Method of forming an integrated automated control system for intelligent objects

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Abstract. The sequence of constructing the scientific and methodological apparatus of the monitoring system by the energy networks of modern intelligent buildings and structures is presented. The program for monitoring and control of energy networks of intelligent buildings and structures based on the use of intelligent automated systems has been substantiated. The types of support for the control system of energy networks of intelligent buildings and structures, when creating a local automated system for monitoring energy consumption, are determined, which are important in the formation of many tasks that are intended to perform functions at different levels and in various aspects. The result of the study is algorithms for creating an intelligent energy management system during the operation of engineering systems and electrical equipment of buildings and structures, monitoring it in real time and predicting the energy consumption of buildings, which will provide the accumulation of data necessary for optimal planning with energy resources, which will increase the validity of the adoption solutions.

Keywords: Methodology, Energy networks, Monitoring systems, Buildings.

1 Introduction

The basis of current theoretical research on reducing the cost of energy consumption during the operation of engineering systems and electrical equipment of intelligent buildings and structures, and as a result, reducing the negative impact on the environment, in the conditions of intensively changing quantitative and structural parameters of intelligent technical means with limited urban planning changes, historically established target-generating zones became both federal and regional target programs for the modernization of the energy system within the framework of the "Smart St. Petersburg" program. The relevance of the topic under consideration is due to the fact that the use of automation systems that make it possible to effectively manage the engineering systems of buildings is in demand both in the restoration of existing electrical installations and in the design of new ones, but there is no scientific and methodological apparatus for their rational construction that can effectively manage such building systems. like lighting, heating and air conditioning and allowing you to reduce energy costs [1].

2 Materials and methods

As a result of the study [2], practical recommendations were developed for the formation of a monitoring system by energy networks of intelligent buildings and structures for the rational use of intelligent technical means of systems, which contain methods, algorithms of actions for the selection and rational functioning of intelligent technical means, provide for specific measures to improve them. The objective necessity of scientific substantiation and creation of a methodology for innovative technical and technological solutions to ensure a reduction in energy consumption costs during the operation of engineering systems and electrical equipment of intelligent buildings and structures in various conditions has been established [3-4], which allows to reduce energy consumption costs during the operation of the energy system by 30-35%.

All this presupposes the integration of oriented technologies for reducing energy consumption in the management of energy networks of buildings based on a system-targeted approach to this process. This approach is based on the provision on the relationship between the work of intelligent technical means and the energy savings generated during its operation (in the general setting) and, therefore, the possibility of joint optimization of these processes. Models linking the work of intelligent technical means (P_{tr}) and the amount of energy costs (R_d) constitute the normative-target basis of alternative implementations of scenarios for their improvement. The optimization criteria are based on the generalized technical and energy performance of this process. In the process of managing the energy resources of smart buildings and structures, three hierarchical levels of the process can be distinguished: at the regional mega-level, at the local macro-level and at the individual micro-level. This is shown in Figure 1.

The volume of technical automation systems that make it possible to effectively manage building systems in the n-th period should not contradict the continuing trend of increasing energy consumption in the future $n + 1$ period $F_{tr\,(n+1)} > F_{tr\,(n)}$ ($F_{tr\,(n)}$ not equal 0).

The size of energy costs (R_d), $R_d < R_{pd} = f\,(c_r)$ should not be larger than the size that can create, not exceeding the permissible.

