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Satbayev University

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DEVELOPMENT OF STRUCTURAL SCHEMES AND OPERATION ALGORITHMS FOR THE AUTOMATIC CONTROL SYSTEM OF A MULTIFUNCTIONAL ENERGY COMPLEX

Abstract. Among the promising automatic control systems, logical-dynamic control systems that change both the structure and parameters of the control device using switches formed on the basis of a certain logical algorithm have proven themselves well. The use of logical algorithms as part of MACS subsystems for complex technical objects makes it possible to increase the static and dynamic accuracy of control due to purposeful qualitative and quantitative changes in the control signal. This approach will give the control system fundamentally new properties that allow to fully take into account the nature and dynamics of the movement of the control object. When developing existing logical control algorithms, the issues of their application for multi-connected and multi-functional objects control were not considered. Common to existing logical algorithms is that when switching the structure and/or changing parameters, only the dynamics of its own subsystem is taken into account, which is unacceptable in the case of multi-connected dynamic object control, since cross-links have a significant impact on the quality of control. Thus, the problem of synthesis of logical algorithms for multi-connected objects control is an actual theoretical and applied problem. Despite the considerable amount of research conducted in this area, the application of logical algorithms for complex multidimensional objects control is not sufficiently considered, and there is no unified design concept for this type of MACS, taking into account the required quality of functioning in various operating modes. In this regard, there is a need to synthesize algorithms for logical multi-connected control that form control signals in order to coordinate the actions of all separate MACS subsystems in accordance with new external conditions and operating modes. The problem under consideration determined the purpose of this work and the research objectives.

Key words: structural scheme, algorithm, model, multifunctional energy complex, automatic control system, object, automation, research methods.

Introduction. Automation of various technological processes and industries, in the modern digital world, is very relevant in all industrial circles and areas, and this is one of the decisive factors in increasing productivity and improving working conditions in heavy industrial conditions. All existing and under construction industrial facilities are equipped with technical and software automation at one level or another. The development and widespread implementation of computer technology opens up new opportunities for control of various objects and allows the use of new technologies, including in automatic regulation systems (ARS) and automatic control systems (ACS). It becomes quite realistic to automate the control process, using the professional knowledge and experience of a specialist in the relevant field for the operation of the object in various conditions and technological modes. This formulation allows to speak about the creation of qualitatively new systems for the automation of energy complex facilities. Such systems are based not on a complex mathematical description, but on a management strategy developed on the basis of the production experience of a specialist in the relevant field [1].

The main functional blocks of ACS, elements of structural schemes. Information aspect of control.

The object of the research is the MFEC control systems operating in conditions of unpredictability and changing external environment. MFEC - as a control object is non-stationary - during its operation, changes in the dynamic parameters of both energy subsystems and cross-links are possible, which is caused by a change in operating modes or changes in external conditions of functioning [1]. Such parametric changes lead to a significant change in the dynamics of transient processes in all subsystems, which cannot be fully compensated by linear controllers. For complete and adequate control of such a complex technical object, it is required to develop automatic control systems in the class of multi-connected ACS, which are a set of subsystems interconnected through natural cross-links in the control object and interacting with each other in order to achieve a common goal of functioning.

The proposed algorithms for creating an ACS controller for maintaining the level are not highly specialized and can be used in almost any field of technology, and the outlined methodological foundations allow to create an ACS using fuzzy logic to maintain any parameter, taking into account the specifics of a particular unit.

The subject of the research is the control processes of technological complexes, the peculiarities of their dynamics, methods and technical means of implementing control algorithms based on the theory of fuzzy sets.

The goal of the work is to increase the efficiency of using energy-saturated objects by introducing automation systems, creating control algorithms using fuzzy logic methods, researching new capabilities of the ACS and solving practical problems in choosing the structure and parameters of such systems.

