EURASIAN PHYSICAL TECHNICAL JOURNAL

2024, Volume 21, No. 4 (50)

https://doi.org/10.31489/2024No4/71-78

Received: 09/04/2024 Revised: 02/09/2024 Accepted: 11/12/2024 Published online: 25/12/2024

Original Research Article

UDC 53.06.011.56

CONTROL PROBLEM FOR A VACUUM TECHNOLOGICAL COMPLEX

Melikov E.A.*, Magerramova T.M., Safarova A.A.

Electronics and Automation Department, Azerbaijan State Oil and Industry University, Baku, Azerbaijan

**Corresponding author*: elchin03@mail.ru

Abstract. *Based on a comprehensive study of technological processes occurring in the vacuum block for an installation of the ELOU-AVT type, the features for the complex technological complex under consideration as a control object were analyzed. In this regard, a physically based mathematical formulation for the optimal control problem of the block under study has been developed, taking into account restrictive conditions on control and input parameters. Taking into account the compiled mathematical models for the quantitative and qualitative characteristics of the process under consideration and the algorithm for their gradient adaptation, to numerically solve the problem of optimizing the functioning for this block, the classical Lagrange method multipliers is used, which allows the transition from the problem of a conditional extremum to the problem of finding the unconditional extremum for the constructed Lagrange function. This method, as well as the proposed algorithm and control principles, were applied for the first time to the vacuum block of the primary oil refining installation of the ELOU-AVT type under study. In wide range conditions of changes in input disturbing factors in quantity and quality, as well as insufficient operational quality information on the selected petroleum products, the proposed method and principles of development algorithm for controlling the process under study allows for prompt preliminary local regulation modes correction and the selection of new optimal modes for adaptive control as a whole. This circumstance leads to an increase in the economic production efficiency and the achievement of the greatest stability in the quality for the resulting target products.*

Keywords: Model, Control problem, Vacuum block, Technological process, Oil fraction.

1. Introduction

Technological complexes for primary oil refining are, in terms of importance, the most important and integral part of the entire oil industry [1-3]. In this regard, in the practice of developing and implementing optimal control systems for complex continuous technological complexes, one of the most important research stages is a comprehensive study of the processes occurring in these technological installations [4-8]. Crude oil coming from various fields, successively passing through distillation columns, is subjected in these technological complexes to the primary distillation process, dividing the crude oil into fractions of different boiling point ranges. At the same time, as control objects, the above-mentioned technological complexes are characterized by the complexity of their constituent devices, a large number of controlled and uncontrolled technological parameters, the need to make decisions on the control of technological apparatus and processes as a whole in conditions of incomplete information about the processes occurring in them and the objects state, high production capacity, a large number of different aggregates types with complex technological connections between them, etc. [9-12].

In the presented article, a vacuum technological complex (block) for primary oil refining of the ELOU-AVT type is considered as an object of research and development an automatic control system. It is known that in vacuum blocks residual fuel oil is processed into various oil fractions used in the lubricants production in mechanical engineering, as well as for internal combustion engines and various technological equipment.

As noted above, from a cybernetic view point, the vacuum block of the primary oil refining installation is a complex control object with a multidimensional matrix of interconnected control and controlled coordinates for the technological process under study. In this regard, solving the actual problem improving the quality of vacuum blocks automatic control in oil refining and, as a consequence, increasing the economic efficiency of petroleum products production is a great scientific and practical value.

A comprehensive analysis and study of modern automation systems for primary oil refining installations shows their primary focus on solving local control functions [13-15]. However, in this case, local automation is no longer able to satisfy the growing competitive modern market demands, which requires multifactor automatic control systems for both quantitative and qualitative characteristics of raw materials and the resulting target petroleum products.

The presented article examines the cybernetic foundations of the controlling problem the vacuum technological complex of a primary oil refining installation and proposes principles for development an algorithm for an automatic control system that allows increasing the economic efficiency and productivity of the production in question as a whole.

At the first stage, operational parametric control of the main technological aggregates for the vacuum block is carried out. This control is based on the synthesis of deterministic mathematical models in conjunction with algorithms for optimizing the control coordinates of the process.

