Noise Immunity Criterion for the Development of a Complex Automated Technological Process

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Abstract. The proposed structure of an automated system of operational dispatch control of a complex technological complex using the criterion of noise immunity for decision-making. On the basis of the proposed noise immunity criterion for the operational dispatch control system of a complex technological complex, tasks are formulated that ensure forecasting the possibility of performing planned tasks, determining the control actions necessary to ensure the possibility of performing planned tasks with a given permissible noise immunity assessment, maximizing output while maintaining the permissible value of noise immunity.

1 Introduction

The analysis of the shortcomings of purely "manual" and purely "machine" control allows us to conclude that the effective use of computers in operational management tasks is the creation of interactive systems in which the computer's capabilities to quickly and accurately perform complex calculations are combined with the opportunity provided to a person to evaluate the solution (including by non-formalized criteria), identify critical situations and take measures to eliminate them. Direct communication of the user with the computer increases the efficiency of decision-making. A user's dialog communication with a computer is a process of solving a problem on a computer in which the operator takes an active part in order to obtain the necessary information, control the decision process, input and correction of initial data, and decision-making in various situations. Thus, a human-machine complex is organized in which the user performs functions that are not yet available for computers, or helps to take into account factors that have manifested themselves in the process of solving the problem. At the same time, the operator evaluates the quality of the solution of the problem, using an informal system of preferences, and makes a decision with proximity to optimal operating conditions, being satisfied with the solution found or continuing the search [1].

As the main requirement for an automated management system in general and an operational management system in particular, the following can be distinguished: the system should help to develop informed decisions in a limited time interval (i.e. promptly).

The concept of the validity of a decision made in conditions of uncertainty is more intuitive than formal today. A more reasonable solution allows you to bring the managed

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object to the goal faster and at a lower cost, without worsening the functioning conditions of the interconnected elements of this object, which this decision may affect indirectly [99]. The purpose of increasing the degree of validity of decisions is the use of mathematical models and methods of information processing. The decisions made will be more reasonable if, firstly, the mathematical models used objectively reflect the content of the processes taking place in the controlled object [2]. This is achieved if more accurate methods of information processing are used, as well as the volume of source data is greater than the decision-maker can process without mathematical models. At the same time, the most significant is the possibility of taking into account the data characterizing the managed object as a whole, which makes it possible to assess the influence of interrelated elements of the object under consideration on each other. Secondly, the degree of validity of the decision can be increased by repeatedly using a mathematical model to evaluate various solutions [3].

However, even an informed decision will be useless if it is not developed in a timely manner. Therefore, mathematical and software should allow the control system to function at the real pace of the flow of the control process. At the same time, the time of preparation of the solution variant by the system should be a temporary controlled value. If algorithms have the ability to prepare a solution only in a fixed time t, then they will be useless in all situations when the time allotted for making a decision is less than t. If, however, a time greater than t is allocated for making a decision, then an algorithm with a fixed decision time will not be able to use the time resource to obtain a more informed decision. Thus, an automated operational management system should have the properties to the time resources available to justify the decision. Reducing the resources of computing time inevitably affects the quality of the results. They will be less accurate, but the decision will be made [4]. Obviously, there is a lower bound on the value of the time resource for making a decision, beyond which it is impossible to carry out the necessary calculations.

Operational dispatch control according to the predicted disturbance using the noise immunity criterion consists in finding such values of workings of technological nodes that would provide a given value of noise immunity of the technological complex [1, 2].

The main idea of the proposed approach is as follows. At the current moment of time t, given a certain value, and the degree of completion of the planned task, determine the noise immunity Z_a (t) of a complex technological complex. If the value of $Z_a(t)$ is less than the permissible value, then determine the control action necessary to achieve the permissible value of noise immunity. In addition to the main task of performing scheduled tasks, the dispatcher may also be tasked with optimizing some indicator or criterion of the production process. In this case, it is necessary to determine the control actions that deliver the permissible value of noise immunity.

The method of solving the problem of noise immunity of the measured parameters of technological units. To implement such an approach in an automated operational dispatch control system, the tasks of assessing noise immunity, increasing noise immunity, optimizing a given objective function while maintaining the permissible value of noise immunity must be solved.

We show that the properties of the noise immunity criterion formulated and proved above retain validity for a complex technological process containing in its structure, in addition to simple ones, elements of separation, branching and merging of flows.

The ratio between the possible operating time of technological nodes and storage stocks is the same as for a linear technological chain obtained by converting the expression

$$S_J(t) = S_J(t_0) + \int_{t_0}^{t} B_j(u)du \quad (1)$$

reflecting the level of product stocks in the C_j storage. At the same time, given the complexity of the structure of the control object under consideration, the difference between the receipt and consumption of the product can be written as

$$B_j(u) = \sum_{k\epsilon k_j^+} g_k(u) - \sum_{k\epsilon k_j^-} g_k(u) \tag{2}$$

Here, all values of $g_k(u)$ are converted into units of the final product, K_j^+ - means the set of index values of technological nodes that are suppliers of the C_j drive, and K_j^- - the set of index values of technological nodes 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 (1) and (2) for C_j we have

$$S_j(t) = S_j(t_0) + \sum_{k\epsilon K_j^+} \int_{t_0}^{t} g_k(u)du - \sum_{k\epsilon K_j^-} \int_{t_0}^{t} g_k(u)du = S_j(t_0) + \sum_{k\epsilon K_j^+}(G_k(t) - G_k(t_0)) - \sum_{k\epsilon K_j^-}(G_k(t) - G_k(t_0)) = -\sum_{k\epsilon K_j^-} G_k(t_0) + \sum_{k\epsilon K_j^-} G_k(t_0) - \sum_{k\epsilon K_j^-} G_k(t_0) - G_i(t) \tag{3}$$

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

$$G_i(t) \leq S_j(t_0) - S_j^{min} - \\ -\sum_{k\epsilon K_j^+} G_k(t_0) + \sum_{k\epsilon K_j^+} G_k(t) + \sum_{k\epsilon K_j^-} G_k(t_0) - \sum_{\substack{k\epsilon K_j^- \\ k\neq i}} G_k(t) \tag{4}$$

The evaluation (4) is valid for all $C_j$whose consumer is node Ii, therefore

$$G_i(t) \leq V_i^-(t) = \min_j \{V_{ij}(t)\}, \tag{5}$$

where$V_{ij}(t)$ defined by the right -hand side of the inequality (3).