In order to achieve the goal of the work, the following tasks were set and solved:

- there was carried out the analysis of tasks arising in the control of dynamic objects; studied the technical base, methods and tools used to solve the tasks;
- there were synthesized the structure and control algorithm of the MFEC system, carried out a detailed analysis of the influence of the parameters of the system itself and external conditions on the dynamics of the control system;
- there was investigated the possibility of using the apparatus of fuzzy logic for the synthesis of control algorithms, revealed the features of the dynamics of these systems;
- there was synthesized an adaptive control algorithm for automatic adjustment of system parameters to changing external conditions;
- there was considered the possibility of implementing diagnostic algorithms for control systems to warn about possible accidents and proposed algorithms for conducting diagnostic tests;
- there was developed a methodology for creating control algorithms based on fuzzy logic and for choosing the parameters of a fuzzy controller;
- based on the analysis of domestic and foreign experience, there was generalized and concretely implemented the approach to the creation of an automatic control system in the hopper of the hydraulic classifier of a mining dredger using the theory of fuzzy sets;
- there was showed the effectiveness of the selected algorithm.

The theoretical and methodological basis of the work consists of approaches and tools of the theory of nonlinear dynamical systems, the theory of fuzzy sets and a computational experiment.

Structural scheme of the investigated class of MACS of complex technical objects. In this work, the P-canonical structure is chosen as the considered class of MACS. With the chosen structure, the interaction between the set of one-dimensional ACS is carried out through natural connections in the control object. Let us consider in more detail the selected structure of object description as a multi-connected control object. Let elements with transfer functions $W_{ii}(s)$, $(i = 1,2)$ be the main ones, and elements with transfer functions $W_{ij}(s)$ $(i \neq j,\ i, j = 1,2)$ - communication elements. Figure 1 shows the P-canonical structure on the example of a two-connected object, where $u_i(s)$ $(i = 1, 2)$ are control signals that are input relative to a multiply connected control object, $y_i(s)$ $(i = 1, 2)$ are output signals from a multi-connected control object.

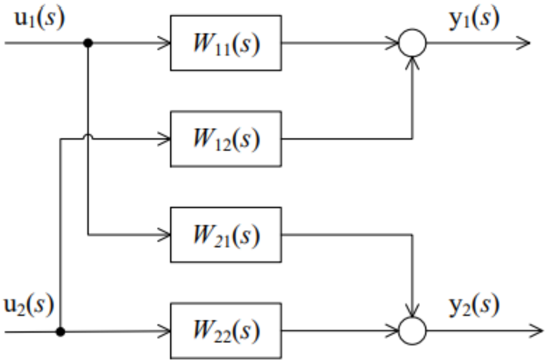


Figure 1 – P-canonical structure on the example of a two-connected object

P-canonical multi-connected objects are described by the following formula:

$$\begin{bmatrix} y_1(s) \\ y_2(s) \end{bmatrix} = \begin{bmatrix} W_{11}(s) & W_{12}(s) \\ W_{21}(s) & W_{22}(s) \end{bmatrix} \begin{bmatrix} u_1(s) \\ u_2(s) \end{bmatrix},$$

or in a generalized form:

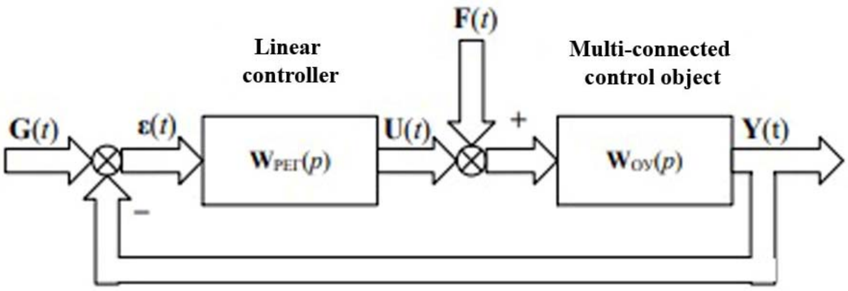
$$Y(s) = W(s)U(s).$$

This structure makes it possible to more clearly assess the influence of cross-links on the dynamics of the subsystem and to form a control signal adequate to the current state of the entire MACS [2].