At the second stage, the solution to the problem of technological regimes invariant stabilization in conditions of insufficient information about the state of the control object under study is provided. Here, a combined system is proposed using self-adjusting controllers that make it possible to stabilize the quality of the resulting target oil products. Let's consider a generalized automation functional scheme of the vacuum block for a primary oil refining ELOU-AVT type presented in Figure 1.

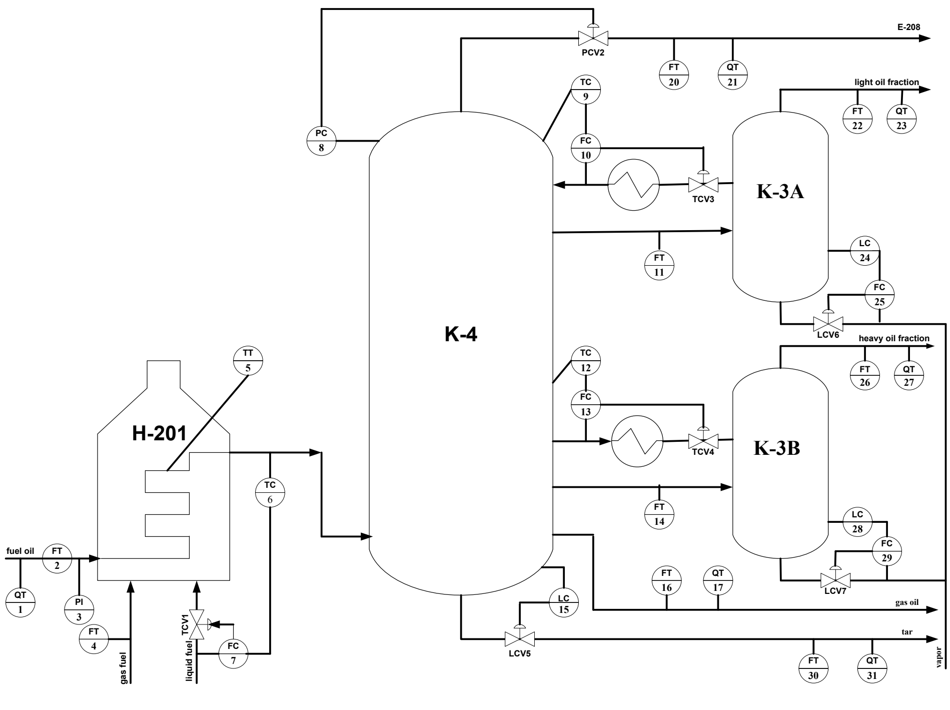

Fig.1. Automation functional scheme of the vacuum block for a primary oil refining ELOU-AVT type installation.

The conducted studies showed that the main and most significant for the effective control of technological apparatuses of the vacuum block are a tubular furnace that provides fuel oil heating, a vacuum column for fuel oil rectification and additional stripping columns.

Being a residual product of the atmospheric block, fuel oil is heated in the H-201 furnace to a temperature of 405÷415 °C and then enters the bottom of the K-4 vacuum column. From the top of the K-4 column, a light oil fraction is removed at a temperature of 155÷185 °C, part of which is used here as irrigation, and the main flow through the K-5A stripper column is fed to product section of the installation. The heavy oil fraction obtained from the middle part of the K-4 column with a temperature of 290÷310 ℃ is also used as irrigation, and the main flow of the fraction itself flows through the bottom of the K-5B stripping column also in the product section. And finally, heavy vacuum gas oil is removed from the bottom of the K-4 column, and residual tar with a temperature of 340÷345 ℃ is pumped out from the bottom. Table 1 shows the regulatory indicators of the vacuum block mode parameters. Note that the fuel oil vacuum distillation column K-4 has the greatest influence on the quality of the resulting target products. In this case, the main controlled coordinates of the technological process under consideration here are the matrices of temperature conditions and residual pressures. The disturbing factors of this process are variations in the quantitative and qualitative characteristics of the fuel oil coming from the atmospheric block.

