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ON THE ISSUE OF ORGANIZING THE HIERARCHICAL STRUCTURE OF CONTROL SYSTEMS

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Abstract
The article discusses the organization of the hierarchical structure of control systems. Hierarchy is defined as “verticality”, “multi-stage” and “orderliness” of elements, tasks and processes in the structure of the control system. A hierarchical structure of the control system of a modern manufacturing enterprise is proposed according to the principle of “hierarchy- control methods”.

Keywords: hierarchy, control system, control methods, control principles, verticality, multi-stage, orderliness.

Introduction

In the classic book by M. D. Mesarovic, D. Mako and I. Takahara [1], mathematical models of hierarchical control structures are systematically studied and the advantages that the use of a hierarchical approach can provide in various systems are analyzed. Sources [2, 3, 4] discuss various aspects of the organization of hierarchical structures. In the source [5], the concept of hierarchy for continuous control systems is defined and characteristics are obtained for hierarchically consistent linear systems according to controllability goals, and a hierarchical controllability criterion for linear systems is also obtained.

Hierarchy is a system for ranking and organizing objects (such as organizations, people, or widgets), where each object in the system (except the top element) depends on another object. The term "hierarchical system organization" is used to describe the tree-type structure of any particular system. In itself, this type of organization of the system structure can be considered adequate or inadequate in relation to the tasks being solved within the framework of a given system. The hierarchical organization of system structure is widespread in technology, for example, an automated enterprise control system organized according to a hierarchical principle, which allows you to control various technological operations within a specific production enterprise. In the design and operation of technical and technological objects, it corresponds to “detailing” - the division of large objects into smaller ones, and in control as a method of detailing control tasks.

Hierarchy in control is the concept of building relationships between classes of different levels of control tasks based on a hierarchical structure. Various types of control tasks form a hierarchy, at different levels of which a certain range of control tasks with differing solution times, complexity and volume of data are located. The possibility of building a hierarchy of a control system is due to the fact that most control tasks are mutually nested within each other.

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The use of a hierarchical structure in control systems optimizes the distribution of control tasks in the system space.

Materials and methods. In fact, hierarchical structure is one of the indicators of system complexity. When designing hierarchical control systems, many trade-offs must be addressed, such as the control processes for each level of the control system hierarchy. You can consider a set of different control tasks $(u_1, u_2, \dots, u_n)$, located in the hierarchy, that is, each u_i level is, as it were, subordinate to the u_(i-1) level of the hierarchy.

For example, in intelligent control systems the following control levels are distinguished[1]:

• Level 0. Robust control with feedback;

• Level 1. Adaptive control - level 0 + adaptive control parameters;

• Level 2. Optimal control - level 1 + minimization or maximization of the quality function;

• Level 3. Planned control - level 2 + the ability to plan for situations that are not determined in advance, to simulate and model uncertainties.

Another example shows the hierarchy of automated systems in an enterprise (Fig. 1). The general control structure has several hierarchical levels (Fig. 1). Here, the automated control system includes the enterprise planning and control system ERP, production planning and material requirements MRP-2, the SCM system, as well as the production execution system MES, designed to solve operational problems of design, production and marketing control.

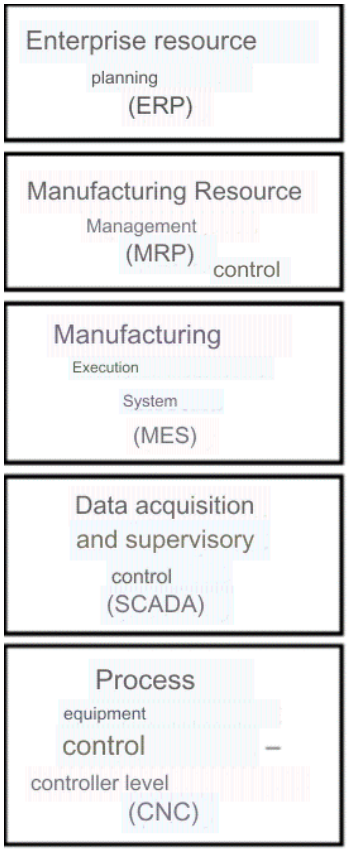

fig. 1. General control structure.

[1] https://ru.wikipedia.org/wiki/Интеллектуальное_управление

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And the process control system includes a SCADA system that performs dispatch functions (collecting and processing data on the state of equipment and technological processes) and helps develop software for embedded equipment, as well as a CNC system for controlling technological equipment based on controllers that are built into technological equipment with numerical control. program control.

