O} - 0.5X_{HNO_3} \quad (10)$$

Classical mathematical models assume the existence of a definite (analytical) mathematical model. However, the technological process is influenced by uncertain parameters that cannot be taken into account in the developed models. The method using a neural network does not limit the linearity of the system, it is effective in noisy conditions, and provides real-time control after training is completed. Neural network control systems (NNCT) are adapted to real conditions, allowing the formation of models that are fully compatible with the task set without the constraints associated with the construction of real systems [1-4].

Figure 2 below shows a neural network adjustment system used to control the technological processes used in the management of inorganic substances [5-6].

The system consists of: T_{1234}-temperature, R_{1234}-pressure, F_{1234}-consumption, L_{1234}-level measurements (where analog 0-4 mA, 4-20 mA current signals or 0/1 digital signals), N_1, N_2, N_3 number of trainings, out1, out2, out3, out4, output signals indicating the results obtained in measurements, label5- weights trained on each row, In5-calculation of results obtained on each row, out5-results calculation window.

The method of operation of the system is as follows: each row value is equal to max = 1 (where the purpose of neuro-adjustment systems is to reduce the error by maintaining the measured parameter at a certain value). the values of the label5 will be 0.5 each if the measurements are performed twice, and the value of each of the label5s will be 0.3 if the measurements are performed three times, this sequence will be performed in the same order) [7-8].

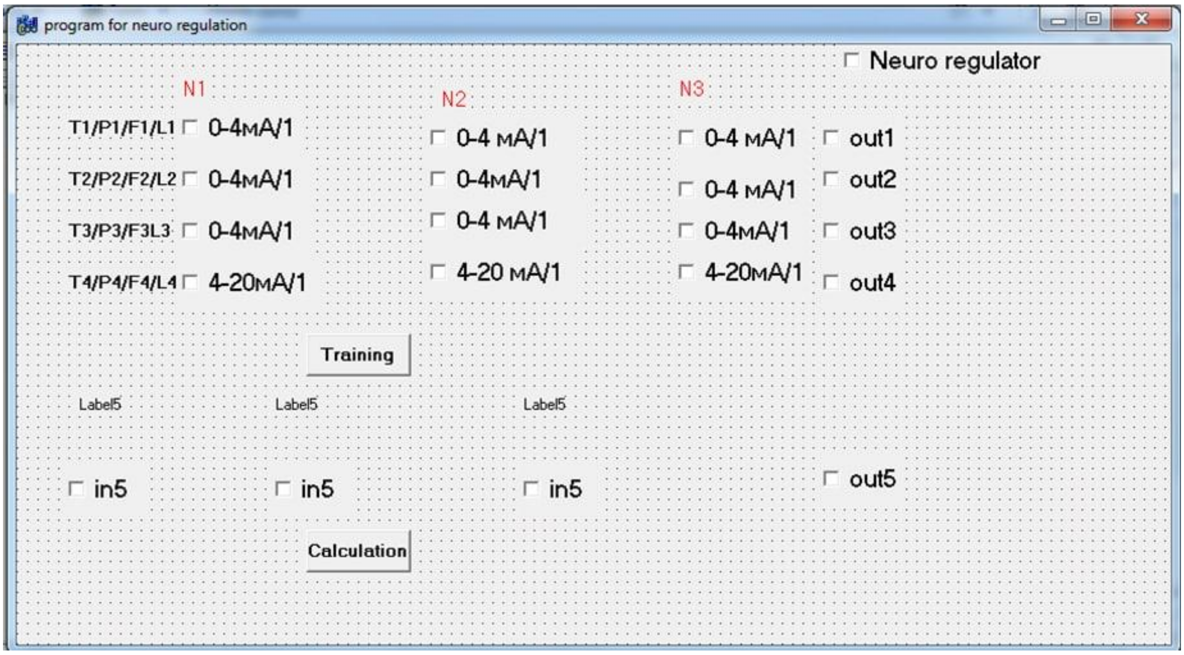

Figure 2. Neuroregulator training.