Table 1. Regulatory indicators of the vacuum block mode parameters.

Technological parameters	Unit of measurement	Range of variations	
		lower limit	upper limit
Quality of raw materials (fuel oil)	-	Not measured	
Consumption of raw materials	kg^3/h	60	100
Temperature at the outlet flow from the furnace H-201	°C	390	400
Temperature of the vacuum column bottom K-4	°C	385	395
Temperature of the vacuum column top K-4	°C	72	88
Level in vacuum column K-4	%	40	60
Residual pressure in vacuum column K-4	mmHg	60	80
Temperature of the plate from which the light oil fraction is taken	°C	155	185
Temperature of the plate from which the heavy oil fraction is taken	°C	290	310
Light oil consumption	m^3/h	10	-
Heavy oil consumption	m3/h	15	-
Light vacuum gas oil	m3/h	45	-
Vacuum residue – tar	m3/h	10	-

2. Statement of the problem

Depending on the amount of a priori information on the controlled and control coordinates, as well as on the disturbing factors of the process under study, the vacuum block as a control object is classified by a deterministic and partially uncertain system.

In addition, significant difficulties in synthesizing a set of mathematical models that most fully describe the specifics for the ongoing processes in a vacuum block are associated with the efficiency and error of measuring technological parameters.

The practice of operating vacuum blocks in real conditions shows that for these technological installations type the main indicator is maximizing the yield and quality of the resulting oil fractions (specific gravity of the resulting product, flash temperature, kinematic viscosity, etc.) contained in the processed fuel oil with minimal energy consumption. The solution to this problem lies in consistently optimal control of the technological process under consideration.

Thus, taking into account the above, a generalized physically based mathematical formulation of the optimal control problem for a vacuum block, taking into account regulatory indicators, will be written in the following form:

$$Y_{l.o.f} = f_1(F_{f.o}, T_b, T_t, P, T_{K-3A}) \rightarrow max \,, \tag{1}$$

$$G_{l.o.f}^{s.g} = f_2(F_{f.o}, T_b, T_t, P, T_{K-3A}) \geq 0.877 \,, \tag{2}$$

$$G_{l.o.f}^{k.v} = f_3(F_{f.o}, T_b, T_t, P, T_{K-3A}) \leq 8.5 \,, \tag{3}$$

$$G_{l.o.f}^{f.p} = f_4(F_{f.o}, T_b, T_t, P, T_{K-3A}) \geq 135 \,, \tag{4}$$

$$Y_{h.o.f} = f_5(F_{f.o}, T_b, P, T_{K-3B}) \rightarrow max\ , \tag{5}$$

$$G^{s.g}_{h.o.f} = f_6(F_{f.o}, T_b, P, T_{K-3B}) \leq 0.907\ , \tag{6}$$

$$G^{k.v}_{h.o.f} = f_7(F_{f.o}, T_b, P, T_{K-3B}) \leq 6.5\ , \tag{7}$$

$$G^{f.p}_{h.o.f} = f_8(F_{f.o}, T_b, P, T_{K-3B}) \geq 205\ . \tag{8}$$

Restrictions imposed on the control and input parameters of the vacuum block:

$$60\frac{m^3}{h} \leq F_{f.o} \leq 100\frac{m^3}{h}\ , \tag{9}$$

$$72\ ℃ \leq T_b \leq 88\ ℃\ , \tag{10}$$
$$385\ ℃ \leq T_b \leq 395\ ℃\ , \tag{11}$$
$$60\ mmHg \leq P \leq 80\ mmHg\ , \tag{12}$$
$$155\ ℃ \leq T_{K-3A} \leq 185\ ℃\ , \tag{13}$$
$$270\ ℃ \leq T_{K-3B} \leq 285\ ℃\ . \tag{14}$$

Here and respectively are the yields of light and heavy oil fractions: $G^{s.g}_{l.o.f}$, $G^{k.v}_{l.o.f}$, $G^{f.p}_{l.o.f}$, $G^{s.g}_{h.o.f}$, $G^{k.v}_{h.o.f}$ and $G^{f.p}_{h.o.f}$ accordingly, the specific gravity, kinematic viscosity and flash point of light and heavy oil fractions; $F_{f.o}$ is consumption of fuel oil supplied to the vacuum block for processing; P is residual pressure in vacuum column K-4; T_b, T_t, T_{K-3A} and T_{K-3B} are temperature conditions at control K-4 vacuum column points.

