Centralized Control System of the Flotation Department: Ross-Eshby Principle

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Abstract. The aim of the study is to scientifically substantiate the need to use the axiomatic approach when choosing and studying the processes of centralized dispatching control of technological parameters for a complex of flotation machines. During the research, the authors performed: comparison of a real object and its properties with the classical control axioms of system analysis; substantiated the use of a hierarchical structure of interrelated technological parameters and their application for situational management. Methods of classical control axioms of system analysis were used for the research. The authors formulated the criteria for situational management, the concept of visualization in the dispatching system. The results obtained allow us to assert that the implementation of the Ross-Ashby principle significantly increases the controllability of technological processes with a large number of units and measured parameters.

1. Introduction

The development of automated control systems for technological processes has passed the stages of general mechanization, general automation and is in the stage of active development of intelligent control systems [1]. This intellectualization was laid down in 2018 by the national project "Science" and requires a transition to advanced digital, intelligent production technologies, robotic systems, new materials and design methods, the creation of systems for processing large amounts of data, machine learning and artificial intelligence [2].

This transition is most relevant for the regions that provide the metallurgical, construction, engineering industries and dual-use production. Enterprises of such industries in the modern economy include beneficiation plants for non-ferrous metals. The high cost and demand for non-ferrous metals determine new challenges to control systems for technological processes of their production, which is confirmed by the positive dynamics of copper production on an annualized basis and a 1.6-fold increase in prices for it in comparison with 2016 [3].

Accordingly, modern scientific developments in the development of automated control systems for flotation processes cover research:
- to identify factors that influence the values of technological parameters and operating modes of the flotation machine on its productivity and the quality of the resulting product [3];

- determination of the structure of the production management system (MES) and integration into it of control subsystems for individual subprocesses: supply of reagents, determination of particle size, material feed rate, etc. [four];

- the human factor and expert assessment of a technologist in control systems in determining the situational state of processes and making decisions based on the results of this assessment [1-3];

- determination of the structure of dispatch control systems, visualization tools and indication of the stability of the state of both the system as a whole and individual processes and subprocesses [1-3].

Modern dispatching systems of large enterprises are complexes, which based on centralized collection of information and system analysis, allow you to see the state of the system as a whole and its individual parts. The authors of the study adhere to the point of view of scientists A.A. Musaev, Yu.M. Sherstyuk. [1-3] on the transition from the traditional control room, focused on the tasks of episodic distribution of material or energy flows, to powerful analytical centers for operational management of all production activities of the enterprise. In the works of V.S. Anfilatov, A.A. Emelyanova, A.A. Kukushkina [4-5] noted that systems with control are created to achieve specific goals that are defined in the framework of other sciences.

In works [1-3], a classification of management systems is proposed: organizational (social) management systems; technical control systems; organizational and technical (integrated) management systems. According to this classification, the automation system of the flotation department of the beneficiation production is an organizational and technical system. This corresponds to the definition of both complex and large systems. In the works of specialists [4-5] it is noted that the management of large systems is based on the joint participation of people and technical means in the process. In this case, the implementation of formalized operations is assigned to computer technology, and decision-making based on informal methods - to technologists and managers.

The availability of modern methods and techniques for collecting and structuring information flows that characterize production processes and subprocesses remains unrealized in the format of a complete centralized dispatching process for industries in which the multistage technology and interdependent factors are presented.

Despite the presence of theoretical and practical research in the field of synthesis of dispatch control systems, the following problems remain unresolved:

- disregard for the fundamental procedures of the system analysis of processes and sub-processes when establishing relationships between individual factors of the same level and between the levels of automated systems;

- insufficient development of a system of universal procedures that allow building a hierarchical structure of technological process parameters for centralized dispatching and situational control with their subsequent use in algorithms for determining production efficiency.

Taking into account the results of modern theoretical and practical developments, the authors determined the purpose of the study: scientific substantiation of the application of the axiomatic approach of system analysis to build an information system for flotation control and detailing decisions when constructing algorithms, as well as the synthesis of key performance indicators in a new system of centralized dispatch control of the flotation department using the example of PJSC "Uchalinsky mining and processing plant".

2. Research methodology
Before applying the classical control axioms of system analysis [4-8], it is necessary to determine the control object. The object of management within the framework of the study was the copper and copper-zinc ore flotation department. The facility is complex-structured, as it includes more than 80 flotation machines.

To collect data and control the complex of flotation machines, the local network of the enterprise is used, which includes automated workstations for controlling parameters to transfer their values to a
server for centralized processing. Let's consider the elements of the existing automation system in accordance with the classical axioms of management of system analysis.

