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OPERATIONAL CONTROL OF THE VACUUM COLUMN OF THE UNIT OF OIL PRIMARY DISTILLATION

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Annotation: The cybernetic foundations of the problem of modeling and algorithmization of the control of the vacuum unit of the primary oil refining unit of the CDU-AVT type, which makes it possible to increase the economic efficiency of the production of the resulting commercial oil products, have been studied.

Keywords: vacuum unit, mathematical formulation of the problem, optimal control, technological process, oil, primary oil refining

Introduction. In the commodity structure of international trade, oil, gas and products of their primary processing have been occupied and stably kept for many years, which are significantly ahead of all other goods and items of export-import operations, which determines their key role in the regional commercial energy balance.

The main systemic problems of oil refining as a key element of the oil industry include the following: low oil recovery factor, low quality and unstable composition of oil products, insufficient automation and quality control of oil refining processes, insufficient efficiency of existing production equipment; low depth of processing, discrepancy between the quality of the final product and export requirements, and some others.

The ever-increasing competition in the global economy and the transition to new standards of energy and resource saving, quality and environmental safety create the need for continuous tightening of requirements for primary oil refining processes, which causes an obvious need to develop new systematic approaches to increase production efficiency in the oil industry, optimizing the management of the main processes and, as a result, improving the quality of the final products of oil refining.

The pronounced systemic nature of this problem determines the need to solve it on the basis of system research using modern methods and tools of system analysis, modeling theory, control and optimization.

One of the main problems of primary oil refining is the insufficient level of efficiency of the existing equipment and the quality of control, the solution of which can be achieved by a systematic analysis of typical industry-specific oil refining processes as objects of control and optimization according to frequency criteria of the quality of multiloop cascade control systems.

Literature review and methodolgy. The process of primary oil refining is the most high-tonnage, energy-intensive and resource-intensive. This circumstance determined the choice of the process of primary oil refining at atmospheric-vacuum distillation units as a complex object of system analysis, control and optimization.

To date, there is no unified strategy for the system analysis of typical industry multi-stage processes of primary oil refining, which, based on integrated system quantitative assessments, can identify inefficiently controlled technological parameters and develop recommendations for optimizing the corresponding multi-loop cascade control systems. [1]

A multi-stage process of primary oil refining as a complex technical object of control and optimization, which includes the following stages:

1. Analysis of the system structure of the primary oil refinery, including the definition and characterization of input and output flows; drawing

up structural and enlarged process diagrams, as well as operator diagrams of blocks and nodes, which reflect topological connections and allow classifying parameters and interconnected flows of blocks and nodes.

2. Analysis of the process control subsystem of an oil refinery, including the compilation of a list and passports of existing local control systems, which indicate the characteristics of parameters and flows, as well as absolute and integral indicators of the quality of control processes in steady-state and transient modes of operation.

3. Analysis of the information-measuring subsystem, including the study of the composition of the complex of technical means and the quality of measuring the parameters of flows and equipment; definition of requirements for their measurements; analysis of the characteristics of existing measuring instruments; assessment of the quality of measuring the parameters of flows and equipment.

4. Analysis of subsystems of interlocks and protections, including the study and characterization of the composition and performance of automatic systems of interlocks and emergency protection, as well as an assessment of the degree of their compliance with the requirements for the performance of the control system.

5. Analysis of the energy efficiency of the oil refining process, including the characteristics of the received and received oil products for the reporting period, the calculation of the planned and actual specific consumption of thermal energy for processing, the determination of the degree of energy efficiency of the process.

6. Analysis of the level of automation of the oil refining process, including the determination of quantitative and qualitative indicators of the degree of automation of the following functions: process control; control of quality indicators of streams; control and registration of parameters of streams and equipment; analysis of regime situations; transfer of information to the upper level of management; start and stop equipment. [2]

7. Analysis of the reliability of the control system, including the compilation of a design logic diagram of reliability and the calculation of the failure rate of all components of the system.