Based on the scientific and theoretical research and analysis, as well as practical experience in operating the K-4 vacuum column, we will accept generalized mathematical models for the output coordinates of the technological process occurring in the vacuum block in the following linear form:

$$y = b_0 + \sum_{i=1}^{n} b_i\, x_i \tag{15}$$

and in nonlinear form:

$$y = b_0 + \sum_{i=1}^{n} b_i\, x_i + \sum_{i=1}^{n}\sum_{j=i+1}^{n} b_{ij} x_i x_j + \sum_{i=1}^{n} b_{ii}\, x_i^2, \tag{16}$$

where y is output coordinate of the technological process under consideration, b_0 is free coefficient of regression equation, b_i, b_{ij} $(i, j = \overline{1, n}, i \neq j)$ linear and nonlinear coefficients, respectively, b_{ii} $(i = \overline{1, n})$ are quadratic coefficients, $x_i (i = \overline{1, n})$ are input coordinates of the technological process, n is the input matrix dimension.

3. Modelling and development algorithm of control problem

As a result of the process under study analysis, it was established that when mathematically formalizing the vacuum block of a technological installation for the oil primary processing it is more appropriate to build mathematical models characterizing the quantitative indicators of the light and heavy oil fractions target products in a nonlinear form, and mathematical models describing the qualitative indicators of the above-mentioned products - in a linear form. This circumstance makes it possible to achieve the necessary adequacy of the developed mathematical models complex to the real process occurring in the vacuum technological complex. In addition, the proposed control system uses a gradient adaptation algorithm, which makes it possible to maintain the adequacy of the obtained mathematical models to the real process in an iterative mode.

In general, here it is proposed to use a well-known postulate, under which the system can be considered adaptive if the deviation of the output parameter real value for the technological process from its mathematical expectation is minimized by an arbitrarily small value ε:

$M|y_{mod} - y_{real}| \geq \varepsilon,$

where, y_{mod} is the output coordinate obtained on the basis of a linear or nonlinear mathematical model (9) or (10), y_{real} is current value of the output coordinate obtained at the control object output under study, ε is a value characterizing technological accuracy in the mathematical models development. Typically the value of ε is a very small value and is expressed as a percentage.

Here, to adapt mathematical models of the vacuum technological komplex to current situations, it seems more appropriate to use an adaptation algorithm based on the gradient method, since in this proposed adaptation algorithm, unlike other algorithms, gradients of input technological parameters are used to adapt mathematical models. The advantage of this adaptation algorithm compared to other algorithms is that each of the mathematical model's coefficients is adjusted depending on the direction of their gradients and the corresponding model error. This, in turn, makes it possible, based on a smaller operations number, to construct the most adequate mathematical models that have the required quality indicators.

Adaptation of mathematical models to current situations based on this algorithm is carried out in the following way:

- for linear models:

$$B_i^{m+1} = B_i^m + a^m\left[y_{real} - \left(B_0 + \sum_{p=1}^{k} B_p^m x_{preal}\right)\right]\cdot \left(\frac{\partial y_m^*}{\partial x_i}\right)_{x_i = x_{ireal}} \tag{17}$$

