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CONSTRUCTION OF THE VECTOR OF MINIMUM WORKS FOR THE PERFORMANCE OF THE SCHEDULED TASKS OF THE OPERATIONAL AND DISPATCH MANAGEMENT OF THE TECHNOLOGICAL COMPLEX

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Annotation---*The properties of the noise immunity assessment for each mine vector are analyzed, which, using the constructed estimate, can determine the minimum mine vector that provides the same results of the complex and has the same noise immunity rating as this vector, but which has the lowest mine values. The properties of the noise immunity criterion for the implementation of a chemical-technological complex with a complex structure are generalized. It is proved that the properties of the introduced noise immunity assessment allow it to be used as an optimality criterion in the formulation and solution of problems of compensation for losses from disturbances in systems of operational dispatch control of chemical-technological complexes with a continuous nature of production.*

Keywords---*operational dispatch control, noise immunity, noise immunity assessments, technological units, chemical-technological complex, optimality criteria, drive, branched structure, technological chains.*

I. Introduction

The main factors determining the quality of production management are the volume of output, its cost and quality. Any change in the mode of production leads, in the general case, to a change in these three indicators.

Management by the criterion of stability allows without unnecessary overloads to ensure that the technological nodes fulfill the planned task. Stability of loads - an indispensable condition for the optimal conduct of the process. Ultimately, this provides an improvement in the technical and economic indicators of production [1].

Typically, the quality assessment of operational dispatch control is carried out according to the unit cost of resources per unit of product – expense ratios. However, the values of the latter are generalized indicators and characterize the losses not only from the inconsistency of the operation of technological units, but also from a number of other reasons that are independent of the operational dispatch control.

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It is very difficult, and often impossible, to isolate the amount of losses due to inconsistency in production work:
- changes in expenditure coefficients can occur due to changes in the number of products in intermediate containers or in the reaction apparatus of the technological unit under consideration;
- the value of the expenditure coefficient is often associated with the level of load, temperature, pressure and other indicators of the technological regime, the fluctuations of which (even within the limits allowed by the rules of the regulation) can lead to significant changes;

II. Solutions to the task

In the process of operational dispatch control of the chemical and technological complex, the dispatcher, in addition to the main goal - ensuring the fulfillment of planned tasks, can be assigned additional tasks to optimize any parameters of the production process. When solving such problems, it is important to maintain at an acceptable level the ability to execute the plan by the management object. For this, it is necessary to determine the minimum values of the workings sufficient for the technological complex to fulfill its planned tasks and use these values as the lower limits when setting and solving the optimization problems mentioned above. The construction of the minimum values of workings that provide a given level of noise immunity can be carried out as follows [2, 3].

Suppose that at time t_0 the technological complex is characterized by a vector of workings $Q^0(t_0) = (g_1^0(t_0), \dots, g_N^0\,(t_0))$. We construct for this complex a new vector of workings as follows.

For each $x \in X_a\left(Q^0(t_0)\right)$ we define a vector of workings $Q^x(t_0) = (g_1^x(t_0), \dots, g_N^x(t_0))$-such that the loads of technological nodes $G_i^x(T), i = 1, \dots, N$ do not limit each other, i.e. so that for each of the nodes separately, equality holds

$$G_i^x(T) = g_i^x(t_0)(T - t_0) + G_i(t_0) - W_i^e. \tag{1}$$

For technological nodes that are not limited by other nodes, put

$$g_i^x(t_0) = g_i^0(t_0) \tag{2}$$

Then, in the process chain under consideration, we choose such sequences of nodes Π_k, Π_m in which either Π_k, or Π_m limit all the other nodes. If the limiting node in this sequence is Π_k, then in accordance with statement (1) for operating time of nodes Π_{k+1}, Π_m,

$$G_i^0(T) = V_i^-(T), \quad i = k + 1, \dots, m \tag{3}$$

is true.

Then, the quantities $g_i^x(t_0)\;(i = k + 1, \dots, m)$ will be determined from the condition of equality of developments

$$G_i^x(t_0) = \frac{V_i^-(T)}{T - t_0}. \tag{4}$$

Thus, we have

$$g_i^x(t_0) = \frac{V_i^-(T)}{T - t_0}. \tag{5}$$

If the limiting node in the selected chain is a node, then for the developments of nodes $\Pi_i(i = m - 1, m - 2, \dots, k)$,

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$$G_i^0(T) = V_i^+(T). \tag{6}$$

is true.