8. Comparative analysis of the relative effectiveness of local ATS based on the DEA method (Data Envelopment Analysis) and includes an assessment of the relative integral indicators of the quality of regulation of local loops in static and dynamic modes, which allows you to set the parameters that the control meets the requirements and identify how far the indicators of inefficiently controlled parameters are far from their potentially possible effective values.

9. Formation of a conclusion on the quality of management, in case of compliance with the requirements, recommendations are developed on the practical use of the results of the system analysis, and the task is considered solved, otherwise the transition to the subsequent stages of the system analysis is carried out.

10. Analysis of the dynamics of circuits with inefficiently controlled parameters, including the selection and justification of mathematical models focused on the use in parametric optimization problems to describe the objects of regulation of local automatic control systems in the form of transfer functions for the considered channels of action of master and disturbing influences.

11. Parametric optimization by frequency quality criteria of typical controllers of local automatic control systems with inefficiently controlled parameters of a multiloop control system based on the alternance optimization method.

12. Evaluation of the absolute quality indicators of control processes in optimized local loops in static and dynamic modes of operation, after which the transition to stage 8 is carried out.

The main task of the considered multi-loop control system is to control the temperature of fuel oil at the furnace outlet, and the main disturbances, for which the ACS is designed to compensate, are the fuel oil temperature at the furnace inlet, fuel oil consumption in the vacuum column and superheated steam consumption at the furnace coils inlet.

For the mathematical description of the processes of movement of liquid and vapor through the pipeline, which have a significantly lower inertia compared to other processes occurring in the vacuum unit of the AVT installation, first-order aperiodic links were used.

The resulting mathematical description is oriented to further use in optimization procedures when solving the problem of parametric optimization of a multi-loop automatic control system by the process of heating raw materials. [2]

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Ensuring the maximum degree of invariance of local control loops with respect to each other and to external disturbances can be considered as the main optimality criterion in the problems of parametric synthesis and optimization of cascade automatic control systems, taking into account additional requirements for the quality of transient processes formulated in the form of given restrictions on the maxima of the amplitude-frequency characteristics of local closed circuits of the synthesized system through the channels of the setting influences.

Results. In the most general case, a multiloop cascade control system, including n loops, can be represented as shown in Figure 2, where $z_i(s)$ is the controlled variable i of the -th loop; $W_{ui}(s)$ and $W_{fi}(s)$ are the correct rational transfer functions of the control object i of the th circuit through the channels of the control and disturbing influences $u_i(s)$ and $f_i(s)$, respectively. In this case, the transfer function $W_{fi}(s)$ can contain any necessary information that satisfies the hypothesis of the low-frequency nature of the disturbances. [3]

Transfer Functions of Regulators $W_{pi}(s,\Delta_i), i=\overline{1,n}$ are considered to be functions of the desired vectors $\Delta_i=(\Delta_{ij}), j=\overline{1,k_i}$ of unknown parameters of their settings, given in the standard fractional-rational form.

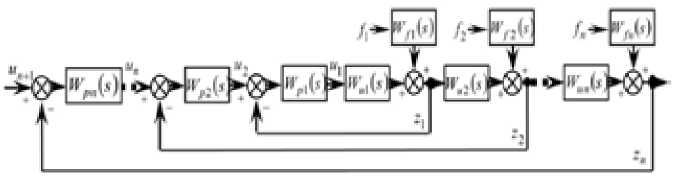

Figure 1 - Structural diagram of the cascade control system

In a number of practical cases, as an optimization criterion $I_i(\Delta_i)$ i - circuit, it is advisable to choose the maximum amplitude-frequency characteristic $I_i(\Delta_i)=\max\limits_{\omega\in[0,\infty)}|W_{zfi}(i\omega,\Delta_i)|$ of this circuit through the channel of the perturbing action, which has a transfer function $W_{zfi}(s,\Delta_i)$. As a result, the problem is reduced to finding n parameter vectors $\Delta_i=(\Delta_{ij}), j=\overline{1,k_i}, i=\overline{1,n}$ settings of regulators that minimize the maximum frequency response of all circuits of the nominal system through the channels of disturbance action:

$$I_i(\Delta_i)=\max_{\omega\in[0,\infty)}|W_{zfi}(i\omega,\Delta_i)|\to\min_{\Delta_i\in G_n\subset E^n}, i=\overline{1,n}, \tag{1}$$

where G_n is the set of parameters Δ_i that ensures the stability i of the contour; $W_{zfi}(i\omega,\Delta_i)$ - amplitude-phase characteristic i of the -th circuit along the perturbation channel.