Analysis of existing neural networks shows that their application provides a positive solution to existing problems in various fields. The use of neural network devices to predict the system poses a number of problems:

- Uncertainty of the number and layers of neurons in the neural network;

- search for the minimum value of the RMS error is associated with the random selection of weight functions of the neural network;

- gradient method cannot determine which internal minimum value is global;

- the gradient method takes a lot of time in selecting the continuous learning phase

The article proposes its model for the development of an intelligent control system of the absorption column, one of the important objects in the production of nitric acid, and on this basis a modern control system, which affects the change in product quality. A point logic method can be used to solve this problem. The task is performed in the following order. Determining the change in time of known values of the coefficients of sustainability. The task is to determine the change in the values of the stagnation coefficient taking into account the initially given data. The following prediction techniques are suggested to solve the problem:

1. Determine the structure of the initial data
2. To determine the linguistic values of this variable for a simple (qualitative) human description of the values of the coefficient of sustainability-linguistic variable.
3. Describe the expert-linguistic laws through the observed changes in the graph of changes in the coefficient of sustainability.
4. Determine the functional relationships between the values of the sustainability coefficient.
5. Formation of expert-linguistic legislation using the function of reliability.
6. Defasitization of the obtained results to convert the reliability functions to exact values.

Table 1. shows the values of the change in the sustainability coefficients per unit of time.

Unit time	Value of sustainability coefficient	Change (difference) value
t_1	1,9781	
t_2	2,0036	+0,0255
t_3	1,9592	-0,0189
t_1	1,9492	-0,0289
t_5	1,9722	-0,0059
t_6	2,0594	+0,0813
t_7	2,0030	+0,0249
t_8	1,9623	-0,0158
t_9	2,0030	+0,0249
t_{10}	2,0375	+0,0894
t_{11}	1,8903	-0,0878
t_{12}	1,8890	-0,0891

The dynamics of change of the obtained results is given in the graph below. In developing a model that predicts changes in the stagnation coefficient based on the point logic method, the concept of “stagnation coefficient value” of the linguistic model change is defined. Based on the results obtained 12 times, the result of the change in the value of the stagnation coefficient allows to obtain 3 insights. High value, medium value and small values. The more change values are obtained, the more accurate the result will be.

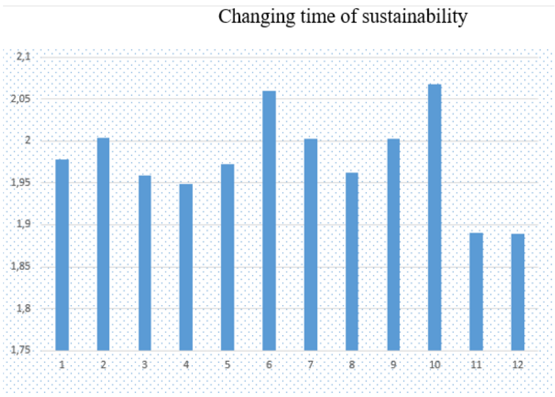

Figure 3. Graph of stagnation change over time.

From the obtained results we can determine the expert-linguistic regularity of the predicted model, which shows that the increase points are 2, the decrease points are 3, and the relatively close values of one point are 3.

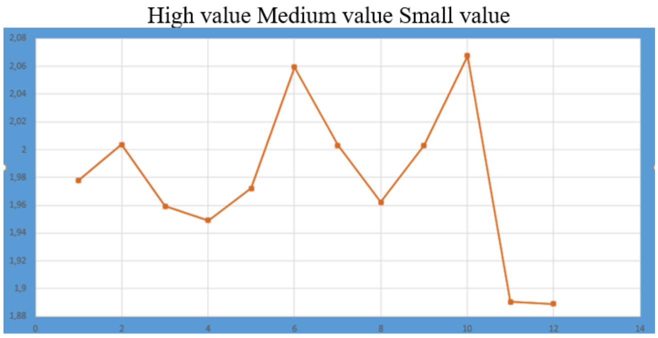

Figure 4.

The change values of the results obtained in Figure 4.

In this information we can obtain the following law:

$$\cdots x_7^{i-1}, x_8^{i-1}\}\{x_1^i, x_2^i, x_3^i, x_4^i, x_5^i, x_6^i, x_7^i, x_8^{i1}\}\{x_1^{i+1}, x_2^{i+1}\cdots$$

where -8 is the number of cycles, - are the values of the stagnation coefficient corresponding to the cycle. Summarizing the results from Figure 4 above, we write the system window logical sequence of rules.