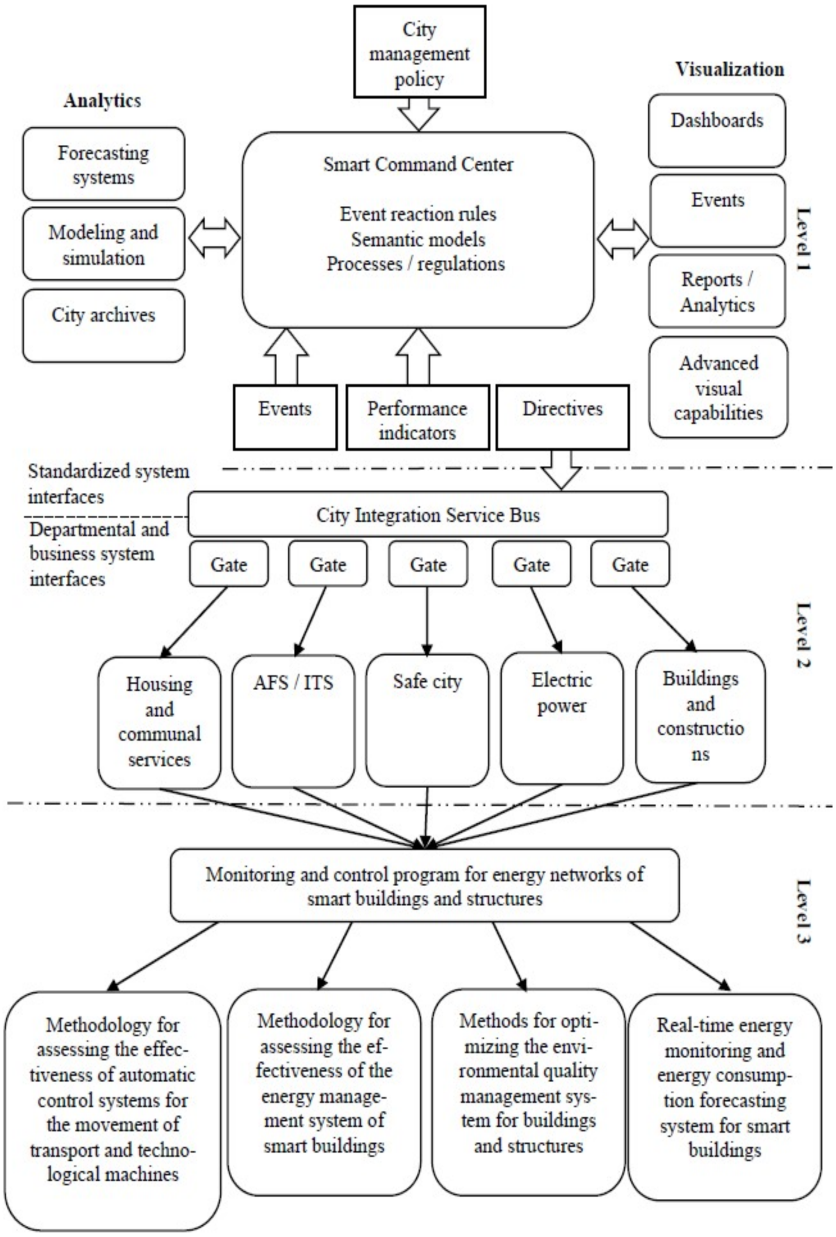

Fig. 1. Program for monitoring and management of energy networks of intelligent buildings and structures.

At each level, the energy resource management process is optimized according to the following criteria:

Optimization models are as follows:

Level 3:

$$P_3 = \sum f(A_{31}, A_{32}, ..., A_{3n}; W_{31}, W_{32}, ..., W_{3n}),$$
$$R_3 = \sum f(A_{31}, A_{32}, ..., A_{3n}; r_{31}, r_{32}, ..., r_{3n}), \tag{1}$$

where A_{3i}, - number of intelligent building systems i; W_{3i} and r_{3i} - accordingly, the amount of automation and the amount of cost reduction of one unit i of intelligent building systems for a calendar period.