At the same time, the requirements for the quality indicators i of the th circuit can often be formulated as a restriction on the maximum frequency response $|W_{zui}(i\omega,\Delta_i)|$ of this circuit through the channel of the driving influence, where $W_{zui}(i\omega,\Delta_i)$ is the amplitude-phase characteristic i of the -th circuit along the channel of the driving influence. As such a limitation, it is advisable to consider the limitation on the value of the oscillation index M_i, which is the maximum value of the amplitude-frequency characteristic $|W_{zui}(i\omega,\Delta_i)|$ on the frequency axis in relative units:

$$F_i(\Delta_i)=\max_{\omega\in[0,\infty)}|W_{zui}(i\omega,\Delta_i)|\le M_i, i=\overline{1,n}. \tag{2}$$

Thus, we come to the parametrized problem (1)-(2) of optimizing n control loops of a multidimensional cascade system, while the problem of parametric synthesis i of the loop is reduced to the standard form of the following semi-infinite optimization problem:

$$I_i(\Delta_i)=\max_{\omega\in[0,\infty)}|W_{zfi}(i\omega,\Delta_i)|\to\min_{\Delta_i\in G_n\subset E^n}, \tag{3}$$

$$F_i(\Delta_i)=\max_{\omega\in[0,\infty)}|W_{zui}(i\omega,\Delta_i)|\le M_i, \tag{4}$$

in which it is required to find the vector of optimal parameters $\Delta_i=(\Delta_{ij}), j=\overline{1,k_i}$ typical regulator $W_{pi}(s,\Delta_i)$, which provides the minimum response i of the i- circuit to an external disturbing action according to criterion (3) under the conditions of limitation (4) on the index of the oscillatory processes of transients i of the i-circuit along the setting channel. [4]

With the chosen structure of the controller, $W_{pi}(s,\Delta_i)$, the problem (3)-(4) of parametric synthesis of the optimal controller is a mathematical programming problem with an infinite number of restrictions of type (4), which is proposed to be solved in the paper on the basis of the alternance method of parametric optimization.

According to this method, the solution of problem (3)-(4), which is a certain vector of parameters Δ_i^{opt}, satisfies special alternance properties, according to which on the frequency axis $\omega \in [0;+\infty)$ there are at least $R_{fi} \ge 1$ different points $\omega_{fiq}, q=\overline{1,R_{fi}}$ and $R_{ui} \ge 1$ various points $\omega_{uis}, s=\overline{1,R_{ui}}$ at which the amplitude-frequency characteristics $\left|W_{zfi}\left(i\omega,\Delta_i^{opt}\right)\right|$ And $\left|W_{zui}\left(i\omega,\Delta_i^{opt}\right)\right|$ reach their maximum values equal to $I_i\left(\Delta_i^{opt}\right)$ and $F_i\left(\Delta_i^{opt}\right)=M_i$, respectively, under the condition:

$$R_{fi}+R_{ui}=k_i+1, \qquad (5)$$

where k_i is the number of desired controller settings $W_{pi}(s,\Delta_i)$.

An exception is the situation when there is a minimum number of such points, i.e. $R_{fi}=1$ and (or) $R_{ui}=1$, then the inequality is possible $R_{fi}+R_{ui}<k_i+1$ if $k_i \ge 2$.