- for nonlinear models:

$$B_i^{m+1} = B_i^m + a^m[y_{real} - (B_0 + \sum_p^k B_p^m x_{preal} + \sum_t^k \sum_p^k B_{tp}^m x_{treal} x_{preal})]\left(\frac{\partial y_m^*}{\partial x_i}\right)_{x_i = x_{ireal}} \tag{18}$$

$$B_{ij}^{m+1} = B_{ij}^m + a^m[y_{real} - (B_0 + \sum_p^k B_p^m x_{preal} + \sum_t^k \sum_p^k B_{tp}^m x_{treal} x_{preal})]\left(\frac{\partial^2 y_m^*}{\partial x_i \partial x_j}\right)_{x_i = x_{ireal}, x_j = x_{jreal}} \tag{19}$$

$$i = 1,2,\dots,k;\ j = 1,2,\dots,k;\ j \ge i$$

Here y_{real} , x_{ireal} $(i = \overline{1,k})$ are accordingly, the current values of the output and input parameters of the object under study; $\left(\frac{\partial y_m^*}{\partial x_i}\right)_{x_i = x_{ireal}}$, $\left(\frac{\partial^2 y_m^*}{\partial x_i \partial x_j}\right)_{x_i = x_{ireal,}, x_j = x_{jreal}}$ are partial derivatives calculated values according to the corresponding input parameters of the model at points $\{x_{1real}, x_{2real}, \dots, x_{kreal}\}$ on the m-th tact, a^m is a positive number that satisfies certain conditions; y_m^* is calculated value of the output technological parameters based on model expressions (15) or (16) at the m-th cycle, m are tacts.

It should be noted that the optimization speed of the adaptation algorithm, performed on the expression's basis (17)-(19), depends on several factors, the most important of which is the sequence a^m choice. When developing adaptive mathematical models, it is desirable to choose such a^m coefficients that the deviation of the model coefficients current values from their desired values at each stage is minimal.

In accordance with the above, mathematical models have been obtained that have been adapted to the current situation relative to the output coordinates in the vacuum block upper part and have the following form:

$$\begin{aligned} Y_{l.o.f} &= -4501.1558 + 5.7527F_{f.o} + 8.8673T_b + 45.9481T_t + 3.0525P + 8.76462T_{K-3A} + \\ &+ 0.0432F_{f.o}^2 - 0.0044F_{f.o}T_b - 0.164F_{f.o}T_t - 0.0079F_{f.o}P + 0.0018F_{f.o}T_{K-3A} - 0.127T_b^2 - \\ &-0.127T_b^2 - 0.085T_bT_t + 0.055T_bP - 0.06T_bT_{K-3A} + 0.106T_t^2 - 0.036T_t P - -0.0856T_tT_{K-3A} - \\ &0.0024P^2 + 0.0019P\, T_{K-3A} - 0.00292T_{K-3A}^2 \end{aligned} \tag{20}$$

$$G_{l.o.f}^{s.g} = 0.9236 - 0.00012F_{f.o} - 0.00117T_b - 0.00517T_t - 0.0001064P - 0.00000177T_{K-3A} \tag{21}$$

$$G_{l.o.f}^{k.v} = 0.0213 - 0.04616F_{f.o} + 0.02752T_b - 0.1339T_t - 0.003585P + 0.05854T_{K-3A} \tag{22}$$

$$G_{l.o.f}^{f.p} = 31{,}3126 - 023486F_{f.o} + 0.1164T_b - 0.3665T_t - 0.000773P + 0.259T_{K-3A} \tag{23}$$

$$\begin{aligned} Y_{h.o.f} &= -3397.998 + 8.8025F_{f.o} + 2.3294T_b + 11.961P + 15.7958T_{K-3B} + 0.00798F_{f.o}^2 - \\ &- 0.008F_{f.o}T_b - 0.0599F_{f.o}P + 0.00189F_{f.o}T_{K-3B} - 0.0112T_b^2 + 0.00247T_bP - \\ &- 0.03949T_bT_{K-3B} + 0.0024P^2 - 0.03193PT_{K-3B} - 0.004949T_{K-3B}^2 \end{aligned} \tag{24}$$

$$G_{h.o.f}^{s.g} = 0.885 + 0.000455F_{f.o} + 0.00002T_b - 0.000022P - 0.000041T_{K-3B} \quad (25)$$

$$G_{h.o.f}^{k.v} = 0.3416 + 0.002496F_{f.o} - 0.00175T_b + 0.0385P + 0.0010854T_{K-3B} \quad (26)$$

$$G_{h.o.f}^{f.p} = 120.25 - 0.26975F_{f.o} - 0.02962T_b - 0.046579P + 0.433051T_{K-3B} \quad (27)$$

As can be seen from the above, the mathematical formulation of the optimizing problem the functioning for the vacuum technological complex (1)-(14), built on the mathematical models basis (20)-(27) is by its nature a nonlinear programming problem. Based on the scientific publications analysis, it has been established that to numerically solve the above optimization problem, it is more rational and efficient to use the classical Lagrange multipliers method, since to solve this large-dimensional optimization problem, this method makes it possible to reduce it into a relatively simple subtasks complex that make it up.