Research methods. The considered method defines an object using the individual characteristics of the subsystems and the characteristics of the connections between them. Multi-connected automatic control systems (figure 2), in which all connections between subsystems are carried out through a multidimensional object, are described by the following equations:

$$\begin{cases} \mathbf{Y}(t) = \mathbf{W}_{OY}(p)[\mathbf{U}(t) + \mathbf{F}(t)], \\ \mathbf{U}(t) = \mathbf{W}_{PE\Gamma}(p)[\mathbf{G}(t) - \mathbf{Y}(t)]. \end{cases}$$

where G(t), Y(t), U(t), F(t) – vector of the set, controllable, and disturbing coordinate, ε(t) – own control error vector, p – differentiation operator.



Fugure 2 – Structural scheme of MACS

As an individual characteristic of a subsystem, there is used such a characteristic of a diagonal element of a multi-connected control object, which would fully reflect the studied properties of this element of the MACS. An example of such a characteristic is the transfer function of the subsystem in the control mode:

$$\Phi_i(s) == \frac{Y_i(s)}{G_i(s)} = \frac{W_{PE\Gamma ii}(s) W_{OYii}(s)}{1 + W_{PE\Gamma ii}(s) W_{OYii}(s)}, \quad i = 1, \ldots, n,$$

where for each i-th subsystem, $W_{PE\Gamma ii}(s)$ – the transfer function of the linear controller, $W_{OYii}(s)$ – the transfer function of the control object

In the general case, the connection between a group of subsystems is characterized using the determinants of matrices of the corresponding dimensions $||W_{OY}ij(s)\gamma ij||$, where γij - a discrete function:

$$\gamma_{ij} = \begin{cases} 1, & i \neq j, \\ 0, & i = j. \end{cases}$$

This characteristic reflects the integral connection between a group of subsystems. In general case, the function H(s) characterizes both the sign and the magnitude ("strength"), as well as the nature of the connections in the group of subsystems that are connected by this multi-connected connection element. An important feature of this approach is that when describing cross-links between subsystems, their number does not matter. The work gives preference to a systematic approach to describing MACS based on decomposition into subsystems and multidimensional communication elements between them.

Mathematical model of the investigated class of MACS of complex technical objects. Another important aspect of the creation of MACS is the way of creating a mathematical model of a multi-connected control object, which describes the dynamics of its transient processes. One of the very first ways to describe MACS is based on the description of the behavior of the system under study in the state space, which are expressed as a system of differential equations in the Cauchy form. In the context of this approach, for a description in a dynamic system, there is created a matrix mathematical model that includes matrices of input control parameters ($Bn\times r$), of output parameters ($Cm\times n$), of a system ($An\times n$) and of a direct connection ($Dm\times n$).

In general, for multi-connected stationary dynamical systems, the linearized equations of state in the Cauchy normal form have the following form:

$$\begin{cases} \dot{X}(t) = AX(t) + BU(t), \\ Y(t) = CX(t) + DU(t), \end{cases}$$

where $X(t)1\times n$ –vector of states, $U(t)1\times r$ – vector of control (input) coordinates, $Y(t)1\times m$ – vector of controlled (output) coordinates. The state space is determined by the smallest set of phase coordinates that fully characterize the investigated complex technical object at any moment of time [5].

This approach makes it possible to develop unified methods for developing control algorithms regardless of the physical nature of the control object. However, the use of this approach in practice is mathematically complex and requires significant computational resources. Moreover, the abstractness of the vector of states and the difficulty of measuring lead to the loss of "physicality." All MACS parameters are mixed, and it is problematic to analyze the influence of the parameters on the MACS stability margins [5].