This equality is valid because of the above statement (1). In this case, the values величины $g_i^x(i = m - 1, m - 2, \dots, k)$, are also determined from condition (4) and have the following values

$$g_i^x(t_0) = \frac{V_i^+(T)}{T - t_0}. \tag{7}$$

For values $g_i^*(t_0)$, select values

$$g_i^*(t_0) = \max_{x \,\epsilon\, X_a(Q^0(t_0))} g_i^x(t_0) \tag{8}$$

The constructed vector of workings $Q^*(t_0)$ is called minimal. We show that it has the following properties.

1. $G_i^*(T) = G_i^0(T), \dots, (i = 1, \dots, N)$; for all
2. $x \,\epsilon\, X_a(Q^0(t_0))$ (9)

$$Z_a(Q^*(t_0)) < Z_a(Q^0(t_0)) \tag{10}$$

3. For any vector $Q^k(t_0)$, such that $G_i^k(T) \geq G_i^0(T), (i = 1, \dots, N)$ for all $x \,\epsilon\, X_a(Q^0(t_0))$, the inequality

$$g_i^*(t_0) \leq g_i^k(t_0), (i = 1, \dots, N) \tag{11}$$

is true.

The validity of equality (9) for nodes whose operating time is not limited to the operating time of other nodes follows from (2).for the rest, equality (8), since (4) is true for any $x \,\epsilon\, X_a(Q^0(t_0))$.

Let us now show the validity of equality (10). To do this, it is enough to prove that

$$x \,\epsilon\, X_a(Q^0(t_0)) = x \,\epsilon\, X_a(Q^*(t_0)). \tag{12}$$

From (9) it follows that for each $x \,\epsilon\, X_a(Q^0(t_0))$

$$r(x, Q^0(t_0)) = r(x, Q^*(t_0)), \tag{13}$$

i.e. $x \,\epsilon\, X_a(Q^*(t_0))$, hence

$$X_a(Q^0(t_0)) < X_a, (Q^*(t_0)). \tag{14}$$

Let now there is such a $x \,\epsilon\, X_a(Q^*(t_0))$, that

$$x' \notin X_a(Q^0(t_0)). \tag{15}$$

This means that for x' the inequality

$$r(x', Q^0(t_0)) < a \leq r(x', Q^*(t_0)) \tag{16}$$

holds or, according to the definition of the mapping r,

$$\min_{i = 1, \dots, N} r_i(x_1' Q^0(t_0)) < \min_{i = 1, \dots, N} r_i(x_1' Q^*(t_0)) \tag{17}$$

formulated above.

Let $\min_{i = 1, \dots, N} r_i(x_1' Q^0(t_0))$ be reached at $i = k$. Then, inequality

$$G_k^0(T) < G_k^*(T) \tag{18}$$

follows from (17), which contradicts equality (9) proved above, therefore, premise (15) is false, and for any it follows that $x \,\epsilon\, X_a(Q(t_0))$, that is,

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$$X_a(Q^*(t_0)) < X_a(Q^0(t_0)). \qquad (19)$$

Expressions (14) and (19) taken together indicate the validity of (12), from which directly follows (10). Thus, the second property is proved.

We prove the third property by contradiction. To do this, suppose that, under the conditions of the considered property, one can still find a vector $Q^k(t_0)$, such that inequality (11) is violated for some node Π_m, in other words,

$$g_m^*(t_0) > (t_0). \qquad (20)$$

From the construction of vector $Q^*(t_0)$ it follows that there is $x' \epsilon X_a(Q^0(t_0))$, such that the operating time of $G_m^*(T)$ nodes Π_m is not limited by the operating time of other nodes:

$$G_m^*(T) = g_m^*(t_0)(T - t_0) + G_m(t_0) - W_m^e \qquad (21)$$

Then, by virtue of (20), in this case, x' will not be limited by the operating time of $G_m^k(T)$, hence,

$$G_m^k(T) = g_m^k(t_0)(T - t_0) + G_m(t_0) - W_m^e \qquad (22)$$

It follows from (20), (21), (22) and the proved expression (9) that

$$G_m^0(T) = G_m^*(T) > G_m^k(T) \qquad (23)$$

However, this contradicts the conditions of the third property. From this we can conclude that assumption (20) is false. Thus, this property is proved.