The noted properties make it possible to compose in the case (5) a closed system k_i+1 equations for frequency response $\left|W_{zfi}\left(i\omega,\Delta_i^{opt}\right)\right|$ And $\left|W_{zui}\left(i\omega,\Delta_i^{opt}\right)\right|$ about all k_i+1 desired parameters, which are k_i component $\Delta_i^{opt}=\left(\Delta_{ij}^{opt}\right), j=\overline{1,k_i}$ vector Δ_i^{opt} and minimax $I_i\left(\Delta_i^{opt}\right)$.

If there is additional information about the form of the corresponding AFC, this system of equations can be supplemented with the condition for the existence of an extremum of the indicated frequency characteristics at these points. Then we get the system $2(k_i+1)$ equations, the solution of which are k_i the parameters of the controller settings $\Delta_i^{opt}=\left(\Delta_{ij}^{opt}\right), j=\overline{1,k_i}$; magnitude $I_i\left(\Delta_i^{opt}\right)$, frequencies $\omega_{fiq}^{opt}, q=\overline{1,R_{fi}}$ and $\omega_{uis}^{opt}, s=\overline{1,R_{ui}}$:

$$\begin{cases} \left|W_{zfi}\left(i\omega_{fiq}^{opt},\Delta_i^{opt}\right)\right|-I_i\left(\Delta_i^{opt}\right)=0; \dfrac{\partial\left|W_{zfi}\left(i\omega_{fiq}^{opt},\Delta_i^{opt}\right)\right|}{\partial\omega}=0; q=\overline{1,R_{fi}}; \\ \left|W_{zui}\left(i\omega_{uis}^{opt},\Delta_i^{opt}\right)\right|-M_i=0; \dfrac{\partial\left|W_{zui}\left(i\omega_{uis}^{opt},\Delta_i^{opt}\right)\right|}{\partial\omega}=0; s=\overline{1,R_{ui}}; R_{fi}+R_{ui}=k_i+1 \end{cases}$$

(6)

For an unambiguous representation of the system of equations (6), a preliminary unambiguous choice of a combination of quantities is required, which requires additional analysis R_{fi} and R_{ui}, implemented within the framework of the variant under consideration, after which the problem is reduced to solving this system. [5]

For a typical case, when $R_{fi}+R_{ui}=k_i<k_i+1$, system (6) is supplemented by an equation written as a condition of equality to zero of the determinant, composed of the derivatives of the frequency response over the reference and disturbance channels for the desired controller parameters:

$$\det\left[\frac{\partial\left|W_{zui}\left(i\omega_{uis}^{opt},\Delta_i^{opt}\right)\right|}{\partial\Delta_{ij}}; \frac{\partial W_{zfi}\left(i\omega_{fiq}^{opt},\Delta_{fis}^{opt}\right)}{\partial\Delta_{ij}}\right]=0,$$

$$s=\overline{1,R_{ui}}; q=\overline{1,R_{fi}}; R_{ui}+R_{fi}=k_i; j=\overline{1,k_i}.$$

(7)

To solve the problem of parametric synthesis and optimization of a multi-loop cascade ACS based on the alternance method, the following algorithm is proposed in the work:

1. At the first stage, the requirements for the quality of regulation in the frequency domain are formulated in the form of setting restrictions on the oscillation indicators $M_i, i=\overline{1,n}$ for all control loops.

2. At the second stage, the optimal settings are determined $\Delta_1^{opt}=\left(\Delta_{1j}^{opt}\right), j=\overline{1,k_1}$ typical control loop controller $i=1$ according to the scheme of the alternance method described above , based on the requirements for ensuring a given degree of oscillation M_1 of the first circuit through the channel of the master influence and minimization of the circuit's response to an external unregulated disturbing influence f_1.

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3. At each subsequent stage, the problem of parametric synthesis of a typical controller of the i-control loop is solved $\left(i=\overline{2,n}\right)$, i.e. optimal settings are determined $\Delta_i^{\text{opt}}=\left(\Delta_{ij}^{\text{opt}}\right), j=\overline{1,k_i}, i=\overline{2,n}$ regulator according to the scheme of the alternance method, based on the requirements for providing a given degree of oscillation M_i of the circuit under consideration through the channel of the driving influence and minimizing the response of the circuit to an external unregulated perturbing influence f_i, with the optimal settings of the regulators determined at the previous stages $\Delta_l^{\text{opt}}=\left(\Delta_{lj}^{\text{opt}}\right), j=\overline{1,k_l}, l=\overline{1,i-1}$ contours from the 1st to (i -1).