As is known, the Lagrange multiplier method allows you to find the maximum or minimum of a function under equality-constraints. Based on finding the objective function partial derivatives, solving the optimization problem using the Lagrange method is reduced to finding the coordinates of the Lagrange function saddle point. Then, for the problem under consideration, the Lagrange function will be written in the following form:

$$\begin{gathered} L = f_1(F_{f.o}, T_b, T_t, P, T_{K-3A}) + f_5(F_{f.o}, T_b, P, T_{K-3B}) + \lambda_1[f_2(F_{f.o}, T_b, T_t, P, T_{K-3A}) - 0.877] + \\ +\lambda_2[8.5 - f_3(F_{f.o}, T_b, T_t, P, T_{K-3A})] + \lambda_3[f_4(F_{f.o}, T_b, T_t, P, T_{K-3A}) - 135] + \lambda_4[0.907 - \\ -f_6(F_{f.o}, T_b, P, T_{K-3B})] + \lambda_5[6.5 - f_7(F_{f.o}, T_b, P, T_{K-3B})] + \lambda_6[f_8(F_{f.o}, T_b, P, T_{K-3B}) - 25] + \\ + \lambda_7[T_b - 385] + \lambda_8[395 - T_b] + \lambda_9[T_t - 72] + \lambda_{10}[88 - T_t] + \lambda_{11}[P - 60] + \lambda_{12}[80 - P] + \\ +\lambda_{13}[T_{K-3A} - 155] + +\lambda_{14}[185 - T_{K-3A}] + \lambda_{15}[T_{K-3B} - 270] + \lambda_{16}[285 - T_{K-3B}], \end{gathered} \quad (28)$$

where λ_i $(i = \overline{1,16})$ are the Lagrange multipliers.

The proposed algorithm for solving the nonlinear problem of optimizing the functioning for the vacuum block in this case consists of the following steps:

1) the Lagrange function (28) is compiled;

2) the unconditional extremum of the constructed Lagrange function is found based on the controlled coordinates of the process under consideration;

3) according to the Kuhn-Tucker theorem, necessary and sufficient conditions for the extremum point are fixed;

4) using the artificial basis method, the coordinates of the extremum point are found;

5) the optimal form of the original problem is found and the objective function values are calculated.

Below, the solving results the optimization problem under consideration (1)–(14), obtained for the vacuum block of ELOU-AVT type technological installation at an oil refinery, are summarized in tabular form (Table 2). As noted above, the use of traditional automation systems in oil refining under conditions of a wide range of changes in the quantitative and qualitative characteristics of the raw materials supplied to the installation and the insufficiency of available operational qualitative information on the selected fractions no longer meets modern market requirements and is unprofitable in terms of energy costs. In this regard, there is an urgent need to develop fundamentally new automatic control systems based on energy-saving and disturbance-invariant strategies, and also capable of functioning effectively in information deficiency conditions.

Considering various rectification processes from these concepts, it should be noted that in conditions of the existence of a changes wide range in disturbing influences at the vacuum block inlet under consideration, stabilization of the various fractions quality obtained in distillation columns to one degree or another depends from adequate and, most importantly, proactive regulation of the irrigation degree and temperature conditions at the distillation products selection points for the block under study. During transient operating modes of technological installations, in conditions of the significant variations existence in the input quantitative and qualitative incoming raw materials characteristics, only local and traditional parameters stabilization on the stripping plates of the column it is not always possible to achieve the desired result.