However, despite all the positive qualities, these control means are also characterized by significant disadvantages, which include:

- small variation of the parameters of the configured regulator, which does not allow to ensure the required quality of operation in all modes of operation,
- limited possibilities of applicability in MACS due to the fact that parametric changes in the control system can not always compensate the qualitative changes in the control object,
- the need to comply with the adequacy of the reference model and the presence of significant a priori information about the control object.

All of this greatly complicates the synthesis and subsequent analysis of such systems, which leads to a rather high complexity of the application of this approach in engineering practice. Also, adaptive control systems imply preliminary parameterization of the object. But often a priori information is not enough to create a model of an object with an accuracy of a parameter, since the dynamics of an object is nonlinear, which greatly complicates the creation of an accurate mathematical model of an object. In connection with the above problems, it becomes expedient to use robust control methods, which not only allow maintaining the stability of the MACS within certain limits, but are also characterized by less sensitivity to changes in the parameters of the control object compared to optimal systems [7].

Neural network control systems are characterized by a number of properties that make it possible to create highly efficient ACS on their basis:

- the ability to train n example and to generalize data,
- the adaptation to structural and parametric changes, both of the control object and the external environment,
- the possibility of synthesis of regulators that form a control signal based on nonlinear laws, as well as the high stability of its structure [10].

Results of the study of the effectiveness of MACS with a double logic control algorithm. In modern MACS, complex multidimensional technical objects in different modes of operation undergo significant changes in the properties and parameters of a multi-connected control object, which lead to a change in the quality of control. Let us consider a homogeneous three-connected ACS without logic controllers, the structural scheme of which is shown on figure 3.

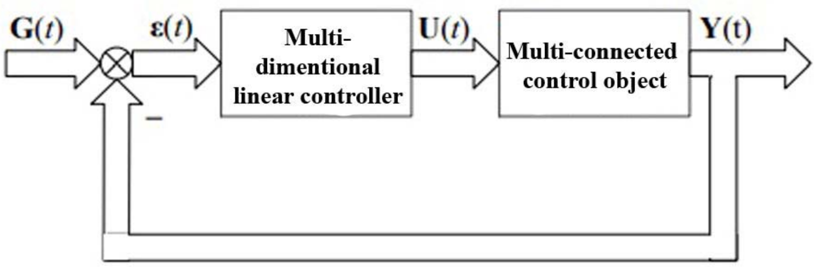


Figure 3 – Structural scheme of the investigated MACS

In the study of homogeneous MACS, it is proposed to use an individual characteristic of a subsystem, reflecting its properties in the control mode, and a multidimensional communication element, reflecting the strength and nature of cross-links between subsystems. Since the considered MACS is homogeneous, the individual characteristics of all subsystems are identical to each other and have the following form:

$$\Phi_i(s) = \frac{W_{OY_{ii}}(s) W_{PE\Gamma_{ii}}(s)}{1 + W_{OY_{ii}}(s) W_{PE\Gamma_{ii}}(s)}, \quad i = 1, 2, 3,$$

where $W_{OYii}(s)$, $W_{PE\Gamma ii}(s)$ – transfer functions of the control object and linear regulator as part of the i-th subsystem, respectively. As a control object as part of the autonomous i-th subsystem, let us consider the serial connection of the aperiodic link and the oscillatory link, which is described by the following given transfer function $W_{OYii}(s)$:

$$W_{OY_{ii}}(s) = \frac{K_{ИМ}}{(T_{ИМ} s + 1)(T_{OY}^2 s + 2\xi_{OY} T_{OY} s + 1)}, \quad i = 1, 2, 3,$$