Investigation of the properties of the proposed noise immunity criterion. We show that the properties of the noise immunity criterion, formulated and proved above, remain valid for a complex chemical-technological complex, which contains in addition to simple elements of the connection of separation, branching and merging of flows [4, 5].

The relationship between the possible operating time of the technological units and the reserves of the drives as well as for the linear technological chain will be obtained by converting the expression

$$S_J(t) = S_J(t_0) + \int_{t_0}^{t} B_j(u)du\,, \qquad (24)$$

reflecting the level of product stocks in the drive C_j. Moreover, given the complexity of the structure of the control object under consideration, the difference between the intake and consumption of the product can be written in form

$$B_j(u) = \sum_{k\epsilon k_j^+} g_k(u) - \sum_{k\epsilon k_j^-} g_k(u). \qquad (25)$$

Here, all $g_k(u)$ values are converted into units of the final product, K_j^+ - means the set of values of the indices of technological units that are suppliers of drive C_j, and K_j^- - the set of values of indices of technological units that are consumers of the same drive.

Let node Π_i be the consumer of node C_j, and the supplier of node C_m, then from (24) and (25) for C_j we have

$$S_j(t) = S_j(t_0) + \sum_{k\epsilon K_j^+} \int_{t_0}^{t} g_k(u)du - \sum_{k\epsilon K_j^-} \int_{t_0}^{t} g_k(u)du ==$$
$$S_j(t_0) + \sum_{k\epsilon K_j^+}(G_k(t) - G_k(t_0)) - \sum_{k\epsilon K_j^-}(G_k(t) - G_k(t_0)) = S_j(t_0) + \sum_{k\epsilon K_j^+} G_k(t) - \sum_{k\epsilon K_j^-} G_k(t_0) +$$
$$\sum_{k\epsilon K_j^-} G_k(t_0) - \sum_{k\epsilon K_j^-} G_k(t_0) - G_i(t) \qquad (26)$$

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Hence, since $S_j(t) \geq S_j^{min}$ we get

$$G_i(t) \leq S_j(t_0) - S_j^{min} - \sum_{k\epsilon K_j^+} G_k(t_0) + \sum_{k\epsilon K_j^+} G_k(t) + \sum_{k\epsilon K_j^-} G_k(t_0) - \sum_{\substack{k\epsilon K_j^- \\ k\neq i}} G_k(t). \quad (27)$$

The estimate (27) is valid for all C_j, the consumer of which is the node Π_i, therefore

$$G_i(t) \leq V_i^-(t) = \min_j \{V_{ij}(t)\}, \quad (28)$$

where $V_{ij}(t)$ is determined by the right-hand side of inequality (23).

Similarly, for node C_m we get

$$G_i(t) \leq S_m^{max} - S_m(t_0) - \sum_{\substack{k\epsilon K_m^+ \\ k\neq i}} G_k(t) + \sum_{k\epsilon K_m^+} G_k(t_0) - \sum_{k\epsilon K_m^-} G_k(t_0) + \sum_{k\epsilon K_m^-} G_k(t) \quad (29)$$

Since inequality (29) is valid for all C_m, the supplier of which is node Π_i, then

$$G_i(t) \leq V_i^+ = \min_m \{V_{im}(t)\}, \quad (30)$$

where $V_{im}(t)$ is determined by the right-hand side of inequality (29).

Then, for operating time $G_i(t)$ of technological unit Π_i, a chemical-technological complex with a branched structure, an estimate of

$$G_i(t) min\{G_i(t_0) + g_i(t_0)(t - t_0) - W_m^e, V_i^+(t)\} \quad (31)$$

establishes the relationship between the possible operating time of the nodes of the control object under consideration.

It is easy to verify, repeating the corresponding arguments, that the corollary arising from statement (24) remains valid for a complex technological complex.