Similarly, for a node $C_m$we get

$$G_i(t) \leq S_m^{max} - S_m(t_0) - \\ -\sum_{\substack{k\epsilon K_m^+ \\ k\neq i}} G_k(t) + \sum_{k\epsilon K_m^+} G_k(t_0) - \sum_{k\epsilon K_m^-} G_k(t_0) + \sum_{k\epsilon K_m^-} G_k(t) \tag{6}$$

Since inequality (6) is true for all C_m, the supplier of which is node Pi, then

$$G_i(t) \leq V_i^+ = \min_m \{V_{im}(t)\} \tag{7}$$

where$V_{im}(t)$ is determined by the right-hand side of the inequality (6).

Then, for the development of $G_i(t)$ of the technological node Π_i, a chemical-technological complex with a branched structure, an estimate is valid

$$G_i(t)\min\{G_i(t_0) + g_i(t_0)(t - t_0) - W_m^e, V_i^+(t)\} \tag{8}$$

establishing the relationship between the possible operating times of the nodes of the control object under consideration.

It is easy to verify, by repeating the relevant reasoning, that the consequence arising from statement (8) 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 nodes for the linear production chain remains valid regardless of the structure of the object under consideration.

When proving the second of these statements, sequences of technological nodes are considered, in which either each subsequent technological node limits the previous one, or vice versa, each previous technological node limits the next one. Similar sequences can be chosen for a complex chemical-technological complex. Let, for example, the operating time of the Π_i node is limited by the operating time of subsequent technological nodes. This means that the drive, the supplier of which is this technological node, is overflowing. If there are several such drives, then we choose among them the one that will overflow faster than the others, let it be a C_j drive and consider its consumers. As the next element of the limiting sequence, any of the consumers of the C_j node can be selected, the operating time of which is limited by the operating time of subsequent technological nodes. For the next technological node selected in this way, we repeat the described procedure. And so on until, at the next step, it turns out that the technological nodes, the developments of which are limited by the developments of subsequent technological nodes, are exhausted. In the same way, you can choose a limiting sequence going from this technological node to the beginning of the technological complex. The constructed limiting sequences are linear, therefore, for them it is possible to repeat all the arguments given in the proof of the statement in question. This ensures the validity of the established relationship between the amount of noise immunity and the values of the workings of technological nodes for objects with a branched structure. Let's generalize the concept of the vector of minimum workings for a complex chemical-technological complex.

From the above description of the procedure for constructing the limiting sequence of the technological node Π_i, it follows that such a sequence is not the only one, since there are several possibilities for choosing the next element of this sequence if the node C_j has several consumers whose operating time is limited by subsequent nodes. To construct a vector of minimum workings, it is necessary to consider for all technological nodes Π_i and all $x \epsilon X_a(Q^0(t_0))$ a complete set of limiting sequences. The values of $g_{ij}^x(t_0)$are determined for each limiting sequence from condition (5) based on the estimate (8) and then as $g_i^x(t_0)$, the maximum for all possible limiting sequences for a given node Π_i is taken for a given x, that is

$$g_i^x(t_0) = \max_j g_{ij}^x(t_0) \tag{9}$$

Values of $g_i^*(t_0)$for a complex chemical-technological complex, they are determined in the same way as for a linear technological chain using expression (9).

The constructed vector of minimum workings for a chemical-technological complex with a complex structure has all the properties previously established. This follows from the fact that the choice of values $g_i^x(t_0)$according to expression (9) ensures the validity of all calculations given in the proof of the corresponding statement for the linear technological chain.

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 node 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 of the Z_a complex should correspond to a greater value of the output (at least, at least only one technological node) [3].

These conclusions are in good agreement with the general idea of the relationship between the workings of technological nodes and the logic of obtaining an assessment of

the possibility of performing planned tasks. These general ideas boil down in the end to the fact that the level of production of technological nodes is higher. However, due to the mutual influence of technological nodes, not every increase in the production of a technological node leads to an increase in its operating time (and therefore to an increase in the potential for performing planned tasks). As it was shown above, the latter is true for the proposed method of evaluating the possibility of performing planned tasks based on the criterion of noise immunity of the system. Therefore, the proposed criterion, taking into account the dependence 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 chemical-technological complex under study.

The vector of minimum workings $Q^*(t_0)$, built on the basis of the original vector of workings $Q^0(t_0)$, is important. According to the last proven statement, this vector, providing the same developments and having the same noise immunity as the original vector, is made up of the smallest loads of technological nodes.

2 Conclusion

Thus, the vector of minimum workings $Q^*(t_0)$can be used by the dispatcher as a constraint from below when solving operational dispatch control tasks according to other criteria. At the same time, according to the proven properties of the vector of minimum workings, the value of noise immunity of the considered complex technological complex remains.

The above indicates in favor of the application of the proposed criterion in the implementation of the tasks of operational dispatch control of chemical and technological complexes with a continuous nature of production.

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