Level 2:

$$P_2 = \sum f(q_{21}, q_{22}, ..., q_{2n}; A_{21}, A_{22}, ..., A_{2n}),$$
$$R_2 = \sum f(g_{21}, g_{22}, ..., g_{2n}; N_{21}, N_{22}, ..., N_{2n}), \tag{2}$$

where q_{2i} and g_{2i} – accordingly, the amount of automation and the amount of cost reduction from the operation of one unit i intelligent building systems, A_{2i} and N_{2i}, – number of i intelligent building systems;

Level 1:

$$P_1 = \sum f(\omega_{11}, \omega_{12}, ..., \omega_{1n}; A_{11}, A_{12}, ..., A_{1n}),$$
$$R_1 = \sum f[T_2, g_{1l}, + g_{1t}(tp_{11}, tp_{12}, ..., tp_{1n})], \tag{3}$$

where g_{1l} and g_{1t} – the size of cost reduction from the operation of one unit i of intelligent building systems; ω_{11} and tp_{11} - hourly productivity and uptime of i intelligent building systems under operator control.

3 Results

Modeling is carried out both for individual buildings and structures, and for residential areas, micro districts, with a changing ratio of the number of intelligent building systems that meet the standards.

Level 1 [5-6] optimizes the mode of operation of an individual room in a building. The selection of intelligent building systems according to these criteria allows you to perform optimal work with a minimum of modes not due to the energy saving process.

When considering the functionality of any system for managing energy networks of intelligent buildings and structures, when creating a local automated system for monitoring energy consumption, it is important to create many types of software that are intended to perform functions at different levels and in various aspects. Consider the types of security that are most important in the work of this system. These include the following: hardware and technical support; software; Information Support; organizational support; metrological support; software; methodological support; methodological support [7].

Without active interaction with the environment, the system under consideration cannot function effectively. But not only active interaction is required for this – also archival and forecast information about the control object and from adjacent systems is fed to the input of the integrated automated control system on the road. The main directions of the development of this system can be briefly explained by the presented scheme as a local automated system for monitoring energy consumption. This is shown in Figure 2.

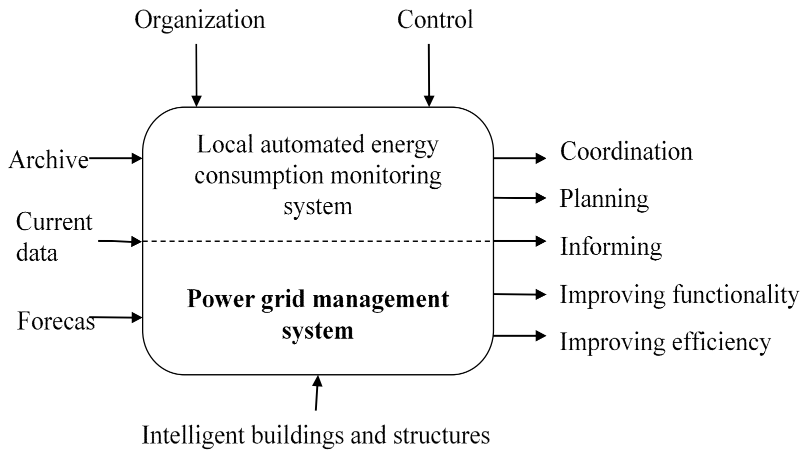

Fig. 2. The main directions of development of an integrated automated energy management system.

The hardware and technical support include all server, switching and peripheral equipment, as well as automated workstations for personnel. The composition of server equipment includes such types as servers themselves, as well as video servers, automatic telephone exchanges, data storage systems and other specialized server-type devices that are located in racks and are usually placed in data centers, where a "harness" is created to ensure their performance. From a large number of specialized engineering systems. Switching equipment is represented by switches, routers, routers, firewalls – everything that ensures the creation and operability of physical channels of information transmission. Most of the switching equipment is located together with the server room, but some also go to the communication lines and facility complexes for organizing communication with peripheral equipment.

Peripheral equipment, which is almost the most important part of the hardware and technical support of the system, is a wide variety of equipment that is used to perform the functions of subsystems, which is called "in places". It is difficult to give a complete list of types of peripheral equipment, since everyday there are new examples of what can be used to implement the functionality of the system. The next important type of system support is software. Software is understood as the whole complex of programs and documentation for them, necessary and sufficient for the operation of this complex of programs. Programs are divided into system, application and embedded. System software is an operating system, drivers in it and other basic programs that ensure the operability and interfacing of application programs and hardware and hardware elements. Application software is a part of information and automated systems within the system and performs application functions. Firmware is usually hardwired into peripheral hardware and is used for low-level control of its operation.