The proof of the first of two statements establishing the dependence of the noise immunity value on the values of the workings of technological units for a linear production chain remains valid regardless of the structure of the object in question [6].

When proving the second of these statements, sequences of technological units are considered, in which either each subsequent technological unit limits the previous one, or vice versa, each previous technological unit limits the next one. Similar sequences can be chosen for a complex chemical-technological complex. Let, for example, the operating time of unit Π_i be limited to the operating time of subsequent technological units. This means that the drive is overflowing, the supplier of which is the given technological unit. If there are several such drives, then we select one among them that will overflow faster than the rest, let it be drive C_j and consider its consumers. As the next element of the limiting sequence, any of the consumers of node C_j can be selected, the operating time of which is limited by the operating time of subsequent technological nodes. For the next technological unit selected in this way, we repeat the described procedure. And so on, until at the next step it turns out that the technological units, the operating time of which are limited by the operating time of subsequent technological units, are exhausted. In the same way, you can select the limiting sequence going from this technological unit to the beginning of the technological complex. The constructed limiting sequences are linear, therefore, for them one can repeat all the arguments given in the proof of the statement under consideration. This ensures the validity of the established

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relationship between the value of noise immunity and the values of the workings of technological units for objects with a branched structure.

We generalize the concept of a vector of minimum workings for a complex chemical-technological complex [7, 8].

It follows from the above description of the procedure for constructing the limiting sequence of technological unit Π_i that such a sequence is not unique, since there are several possibilities for choosing the next element of this sequence if node C_j has several consumers whose operating time is limited by subsequent nodes. To build a vector of minimum workings, it is necessary to consider for all technological nodes Π_i and all $x \epsilon X_a\left(Q^0(t_0)\right)$ a complete set of limiting sequences [9]. The values $g_{ij}^x(t_0)$ are determined for each 2nd limiting sequence from condition (4) based on the estimate (7) and then, as $g_i^x(t_0)$, the maximum is taken for all possible limiting sequences for a given node Π_i for a given x, i.e.

$$g_i^x(t_0) = \max_j g_{ij}^x(t_0) \quad (32)$$

The values of $g_i^*(t_0)$ for a complex chemical-technological complex are determined in the same way as for a linear technological chain using expression (8).

The constructed vector of minimum workings for a chemical-technological complex with a complex structure has all the properties established earlier. This follows from the fact that the choice of $g_i^x(t_0)$ values according to expression (8) ensures the validity of all calculations presented in the proof of the corresponding statement for a linear technological chain [10].

III. The results obtained in the study of the properties of the proposed noise immunity criterion allow us to draw the following conclusions.

Firstly, an increase in the production of a technological unit can only lead to an increase in the noise immunity Z_a of the entire chemical-technological complex. Secondly, a greater value of the noise immunity Z_a of the complex should correspond to a greater value of the output (at least at least one technological unit).

These conclusions are in good agreement with the general idea of the relationship between the development of technological units and the logic of obtaining an assessment of the possibility of fulfilling planned tasks. In the end, these general ideas come down to the fact that the level of production of technological units is higher. However, due to the mutual influence of technological units, not every increase in the production of a technological unit leads to an increase in its operating time (and, therefore, to an increase in the potential for fulfilling planned tasks). As shown above, the latter is true for the proposed method for assessing the possibility of fulfilling planned tasks based on the noise immunity criterion of the system. Therefore, the proposed criterion, given the relationship between the production and operating time of technological units, reflects the mutual influence of technological and storage units on each other, due to the structure of the studied chemical-technological complex.

Of great importance is the vector of minimum workings $Q^*(t_0)$, built on the basis of the initial vector of workings $Q^0(t_0)$. According to the last proven statement, this vector, providing the same operating time and having the same noise immunity as the original vector, is composed of the smallest loads of technological units.

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Thus, the vector of minimum workings $Q^*(t_0)$ can be used by the dispatcher as a restriction from the bottom when solving tasks of operational dispatch control according to other criteria. In this case, according to the proven properties of the vector of minimum workings, the value of the noise immunity of the chemical-technological complex under consideration is preserved.

zThe foregoing testifies in favor of applying the proposed criterion in the implementation of the tasks of the operational dispatch control of chemical-technological complexes with a continuous nature of production.

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