Table 2. Results of solving the optimization problem obtained for the vacuum block of ELOU-AVT type technological installation

Parameters	Real value	Optimal value
Raw material consumption (fuel oil), m^3/h	71.66	71.66
Column bottom temperature K-4, ℃	388.49	385.00
Column top temperature K-4, ℃	72.83	82.00
Residual pressure in column K-4, mmHg	64.18	62.00
Temperature at the light oil fraction selection plate of column K-4 (line K-3A), ℃	175.88	177.00
Temperature at the heavy oil fraction selection plate of column K-4 (line K-3B), ℃	276.13	285.00
Consumption of light oil fraction, m^3/h	14.98	17.04
Specific gravity of light oil fraction, g/m^3	0.8771	0.8772
Kinematic viscosity of light oil fraction	7.72	6.47
Flash point of light oil fraction, ℃	132.00	135.24
Consumption of heavy oil fraction, m^3/h	32.00	38.12
Specific gravity of heavy oil fraction, g/m3	0.9061	0.9073
Flash point of heavy oil fraction, ℃	206	212

4. Conclusion

This problem is also aggravated by the certain errors presence in the operational control of the process controlled coordinates under consideration, leading to a lack of adequate parametric information from the control object as a whole. The solution to this problem can be the synthesis of the proposed combined automatic control system with self-adjusting regulators that produce adequate compensation effects in response to existing input disturbances. At the same time, the main idea of developing the proposed combined automatic control system for the vacuum block is the possibility of preliminary correction for the mode parameters of the local control the column stripping trays, depending on the input disturbing factors regarding the quality and quantity of fuel oil entering the unit in question. Thus, by providing a preliminary correction signal, depending on variations in the quality and quantity of fuel oil at the inlet and changes in the irrigation degree, as well as the temperature gradient on the stripping plates, it becomes possible to adapt the settings for local regulators.

As a result, the greatest stability in the quality of the resulting fractions and invariance to input disturbances of the entire system as a whole is achieved.

The main advantage of the approach described in this article to the proposed automatic control system development compared to existing traditional systems is the ability to maintain stability of the quality characteristics for the resulting fractions with sufficiently large changes in the quality and quantity of incoming fuel oil. The proposed principle of development algorithm for a two-level control system of the process under study provides for the corrective influences implementation at both levels. At the same time, existing small disturbances can be corrected during self-tuning of installed local controllers, and large changes at the process input are corrected by choosing new optimal mode parameters for adaptive control of the technological process under consideration. The above also determines the economic feasibility of the proposed control principle, which allows, under conditions of a wide changes range in input disturbances, to achieve the greatest stability in the quality of the resulting commercial product with the lowest energy costs.

Conflict of interest statement

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

CRediT author statement

Melikov E.: Conceptualization, Methodology, Software, Data curation, Writing - Original draft preparation. **Magerramova T.:** Visualization, Investigation, Supervision; **Safarova A.:** Software, Validation, Writing - Reviewing and Editing. The final manuscript was read and approved by all authors.

References

1 Guseinov I.A., Melikov E.A., Khanbutaeva N.A., Efendiev I.R. (2012) Models and algorithms for a multilevel control system of primary oil refinery installations. *J. Comput. Syst. Sci. Int.*, 51, 138–146. DOI: 10.1134/S1064230711060098.

2 Guseinov I.A., Kurbanov Z.G., Melikov E.A., Efendiev A.I., Efendiev I.R. (2014) Nonstationary Multistage Process Control in the Petrochemical Industry. *J. Comput. Syst. Sci. Int.*, 53, 556-564. DOI: 10.1134/S1064230714030095.

3 Melikov E.A., Magerramova T.M., Safarova A.A. (2023) Logical-Linguistic Model for Reactor Cleaning from Impurities. Proceeding of the 15th Intern. Conf. on Applications of Fuzzy Systems, Soft Computing and Artificial Intelligence Tools – ICAFS-2022. ICAFS 2022. *Lecture Notes in Networks and Systems*, 610. Springer, Cham. DOI:10.1007/978-3-031-25252-5_44.