Results and discussion. The concept of "hierarchy" by default implies "verticality," "multi-stage" and "orderliness" of elements, tasks and processes in the structure of the control system (Fig. 2). Here, "multi-level" implies horizontal connections at the levels of the hierarchy.

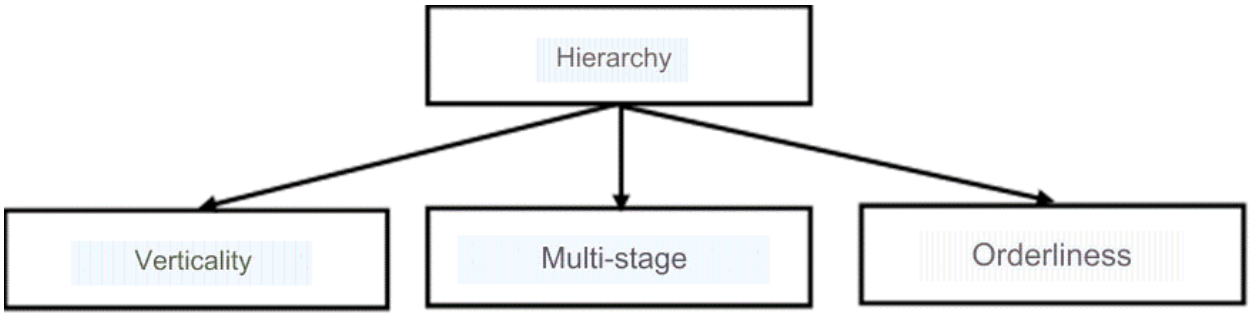

fig. 2. The content of the concept of "hierarchy".

Below, we will consider the issue of organizing the hierarchical structure of control systems using the example of managing a modern production enterprise, where there are automatic, automated, intelligent control systems. The hierarchical control structure of such a complex system is a multi-level set of interacting subsystems, each of which carries its own functional load and is responsible for solving a certain range of tasks. Here we will use the principle of organizing a hierarchy "from top to bottom", when the lower level is completely "subordinate" to the higher one.

Control methods can be adopted as a criterion for organizing the control levels of a system. In Fig. Figure 3 shows the control structure of a modern manufacturing enterprise. There are three levels of control: intelligent, automated, automatic.

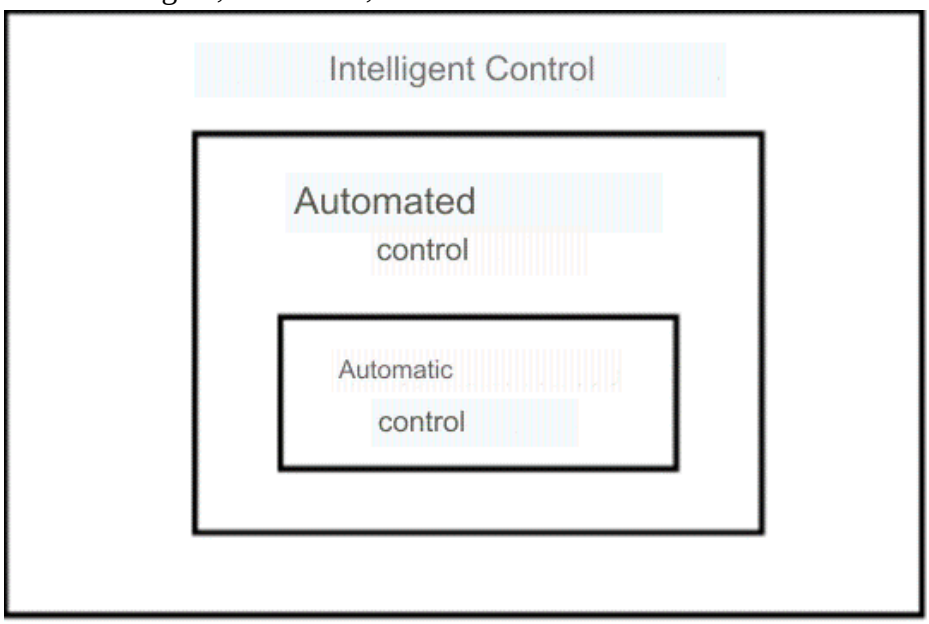

fig. 3. Hierarchical structure of the control system of a modern manufacturing enterprise.

