ISSN 2181-8622

Manufacturing technology problems

Scientific and Technical Journal Namangan Institute of Engineering and Technology

INDEX COPERNICUS INTERNATIONAL

Volume 9
Issue 4
2024

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MATHEMATICAL MODEL OF SYSTEM ANALYSIS OF TECHNOLOGICAL PROCESSES IN THE FORM OF KEY PRINCIPLES FOR EFFECTIVE DECISION-MAKING

ATAJONOVA SAIDAKHON

Associate professor of Andijan machine-building institute, Andijan, Uzbekistan
E-mail.: atajonovas@andmiedu.uz

Abstract: The article considers a mathematical model of system analysis of technological processes as a tool for increasing the efficiency of management decision-making. The proposed approach is based on international principles of system analysis transformation, including target optimization, modeling processes and accounting for uncertainty factors. The model provides the possibility of formalizing complex processes and their structural decomposition, which ensures the development of sound decisions in process technology management. The results obtained can be applied in various industries focused on increasing productivity and reducing costs.

Keywords: Systems analysis, mathematical model, technological processes, decision making, optimization, modeling.

Introduction. Modern technological processes are characterized by high complexity, multicomponent nature and the presence of a large number of additional parameters. Effective management of such processes requires the use of a system connection, which allows not only to take into account all the interrelations, but also to formalize decision-making by the process. One of the most promising methods for achieving this goal is the development of mathematical models of system analysis. In this article, a mathematical model allows formalizing key aspects of process management. The models are based on exceptions of system analysis, such as target orientation, structural decomposition and accounting for uncertainty factors. The purpose of the work is to develop a universal tool that can adapt to various technological tasks, including optimization, forecasting analysis and risks [1,2].

Systems analysis methods are a powerful tool for solving complex problems arising in various areas of human activity. They combine the advantages of various approaches, such as mathematical modeling, expert assessments, neural networks and others, in order to improve the accuracy and reliability of the analysis results. The methods of analysis and research of control systems are based on the principle of idealization as a thought process of creating ideal objects by changing the properties of real objects. The idealized properties of control systems are formalized in the form of a set of systems-analytical technologies, including philosophical, mathematical, physical, chemical and other technologies, adequate models and methods of systems analysis and decision making [3-5].

Research methods. As is known, the decision-making process requires prompt and high-quality processing of information. When developing such a class of systems, it is necessary to use the basic principles of modeling the information processing process. It is necessary to take into account the specifics of managing a set of interbudgetary relations tools, which is characterized by large volumes and heterogeneous nature of the analyzed information and a limited period of time for developing and making a decision. The use of a systems approach allows you to effectively process large volumes of information and a knowledge base for the development of methods, algorithms and information intelligent technologies for subsequent use in modern information systems, computer networks and computer modeling of the development and decision-making. The main task of creating and developing modern intelligent systems is the development and application of methods for integrating technologies for collecting information, analyzing it and methods for using these results in decision-making [6].

With the help of modern specialized software, you can not only model the future management system with high accuracy, but also assess how effectively various design solutions will work when using certain artificial intelligence. Methods of dynamic situation analysis based on cognitive maps provide well-interpretable modeling results (situation development forecasts and strategies for transferring the situation to the target state) for small cognitive maps. Static models of situation state assessment can be used to assess situation development forecasts and management decisions [7, 8]. Various terms such as objective uncertainty, impact of uncertainty on objectives, probability of an (unwanted) event, potential uncertainty/possibility of loss, expected cost (loss), consequence/damage/severity of consequence with uncertainty and event or consequence have been used to express definitions of risk in various fields. In a risk management framework, risks should be analyzed and addressed by making decisions to control them effectively. Risk management systematically applies management policy processes to determine, identify, control and minimize the effects and consequences of potential events. Risk identification and assessment are the core of a risk management framework.

The principles of system analysis and decision-making of technological processes in the field of energy consumption and energy saving assume consideration of many specific factors and characteristics related to generation, storage and distribution of energy. They determine sustainable development and economy as well as reliability of technological process control (Fig. 1). Solving such problems requires the involvement and analysis of information obtained on the basis of analogies, historical experience, experimental and statistical data, and expert assessment results. A feature of these problems is the use of both formal and informal (heuristic) methods for their solution. At present, technologies of multidimensional data presentation and analysis – OLAP systems – are widely used to solve these problems. OLAP system technologies allow promptly receiving, analyzing and processing information related to the nature of uncertain factors, their change ranges, a priori probability distribution, psychological features of decision-making by other decision-making entities, types of interaction between them (neutrality, assistance, opposition), etc.