4. At the final stage, the quality of the obtained transient processes of the system and its stability are assessed.

The developed algorithm for parametric synthesis of typical controllers was first tested in relation to a typical ACS by the process of heating the raw materials of the vacuum unit of the AVT installation, which has the worst integral estimates of the efficiency of local control loops of technological parameters. [6]

The thesis considers a typical block diagram of a multi-circuit automatic control system for the process of heating raw materials (Figure 2), consisting of a cascade system with two control loops (regulators $W_{p1}(s,\Delta_1)$ and $W_{p2}(s,\Delta_2)$) for the temperature of the fuel oil at the outlet of the furnace $\left(z_2\right)$ and changing the flow of fuel oil supplied to the furnace $\left(z_1\right)$, and a single-circuit control system (regulator $W_{p0}(s,\Delta_0)$) of the steam flow to the furnace $\left(z_0\right)$.

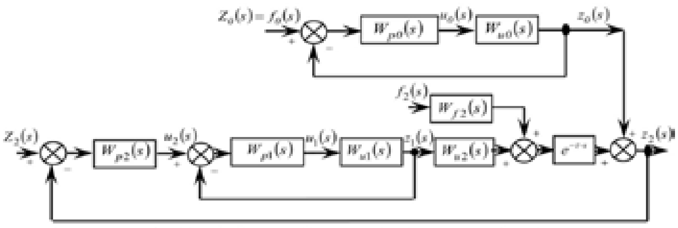

Figure 2 - A typical block diagram of the ACS by the process of heating raw materials

The control object of the internal loop is a section of the pipeline with a transfer function $W_{u1}(s)$, through which fuel is supplied to the furnace.

The transfer function of the control object of the external loop of the cascade system is a linear combination of the transfer function of the closed internal loop and the transfer function $W_{u2}(s)$, which describes the change in the temperature of the raw material volume (z_2) heated in the furnace, and can be represented by a second-order aperiodic link. [7]

The cascade system is affected by external disturbances, the main of which include a change in flow (f_2) superheated steam into the furnace and change in flow (f_0) processed raw materials (fuel oil). At the same time, the consumption (z_0) superheated steam supplied to the furnace is regulated by a local single-circuit ACS (regulator $W_{p0}(s,\Delta_0)$), in which the control action (u_0) is the change in steam flow in the furnace coils.

The control object, described by the transfer function $W_{u0}(s)$, is a section of the steam pipeline through which steam is supplied to the furnace.

In the ACS scheme considered by the structure, the link of the transport delay is assigned to the outputs of the object and the noise filter f_2.

Transfer functions of control objects $W_{u0}(s)$, $W_{u1}(s)$,$W_{u2}(s)$ with constant coefficients are presented in Table 1. Transfer functions of typical regulators $W_{pi}(s,\Delta_i), i=\overline{0,2}$ are considered to be given up to parameter vectors $\Delta_i=(\Delta_{ij}), j=\overline{1,k_i}$ and representable in the standard fractional rational form.

The proportional-integral-differential (PID) law is chosen as the control laws, which is the most universal of the typical control laws and has the greatest control capabilities. Thus, the problem of parametric synthesis and optimization is reduced to the problem of finding the optimal tuning parameters for typical PID controllers in a multi-circuit automatic control system by the process of heating the raw materials of the vacuum unit of the AVT unit.

To solve this problem, we developed an algorithm for solving the problem of parametric optimization of typical controllers in a multiloop control system, which includes the following steps.

1. At the first stage of the solution, using the alternance method, the tuning parameters are

determined $\Delta_1^{opt} = (\Delta_{1j}^{opt}), j = \overline{1,3}$ internal loop controller $i = 1$ cascade system, for which the channel "disturbing influence - controlled value" is not set.