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Although automatic, automated and intelligent control are described as control systems, in essence they are control methods. The sources examine optimal [6], adaptive [7-9], discrete [10-12] control systems. Optimality and adaptability as control principles take place in all control systems. Since the concept of "control" by default means optimization and adaptation in the control process, in this case they cannot be a separate hierarchical level of the control system. Discrete control has a practical orientation depending on the technology used in production and technological processes. Based on these judgments, the diagram presented in Fig. 3, the diagram can be expanded taking into account the optimality, adaptability and discreteness of the processes of modern enterprise control (Fig. 4).

The intelligent control level is a hierarchy level at which various artificial intelligence approaches are used, such as artificial neural networks, fuzzy logic, machine learning, evolutionary calculations and genetic algorithms. The level of intellectual control may also imply organizational (traditional) control in the classical sense.

The level of automated control is a hierarchy level at which a complex of hardware and software is used, as well as personnel designed to control various processes within the technological process and production.

The level of automatic control is the level of hierarchy at which a set of actions is used, aimed at maintaining or improving the functioning of the controlled object without direct human participation in accordance with a given control goal. It is used in technical systems to increase labor productivity, quality and accuracy of regulation, freeing people from managing systems operating in conditions of relative inaccessibility or hazardous to health. The combination of interacting control device and controlled object forms an automatic control system.

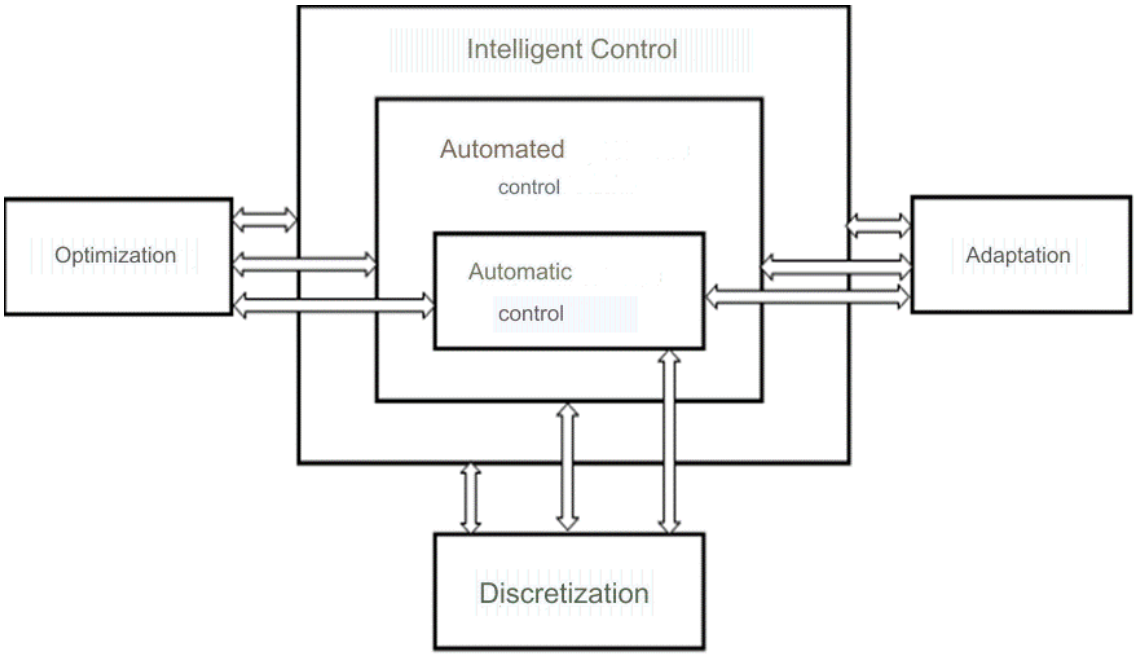

fig. 4. Hierarchical structure of the control system of a modern manufacturing enterprise.

Conclusion

Unlike other systems with a hierarchical structure, the organization of a hierarchical structure according to the principle of "hierarchy-control methods", in our opinion, is more suitable for modern manufacturing enterprises. The hierarchy can also be built according to the principles of "regulatory algorithms", "regulatory laws", "control principles", etc. In general, hierarchy is the "pivot" on which a complex control system "rests."

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