where $T_{ИМ}$ –time constant of the actuator, $K_{ИМ}$ – transfer coefficient of the actuator, T_{OY} – time constant of a multi-connected control object, ξ_{OY} – damping coefficient of a multi-connected control object. In the design mode, the actuator does not change the amplitude of the control signal ($K_{ИМ}$ = 2), but is characterized by inertia ($T_{ИМ}$ = 0,1 sec.). The control object is characterized by significant inertia (T_{OY} = 1 sec.) And a high damping coefficient (ξ_{OY} = 0.9). Thus, in the design mode, the parameters of the control object have the following preset values: $K_{ИМ}$ = 2, $T_{ИМ}$ = 0.1 sec., T_{OY} = 1 sec., ξ_{OY} = 0.9. A multi-connected control object in the design mode is characterized by the presence of both stabilizing and destabilizing connections. The multidimensional connection element K_{OY}, corresponding to this nature of cross-links, in the design mode, is described by the following given matrix:

$$\mathbf{K}_{OY} = \begin{bmatrix} K_{11} & K_{12} & K_{13} \\ K_{21} & K_{22} & K_{23} \\ K_{31} & K_{32} & K_{33} \end{bmatrix},$$

where Kij – cross-links transfer coefficient from the j-th subsystem to the i-th subsystem. In the design mode, the elements of the multidimensional connection element K_{OY} have the following values: K11 = K22 = K33 = 1, K12 = -0.4, K13 = 0.5, K21 = 0.7, K23 = -0.3, K31 = 0, 5, K32 = -0.6. As a linear regulator in the i-th subsystem, let us consider a given isodromic link with the following transfer function WPEΓii(s):

$$W_{PE\Gamma_{ii}}(s) = K_{PE\Gamma} \frac{\tau_{PE\Gamma} s + 1}{s}, \quad i = 1, 2, 3,$$

where for each i-th subsystem $K_{PE\Gamma}$ - the transfer coefficient of the linear controller, τPEΓ - the forcing constant of the linear controller.

Let us synthesize the parameters of a linear regulator that provides the required stability margins (by the amplitude $\theta_{ТРЕБ} \geq 6$, by the phase $\varphi_{ТРЕБ} \geq 50°$) and control quality (regulation time t <10 sec., overregulation δ ≈ 0%) in each subsystem, taking into account the influence of cross-links in MACS. Since the studied MACS is homogeneous, it is advisable to use the generalized characteristic of a multi-connected communication element, which is described and determines the nature and strength of cross-links communication between a group of subsystems:

$$H_2 = h_{12} + h_{13} + h_{23} = 0{,}28 - 0{,}25 - 0{,}18 = -0{,}15, \quad H_3 = h_{123} = -0{,}15.$$

It can be seen that in the design mode, a local stabilizing negative feedback is formed between the first and second subsystems (h12> 0), however, in the studied system as a whole, a destabilizing positive feedback is formed (H2 <0, H3 <0).

Based on the obtained characteristics H2 and H3, we create a characteristic connection equation that allows to estimate the stability margins in MACS [5]:

$$D(x, H) = 1 + \sum_{i=2}^{n} H_i x^i = 1 - 0{,}15x^2 - 0{,}15x^3 = 0.$$

Investigation of stability margins for both closed and open systems are discussed in detail in [27]. The roots x_j(j = 1,2,3) of the characteristic connection equation allow to evaluate the stability of the system by the amplitude-phase frequency response of the closed system, and the modified roots x_j*(j = 1,2,3) - by the amplitude-phase frequency response of the closed system.

$$x_i^* = \frac{x_i}{(1 - x_i)}.$$

The value of the roots xi and modified roots xi* are presented in table.