2. The second stage of solving the problem is the optimization of the outer contour $i = 2$ cascade system, i.e. search for a vector of settings parameters Δ_2^{opt} controller $W_{p2}(s, \Delta_2)$ from the condition of minimizing the response of the ACS to the disturbing action f_2. The solution is carried out according to the scheme of the alternance method described above with fixed (obtained at stage 1) optimal values of the tuning parameters Δ_1^{opt} regulator $W_{p1}(s, \Delta_1^{opt})$. In this case, the optimization criterion $I2(\Delta_2)$ is given in the form of functional (3) minimizing the maximum of the amplitude-frequency characteristic $|W2_{zf2}(i\omega, \Delta_1, \Delta_2)|$ contour along the channel of the action of the perturbation f_2, and the restriction $F2(\Delta_2)$ of the form (4) is superimposed on the maximum of the amplitude-frequency characteristic $|W2_{zu}(i\omega, \Delta_1, \Delta_2)|$ contour on the reference channel. [8]

3. At the third stage of solving the problem of parametric optimization of ACS by heating raw materials, the vector is determined Δ_0^{opt} controller settings $W_{p0}(s, \Delta_0)$ local ATS of steam flow to the furnace. A feature of the application here of the procedure of the alternance method described above is the choice as an optimality criterion $I0(\Delta_0)$ maximum frequency response of the cascade automatic control system for the perturbation channel $|W2_{zf0}(i\omega, \Delta_0, \Delta_1^{opt}, \Delta_2^{opt})|$, for which the synthesized control loop acts as an external controlled influence with pre-fixed optimal values of the tuning parameters of the local controllers of the cascade system Δ_1^{opt} and Δ_2^{opt}, found at steps 1 and 2. Constraint $F0(\Delta_0)$ limits the maximum frequency response $\left|W0_{zu}\left(i\omega_{us}^{opt}, \Delta_0^{opt}\right)\right|$ contour to be optimized $i = 0$ through the channel of the master influence.

4. At the final stage, the quality of control processes in the time domain is evaluated and the effectiveness of the ACS after parametric optimization is analyzed based on system integral estimates obtained by the DEA method.

The described algorithm was tested in solving the problem of parametric optimization of a multi-loop automatic control system by heating raw materials for the cases of the presence and absence of transport delay links in the structure of control objects. [9]

The results of solving the problem of parametric optimization of a multi-circuit automatic control system by the process of heating raw materials in the presence of a delay link in the structure of control objects are presented in tables 2-4 for various values of the oscillation indices of local circuits M0, M1 and M2.

Table 1. Transfer functions of the control objects of the automatic control system for the raw material heating

ACS contour	Transfer function, W(s)	Transp. late .
1	$W_{u1}(s) = \dfrac{1}{16 \cdot s + 1};$	0
2	$W_{u2}(s) = \dfrac{48}{742 \cdot s^2 + 239 \cdot s + 1}; W_{f2}(s) = \dfrac{3,6 \cdot (4,67 \cdot s + 1)}{742 \cdot s^2 + 239 \cdot s + 1}$	$\tau = 175c$
0	$W_{u0}(s) = \dfrac{1}{3,6 \cdot s + 1}$	0

Table 2. Results of solving the problem of parametric optimization of the internal contour $i=1$ of the cascade system

M1	1.05	1,10	1.15	1.20	1.25	1.30	1.35	1.40	1.5	1.6
Δ_{11}^{opt}	15	15	15	10	10	10	10	10	6	6
Δ_{12}^{opt}	48.8	30.6	22.3	16.5	13.8	11.9	10.42	9.29	7.27	6.23
Δ_{13}^{opt}	2.44	10.88	17.18	6.83	9.07	10.9	12.4	13.6	1.94	2.82

Table 3. Results of solving the problem of parametric optimization of the external contour $i=2$ of the cascade system