**Axiom 1.** The presence of observability of the control object.

**Axiom 2.** The presence of controllability of the object of observation

The tasks of observation and controllability in the conditions of the control object are solved quite effectively within the framework of the functioning of local subsystems for controlling the technological processes of the flotation separation.

**Axiom 3.** The presence of the goal of controlling the object of observation.

The purpose of the flotation department management is to ensure the release of commercial copper and copper-zinc concentrate corresponding to a set of technological regulations based on the decision of an expert technologist based on information obtained using technical means of automatic and automated control.

**Axiom 4.** Availability of freedom of choice of control actions from a variety of alternative solutions.

In the process of examining the structure of the flotation department and the technology of flotation of copper and copper-zinc concentrate, it was revealed that the process of flotation control is multi-level. To describe and describe resource-intensive flows, more than 50 stages (flotation, regrinding, cleaning, etc.) with partial recursion are used. Currently, there are opportunities to use alternative and indirect information, with the help of which it is possible to carry out modeling of indicators of the quality of finished products [9-14].

Observance of Axiom 4 requires the definition of a set of key indicators that can be used in the decision-making process and in the formation of a set of trajectories for choosing alternatives.

**Axiom 5.** The presence of a criterion for the effectiveness of control of the object of observation.

The key performance indicator is the maximum recovery of the useful component in the foam product at each stage of flotation. The effectiveness of management in accordance with the criterion is achieved on the basis of analysis and decision-making when integrating data from the product quality control system.

**Axiom 6.** Availability of resources to ensure the implementation of the decisions taken.

Consolidating is informational, which is mainly based on a set of hierarchically ordered indicators. In the production of extraction of copper and copper-zinc concentrate, despite a large number of measured parameters (more than 500) and a continuously changing process, there are problems associated with the discreteness of information. In accordance with [4-5], when controlling the process of extracting copper and copper-zinc concentrate in production conditions, there are deviations of the state of the controlled object relative to the given one. This is determined by the fact that the control system is generally subject to external influences and does not have complete information about the state of the environment and the control object. This leads to the fact that the control actions do not fully correspond to the required actions. The quality of control is determined by the amount of mutual information in the control actions regarding the states of the controlled object. This corresponds to the fundamental principle of cybernetics, known as the principle of required diversity (W. Ross Ashby's principle), formulated as: “The diversity of the control system must be no less than the diversity of the control object” [4-5], which notes that to improve the quality of control it is necessary:

1. to reduce the variety of states of the controlled object;
2. increase the variety of control actions, bringing it closer to the variety of states of the controlled object;
3. to reduce the ambiguity of control actions with respect to the states of the control object.

**3. Results of theoretical research**

When constructing information support for the process of recovering copper and copper-zinc concentrate during flotation, the authors of the work propose to implement the principle of W. Ross Ashby in the direction: "Using the theory of situational management."
The current practice of building dispatching systems is reduced to displaying the structure of the entire consolidated information array and issuing reports in the form of a matrix, in which the number of columns is measured in tens and rows in hundreds. Making managerial decisions in this case, at least, is difficult and requires a change in the technological decision-making process, combining into a single whole the experience of an expert and the capabilities of artificial intelligence, for which an information structure and decision-making trajectories should be prepared based on scientifically sound alternatives.

It is generally accepted that the method of situational control is one of the most promising methods, which allows solving the search problem for a wide class of systems when adapting the algorithms of the control system. Situational management is based on a hypothesis: all the necessary information about object management should be obtained from direct observation of its work.

4. Results of practical research

According to axioms 1-3, the purpose of managing the flotation department is to ensure the release of commercial copper and copper-zinc concentrate corresponding to a set of technological regulations based on the decision of an expert-technologist based on information obtained with the help of technical means of automatic and automated control.

For this purpose, we define the situation for control: the criterion is the extraction of the useful component in the selected compartment or for the flotation machine, for which the chemical composition is determined before and after the flotation machine, and requires integration with the quality control system of the resulting product. The observation and application of the efficiency criterion was carried out in the conditions of the Uchalinsky Goka.

Information on the chemical composition came from the analytical control system of the pulp for the content of elements: the inlet of the flotation machine, and the output of the flotation machine. Data is received every 20 minutes.

After the application of the integration solution (Fig. 1), the situation of the absence of the removal of the useful component is clearly visible, which makes it possible to promptly make managerial decisions.