An equally important type of system support is informational. It includes not only information stored in databases and plying between the elements of the system, but also all information support for the activities of systems, its subsystems and elements, available to external factors. Therefore, when building a system, it is necessary to pay attention not only to the logical and physical structure of databases, not only to the composition of integration flows between subsystems, but also to the physical elements of information support.

The organizational support of the system is understood as a set of methods, processes, tools and personnel collected in specific management structures, which are designed to organize the effective and high-quality functioning of the system. Since the integrated automated energy management system is a very complex system, consisting of many subsystems, each of which, in turn, is a full-fledged control system, the organizational support of the system consists of the corresponding provisions of each subsystem and is supplemented by those necessary components that cover emergent system-forming properties the entire system. The organizational support usually includes internal regulations and descriptions of business processes to maintain the functioning of the system in various modes of operation. Service personnel and everything necessary for their work is also included in the organizational support of the system. Since the system contains many elements and special peripheral equipment that measures various parameters of the control object and its parts, an important issue is the availability of a unified metrological support, which is understood as a set of metrological norms, rules and measurement procedures to meet the requirements for accuracy and standardization. These requirements can be regulated both at the state level and at the industry level or even within the system itself. The presence of standards in the field of accuracy and uniformity of measurement methods provides the basis for the regulatory framework of the system.

Software is a set of algorithms, methods for solving problems and, most importantly, mathematical models for implementing the functionality of the system. Since the intellectualization of functions in the system implies the presence of models for predicting and planning the states of the control object and the system itself, the software of the system and its subsystems should be developed and based on the latest achievements of science. It should be noted that the software includes not only algorithms implemented in the software, but also control scenarios, dynamic models and other "online" mathematical tools that are used in the process of the system functioning.

Methodological support of the system is a set of descriptions of methods for solving problems. It is important not only at the stage of operation of the system and each of its subsystems, but also at the design stage, when specific solutions are incorporated into the system. The decision methodology should be carefully described, understood by the system personnel and accepted for implementation. Thus, methodological support becomes, as it were, a cementing link between organizational and software support.

In turn, methodological support (not to be confused with the previous type) is a set of training materials and procedures for training personnel to work within the system. And, despite the fact that with an increase in the degree of intelligence and autonomy, the importance of the role of personnel will gradually decrease, while the need for methodological support remains quite urgent.

When considering the functionality of any system, including the system itself, an important issue is the many types of software that are designed to perform functions at different levels and in different aspects, which can be seen in Figure 3.

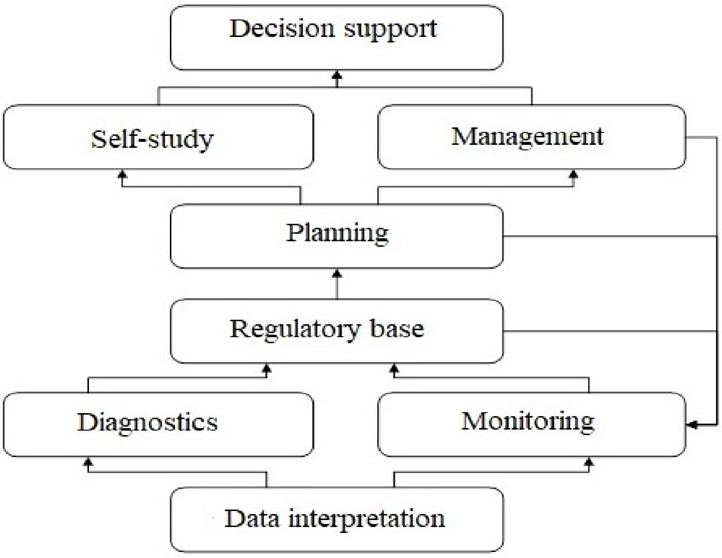

Fig. 3. Stages of decision making when using an integrated automated control system for energy networks.