M1	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70
Δ_{21}^{opt}	0.118	0.144	0.171	0.198	0.226	0.254	0.282	0.311	0.340	0.369
Δ_{22}^{opt}	1.421	1.467	1.511	1.554	1.595	1.634	1.671	1.708	1.742	1.776
Δ_{23}^{opt}	3.711	3.824	3.938	4.052	4.167	4.282	4,398	4.514	4,630	4,746
$I2(\Delta_2^{opt})$	0.072	0.074	0.075	0.077	0.079	0.080	0.082	0.084	0.085	0.087

Table 4. Results of solving the problem of parametric optimization of the local contour $i=0$ regulation of steam flow into the furnace

M1	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70
Δ_{01}^{opt}	1.776	1,760	1.778	1.816	1.897	1.967	2.130	2.302	2.546	2.864
Δ_{02}^{opt}	0.474	0.316	0.198	0.105	0.033	-0.034	-0.081	-0.126	-0.164	-0.197
Δ_{03}^{opt}	10.953	11,530	12.274	13.173	14,330	15.609	17.401	19.499	22.216	25.727
$I0(\Delta_0^{opt})$	1.377	1.432	1.488	1.542	1.598	1.652	1.708	1.763	1.818	1.873

As an example, Figure 4 shows a graph of transient processes in the synthesized control system with optimal settings for the controllers during the initial start-up of the furnace at the time $t_1 = 0$ sec with reaching the specified fuel oil temperature $(Z_1 = (390^0\text{C})$ and the action of external disturbances: a change in the flow rate of superheated steam (through the channel $f_2 \to z_2$) at time $t_1 = 1500$ sec and a change in the flow rate of raw materials (through the channel $f_0 \to z_0$) at time $t_2 = 3000$ sec. [10]

The use of the DEA method for assessing the effectiveness of control showed that after parametric optimization, local ACS, which had the worst integral estimates of the quality of control processes, now received estimates equal to one, which means that they fully comply with the requirements for transient and steady-state operation of the ACS.

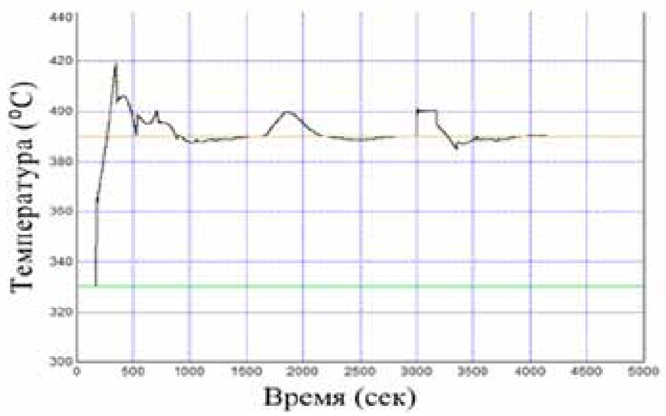

Figure 3 - Transient processes in the automatic control system with the temperature of the fuel oil of the AVT installation at M0=1.25, M1=1.6, M2=1.5

Conclusion. An analysis of a typical multi-stage process of primary oil refining as a complex technical object of control and optimization is given, which allows, based on the construction of system integral estimates of the relative efficiency of local control loops, inefficiently controlled technological parameters are identified and the corresponding multiply connected control systems are optimized.

1. The evaluation of the efficiency of control of typical oil refining processes using the proposed methods leads to the need for parametric optimization of multiloop control systems that do not meet the requirements for control quality.

2. The problem of optimizing cascade control systems is formulated and an algorithm for solving it developed on the basis of the alternance method is proposed, which allows to ensure the maximum degree of invariance of local control loops with respect to external disturbances under given restrictions on the maxima of the amplitude-frequency characteristics of closed local loops of the synthesized ACS along the channels of master influences.

3. The dynamics of control objects is described and the synthesis of mathematical models of local automatic control systems is presented in the form of transfer functions for the considered channels of action of master and disturbing influences on the example of automatic control system by the process of heating the raw material of the vacuum block of the AVT installation. [11]

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