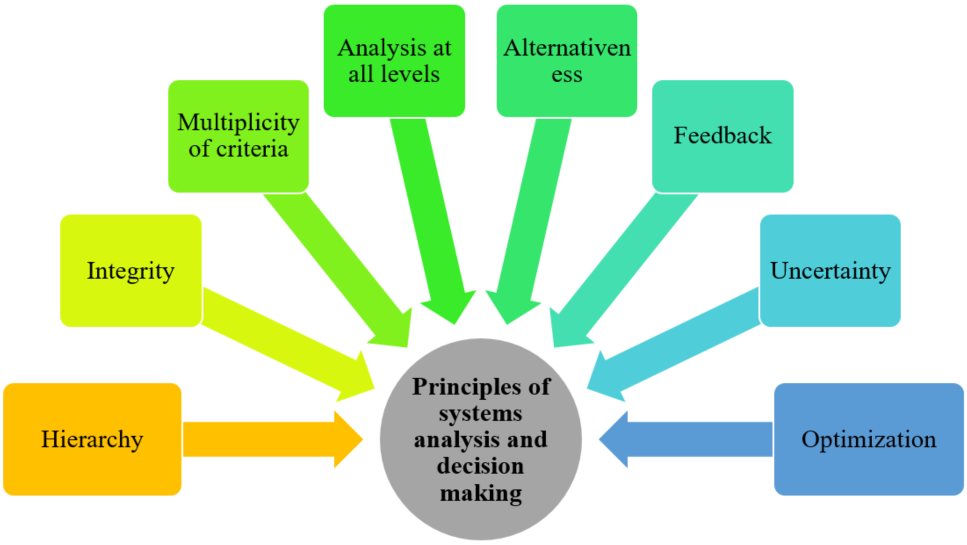

Figure 1. Principles of systems analysis and decision making

Hierarchical structure of the technological process for energy consumption and optimization: Individual components (solar panels, inverters, storage systems) and subsystems (tracking systems, cooling systems) form a complex hierarchical structure. Analysis at each level allows you to optimize the operation of the entire system.

System integrity: The technological process is considered as a single whole, where the interaction of components has a significant impact on its efficiency. For example, the choice of the type of elements and process links should take into account the characteristics of the converters and storage system.

Multiplicity of optimization criteria: When designing and operating technological processes, it is necessary to take into account many criteria, such as cost, efficiency, reliability, environmental friendliness and social aspects.

Analysis at all levels: System analysis allows you to evaluate the efficiency of a solar power plant at the level of individual components, the entire plant and even the energy system as a whole [9].

Alternative solutions: There are many technological solutions for creating technological processes for energy consumption and energy saving. System analysis helps to choose the most optimal solution taking into account specific conditions and requirements. Feedback and adaptability: A systems approach involves continuous monitoring of the process and adaptation of its parameters to changing environmental conditions and loads.

Accounting for uncertainty: Each process is unique in its own way and is therefore subject to the influence of various factors, such as meteorological conditions and fluctuations in demand for electricity. Systems analysis allows you to assess risks and develop strategies for adapting to uncertainty [10].

Optimization of productivity and costs: Systems analysis is aimed at finding optimal solutions that ensure maximum electricity generation at minimum costs.

Methods of mathematical modeling and optimization allow you to find the optimal parameters of the system.

To make the right decision, it is necessary to consider the influence of various factors under uncertainty. Decision making should be based on mathematical models as a strict language of thought. This requires a structural representation of the decision-making problem. Based on the available information, various typical decision-making tasks are used. All tasks of this class have a common origin, reflected in their basic elements.

Research results. To build a mathematical model of system analysis in technological processes for energy consumption and energy saving for the purpose of effective decision-making, several key components can be identified that determine the interaction of system elements, its goals, limitations and optimization methods.

The main elements of the model:

1. **Objective function**: Defines the main goal of the system - for a technological process, for example, maximizing energy production, minimizing costs or increasing the efficiency of resource use**:**

$$maxE(t) = \int_{t_1}^{t_2} P(t)dt$$

Where $E(T)$ **–** is the total energy production over a period of time, $P(t)$ is the power of the solar installation at time t.

2. **Limitations**: Physical, technological and economic limitations are taken into account:

- *Resources*:

$$P(t) \leq P_{max}$$

where P_{max} is the maximum power of the system.

- *Radiation*:

$$P(t) = \eta \cdot A \cdot I(t)$$

where η is the panel efficiency factor, A is the panel area, $I(t)$) is the solar radiation intensity.

- *Economic constraints*:

$C \leq C_{budget}$

where C is the system cost, C_{budget} is the specified budget.

3. **Energy balance**: The system must ensure balanced production and use of energy:

$$P_{produced}(t) + P_{stored}(t) = P_{consumed}(t)$$

where $P_{stored}(t)$is the power stored in the batteries.

4. **Optimization of panel placement and orientation**: The tilt angle (θ) and orientation (ϕ) of the panels are determined to maximize solar radiation capture:

$$max \int_{t_1}^{t_2} I(t) \cdot cos(\theta)dt$$

5. **Forecasting using machine learning**: Models predict solar radiation and energy demand:

$$\hat{I}(t) = f \text{ (base data, historical data)}$$

6. Accounting for climate change: The influence of cloud cover, temperature, and other factors factors:

$$P(t) = \eta \cdot A \cdot I(t) \cdot f_{\text{losses}} \text{ (T, humidity, dust)}$$

7. Optimization of solutions: Linear and nonlinear programming methods are used to determine the optimal parameters of the system:

$$\min Z = C_{capital} + C_{operating}$$

taking into account all the above restrictions.

This model includes a system analysis of all solar energy factors. It can be adapted for specific tasks, such as choosing an installation site, optimizing the system configuration, or predicting performance under uncertainty. Specialized tools can be used for its implementation: MATLAB, Python (using the Pyomo or SciPy libraries), or specialized software for energy calculations.

Conclusion. The developed mathematical model of system analysis of technological processes is a universal tool that can be used to solve a wide range of problems in the management of production systems. It allows integrating key principles of system analysis into the decision-making process, which helps to increase their validity and efficiency.

The application of the model in practice has shown its high adaptability and the possibility of using it in various industries, including manufacturing, the energy sector and logistics. Future research can be aimed at further development of the model, including more detailed modeling of uncertainty factors and the development of automated tools for analysis.

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