![Figure 1](image_url)

**Figure 1.** Situation "extraction of useful component", a) integration of data on the entry and exit of the flotation machine; b) criterion - "extraction of a useful component".

During the observations, an abnormal situation was recorded - the absence of extraction (occurred due to mechanical problems with the equipment), which confirms the correctness of the chosen criterion and the fulfillment of Axiom 3.

It is proposed to solve the fulfillment of the requirements of axioms 4-6, taking into account the Ross-Ashby principle, by creating a designer of the dispatching system interface from standard elements for:
1. display of any technological unit with recognizable outlines, and it is possible to display several sequential units;
2. display of technological parameters obtained from the common information space from SCADA systems.

A site with aggregates should be recognizable by external parameters and consist of replicable primitives, which greatly simplifies the creation of software.

Any technological unit is identified according to its technological (Fig. 2).

![Diagram](image)

**Figure 2.** Sketch of the dispatching system window.

An important visualization element is the display of general shop information, which shows the grade of the processed ore and the initial chemical composition supplied to the processing of commercial ore. This operational information allows you to use the experience of technologists and operators to ensure the best parameters of the technological process. The main field of the screen form is occupied by windows displaying the monitored parameters of the flotation machine. In each group of aggregates, the number of windows can be different, but the most important display in each window is:

1. graph of the current value of the parameter;
2. types of control: automatic or remote;
3. the set value of the technological parameter.

It is proposed to make windows using HTML and CSS styles with the ability to scale, minimize windows using a responsive layout.

5. Conclusion

The results of the study of theoretical and practical developments in the field of building flotation control systems for the extraction of copper and copper-zinc concentrate showed the absence of fundamental procedures for the system analysis of processes and sub-processes when establishing relationships between individual factors of the same level and between the levels of automated systems, as well as insufficient development of the system of universal procedures, allowing to build a hierarchical structure of technological process parameters for centralized dispatching and situational control with their subsequent use in algorithms for determining production efficiency.

Theoretical studies of the object control system made it possible to present the problem in a new formulation using the principle of W. Ross Ashby in the direction: "Reduce the ambiguity of control..."
actions relative to the states of the control object by building a dispatching system according to the hierarchical scheme "site-unit-parameter "using the theory of situational control ".

6. References

[1] Logunova O S, Andreev S M, Garbar E A, Markevich A V, Nikolaev A A 2020 Automation of scientific research of discontinuities of a flat surface: a design solution of a software and hardware complex Electrotechnical systems and complexes 1 pp 54 - 59

[2] Official website of the National Project "Science": passport dated 12.24.2018 URL: tactic.government.ru/media/files/vCAoi8zEXRVSun2Yk7D8hvQbpBUS-wO8y.pdf

[3] Official website of TAdviser State Business It URL: https://www.tadviser.ru/index.phpArticle: Copper_extraction

[4] Official site of the process control system in Russia URL: https://automation-system.ru/main/69-about-scada.html

[5] System V S 2020 analysis in management (Moscow: Finance and Statistics) p 368

[6] Kozletsov A P, Reshetnikov I S 2010 Application of the ISA-95 standard for the integration of information systems at a manuf-acturing enterprise Automation in industry 12 pp 3-7

[7] Official website of MESA internationala URL: http://www.mesa.org/en/modelstrategi-ciniatives/ME-SAModel.asp

[8] Anfilatov V S, Emelyanov A A, Kukushkin A A 2009 System analysis in management: a tutorial (Moscow: Finance and Statistics) p 238

[9] Wonderware MES Official Site URL: http://archestra.info/index.php Wonderware_MES

[10] Milov A V, Timokhin V N, Chernous G A 2004 Economic cybernetics: lecture notes (Donetsk: Donetsk National University Publishing House) p 105

[11] Soloviev N A, Chernoprudova E N, Lesovoy D A 2012 Fundamentals of decision-making theory for programmers (Orenburg: Publishing house of the Orenburg State University) p 187

[12] Rakov V I 2012 System analysis (initial concepts): a tutorial (Moscow: Academy of Natural Science) p 234

[13] Logunova O S, Maksimov M A 2015 The complex of image processing algorithms for granulometry of charging materials Mathematical and software systems in industrial and social spheres 1(6) pp 38-42

[14] Logunova O S, Lednov A V, Shilov R E, Muslimov M B, Baybulatov F R 2018 Segmentation of the image of the froth flotation product: justification of replacing the bubble with their glare Mathematical and software systems in industrial and social spheres Vol. 6 1 pp 12-19