4 Wang L.X. (1998) Stable and optimal fuzzy control of linear systems. *IEEE Transactions on Fuzzy Systems*, 6, 137-143. Available at: https://hdl.handle.net/1783.1/25922.

5 Morari M., Arkun Y., Stephanopoulos G. (1980) Studies in the synthesis of control structures for chemical processes. *Analysis of the Optimizing Control Structures*, 220-232. DOI: 10.1002/aic.690260205.

6 Giwa A. (2012) Decoupling PID Control of a Reactive Packed Distillation Column. *International Journal of Engineering Research & Technology,* 1, 10-12. Available at: https://www.researchgate.net/publication/236899250.

7 Gupta A. (2013) Control of distillation process using neuro-fuzzy technique. *International Journal of Electrical, Electronics and Data Communication,* 1, 16-20. Available at: http://ijeedc.iraj.in/paper_detail.php?paper_id=233.

8 Aliyeva K., Jafarov R. (2023) Safety control systems for ethylene production. *Multidisciplinary Journal, Refereed & Reviewed Journal*, 35 (04), 206-213. DOI: 10.36962/PAHTEI35122023-206.

9 Žilka V., Halás M., Huba M. (2009) Nonlinear Controllers for a Fluid Tank System. Computer Aided Systems Theory - EUROCAST 2009. *Lecture Notes in Computer Science*, 5717, 618-625. Springer, Cham. DOI:10.1007/978-3-642-04772-5_80.

10 Khelassi A., Wilson J.A., Bendib R. (2004) Assessment of Interaction in Process Control Systems. *Proceedings – Dynamical Systems and Applications*, 463-471. Available at: https://www.researchgate.net/publication/228985993.

11 Attarakih M. (2013) Dynamic analysis and control of sieve tray gas absorption column using MATLAB and SIMULINK. *Applied Soft Computing*, 13 (2), 1152-1169. DOI: 10.1016/j.asoc.2012.10.011.

12 Solatian P., Abbasi S.H., Shabaninia F. (2012) Simulation Study of Flow Control Based On PID ANFIS Controller for Non-Linear Process Plants. *American Journal of Intelligent Systems*, 2(5), 104-110. DOI: 10.5923/j.ajis.20120205.04.

13 Yakubov M.S., Xoshimov B.M. (2023) Operational control of the vacuum column of the unit of oil primary distillation. "*Al-Farg'oniy Avlodlari" Electronic Scientific Journal*, 1 (1), 27-34. DOI: 10.5281/zenodo.7698708.

14 H'ng S.X., Ng L.Y., Ng D.K.S., Andiappan V. (2024) Optimisation of Vacuum Distillation Units in Oil Refineries Using Surrogate Models. *Process Integration and Optimization for Sustainability*, 8 , 351–373. DOI: 10.1007/s41660-024-00395-6.

15 Kazakova V.N., Mikhaylova P.G. (2021) Development and research of control systems with fuzzy regulators for installation of primary petroleum refining. *Scientific Journal "Advances in Chemistry and Chemical Engineering*, 35, 22-26. Available at: https://cyberleninka.ru/article/n/razrabotka-i-issledovanie-sistem-upravleniya-s-nechetkimi-regulyatorami-dlya-ustanovki-pervichnoy-pererabotki-nefti/viewer

AUTHORS' INFORMATION

Melikov, Elchin Adil - PhD, Associate Professor, Electronics and Automation Department, Azerbaijan State Oil and Industry University, Baku, Azerbaijan. Scopus Author ID: 55040103800; ORCID: 0000-0002-1411-125X; elchin03@mail.ru

Magerramova, Tamella Mustafa - PhD, Associate Professor, Department of Electronics and Automation, Azerbaijan State Oil and Industry University, Baku, Azerbaijan. Scopus Author ID: 58031678900, ORCID: 0000-0001-8367-0031; tamellatm@gmail.com

Safarova, Aygun Agamirza - PhD, Associate Professor, Department of Electronics and Automation, Azerbaijan State Oil and Industry University, Baku, Azerbaijan. Scopus Author ID: 57422312900, ORCID: 0000-0001-9806-6654; aygsafa@rambler.ru