The decision support system is designed to analyze the current state of the control object as a whole, retrospective analysis, development modeling and preparation of decision options with justification, which leads to decision support by managers at all levels in the organizational structure of the system, from linear management to strategic energy management.

The decision support system performs the following functions: extraction and verification of knowledge about the problem area; collection of information about the control object and the environment in which it operates; storage of archival information about the control object; modeling the development of the control object and environment; conclusion and ranking of recommendations by solution options; explanation of solution options; support for the implementation of the decision; evaluation of the results of the implemented solution; learning by making changes to the knowledge base.

Table 1 lists the types of support that need to be worked out in the development and implementation of decision support systems.

Table 1. Types of support required for the development and implementation of decision support systems.

Type of provision	Decision support system
Hardware and technical	Server hardware running the system core. Automated workstations of system users.
Software	Server and client applications that perform system functionality.
Informative	The entire array of information that is stored in the system database, and also runs through it through integration tools.
Organizational	System personnel working with its functionality.
Metrological	–
Mathematical	Algorithms and methods for processing large amounts of information, modeling, issuing recommendations, etc.
Methodological	Description of methods for analyzing big data, finding patterns, decision support.
Methodical	Training materials for analysts and leadership.

The structure of the decision support system can be represented using Figure 4.

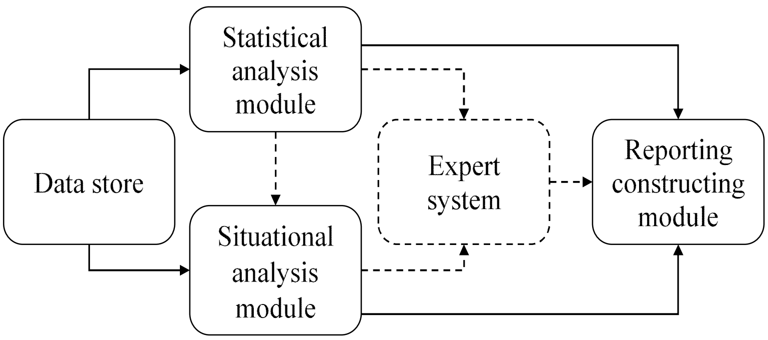

Fig. 4. The structure of the decision support system.

4 Discussion

The statistical analysis module allows you to use various mathematical methods when analyzing large amounts of information (statistical samples), in particular, searching for correlations and causal relationships, analyzing trends, determining statistical patterns, etc. The situational analysis module is used for a deeper analysis of large amounts of information in a short period of time that allows you to discover hidden patterns, non-trivial and practically useful interpretations of data information in real time.

In fact, all other subsystems are integrated with the decision support system, since it is in this system that the aggregation and analysis of information about all aspects of the system's activities are carried out. All of these subsystems transmit information to the decision support system. In addition, in the process of implementing a specific project, the decision support system can be integrated with the subsystems of other blocks of the system for effective management of energy networks.

5 Conclusion

Thus, the study on the application of new intelligent technologies showed that their use significantly increases the efficiency of managing the energy networks of buildings and structures, due to constant monitoring of the energy consumption of buildings and structures in real time and the efficiency of information transfer. At the same time, most of the functions performed are carried out automatically without human intervention, which allows you to reduce the number of maintenance personnel without the threat of reducing the efficiency of the system. This moment is fundamental when creating such systems in energy networks.

The use of modern systems for monitoring technical means in buildings and structures provides the possibility of intelligent interaction with individual buildings and structures or with the energy networks of the city as a whole through information and telecommunication technologies of technical control devices in order to increase the efficiency of energy consumption of buildings in any conditions. The considered system-target approach to the formation of the system allows you to take into account the positive and negative aspects when building an integrated automated control system for energy networks.

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