Table 2. Values of measured parameters

Neuro	Label5 (N1)	Label5 (N2)	Label5 (N3)	max	in5(1/2/3)	out (1/2/3/4)	Out
If T1/P1/F1/L1	0-4 mA/1	0	0	1	1/0/0	1/0/0/0 Else	1 0
If T1/P1/F1/L1	0-4 mA/1	0-4 mA/1	0	0.5	1/1/0	1/1/0/0 Else	1 0
If T1/P1/F1/L1	0-4 mA/1	0-4 mA/1	0-4 mA/1	0.3	1/1/1 1/1/0 0/1/1 1/0/1	1/1/1 1/1/0 0/1/1 1/0/1 Else	1 1 1 1 0
If T2/P2/F2/L2	0-4 mA/1	0	0	1	1/0/0	1/0/0/0 Else	1 0
If T2/P2/F2/L2	0-4 mA/1	0-4 mA/1	0	0.5	1/1/0	1/1/0/0 Else	1 0
If T2/P2/F2/L2	0-4 mA/1	0-4 mA/1	0-4 mA/1	0.3	1/1/1 1/1/0 0/1/1 1/0/1	1/1/1 1/1/0 0/1/1 1/0/1 Else	1 1 1 1 0
If T3/P3/F3/L3	0-4 mA/1	0	0	1	1/0/0	1/0/0/0 Else	1 0
If T3/P3/F3/L3	0-4 mA/1	0-4 mA/1	0	0.5	1/1/0	1/1/0/0 Else	1 0
If T3/P3/F3/L3	0-4 mA/1	0-4 mA/1	0-4 mA/1	0.3	1/1/1 1/1/0 0/1/1 1/0/1	1/1/1 1/1/0 0/1/1 1/0/1 Else	1 1 1 1 0

Graphs of pressure adjustment by means of PID-regulator and graphs of interdependence of system of adjustment by means of neuro-regulator are shown in diagrams in the following figure 5.

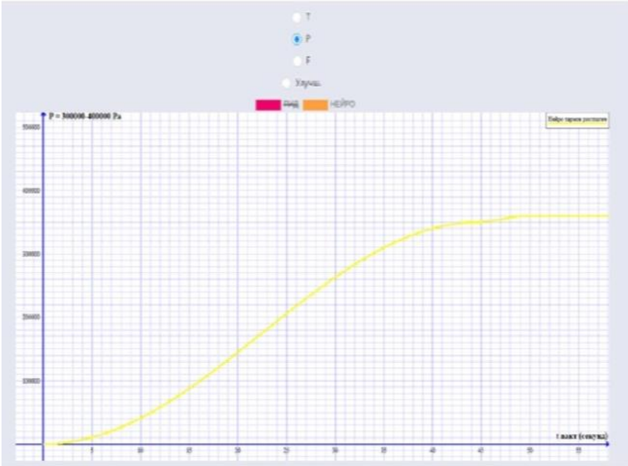

Figure 5a. Adjusting the pressure during the the NR regulator.

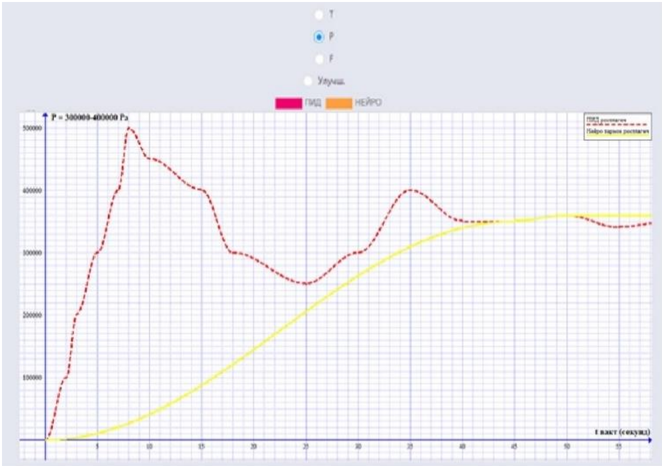

Figure 5b. Adjust the pressure via AK process through the PID regulator and the NR regulator.

The pressure value in these graphs is obtained relative to the pressure of 0.615-0.617 MPa, which is shown in the technological regulation in the production of nitric acid.

The graph of the interaction between the PID regulator and the neuroregulator shows that the PID regulator adjusts to the specified (trained) value of 0.617 MPa in 6 seconds at 0.617 MPa in 6 seconds and the neurostabilizer in 42 seconds.

Based on the research conducted on the system of intelligent control of complex technological processes, a neurostimulatory control system is proposed. In the Neuroband Regulator control system, the adjustment time is longer than in the linear PID-adjuster, but the advantage of the NR control system is the low error of the measured values in the control. Reducing the error serves to improve the quality of the product.

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