Roots x_i and modified roots x_i* of the studied MACS in the design mode

i	*Root*, x_i		*Modified root*, x_i*	
1	1,6	1,6	-2,66	$2{,}66e^{-j180°}$
2	-1,3-*j*1,57	$2e^{-j129{,}6°}$	-0,7-*j*0,2	$0{,}73e^{-j164°}$
3	-1,3+*j*1,57	$2e^{j129{,}6°}$	-0,7+*j*0,2	$0{,}73e^{j164°}$

Let us calculate the parameters of the linear controller that provides the required stability margins both by the phase and by the amplitude relative to the calculated modified roots. In order to do this, we calculate the parameters of the linear controller, which provides for each subsystem the phase stability margin φ = γ –90° , where γ – the smallest argument among the modified roots xi* (in the context of the example under consideration: γ = 164 °).

The graphs of transient processes Y(t) in the investigated MACS in the design mode without a logic controller are shown on figure 4. The simulation results show that the synthesized linear regulator provides the required quality of control as part of the investigated MACS in the design mode.

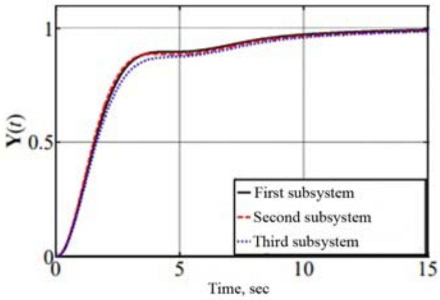


Figure 4 – Graphs of transient processes Y(t) in the investigated MACS in the design mode without logic algorithms

However, there is some "deflection" in the dynamics of the output coordinate due to the presence of an oscillatory link, as well as some difference in the tempo of the subsystems. Based on the simulation results, it can be concluded that the proposed logical controller corrects the dynamics of the output coordinates and approves the rates of each subsystem while maintaining the required performance. Thus, in the design mode, MACS, both without logic controllers, and with them, ensures the specified performance indicators.

The discussion of the results. Based on the results of simulation, it has been established that the proposed logical control algorithm, due to the formation of additional connections between subsystems, allows stabilizing the characteristics of the studied MACS with parametric changes in the cross-links of a multi-connected control object and ensuring high quality control at (H2 <0, H3> 0), (H2> 0, H3> 0).

The scientific novelty of the evaluation results of the effectiveness of the MACS with a double logical control algorithm is to confirm the effectiveness of using the proposed logical control algorithm as part of the MACS with parametric changes, the presence of pure delay and the action of various disturbances by the method of simulation.

Conclusions. In the course of the conducted scientific research, the purpose of which is to improve the quality of multi-connected control of a complex technical object based on logical algorithms, all the tasks were solved and the following results were obtained:

1. Developed the research concept and structure of MACS with a two-channel logic controller based on the decomposition method. The proposed concept consists in the integration of a linear controller that implements linear control laws and a two-channel logical corrector that analyzes both the nature of subsystems and the influence on their dynamics of cross-links in order to improve the quality of control of a multi-connected object in off-design modes. On the basis of the proposed concept, the structure of a two-channel logic controller has been developed as part of the i-th subsystem of the MACS, which forms the main correcting signal for controlling its own subsystem (based on the analysis of its current state and dynamics) and an additional coordinating signal (based on a comparative analysis of the dynamics of all subsystems as part of the MACS). The scientific novelty of the proposed concept of creating an MACS structure with a two-channel logic controller is the formation of a control signal ui*(t) based on the integration of the main signal ui(t) for controlling its own subsystem and an additional coordinating signal $\overline{u}$i(t), which takes into account the influence of cross-links.

2. Conducted the synthesis of a double logical algorithm for controlling the subsystem as part of the MACS. In the context of solving this problem, there was developed a logical algorithm for controlling an autonomous subsystem as part of a multi-connected control object, which generates a correcting error εi*(t) based on the analysis of both the current state and the predicted dynamics of its own i-th subsystem based on control error signals εi(t) and its derivative εi'(t), respectively. Also, a logical algorithm for the control of the subsystem was developed, taking into account the influence of cross-links, which forms an artificial coordinating connection $\overline{u}$i(t) based on the signal $\overline{y}$i'(t) obtained on the basis of a logical comparative analysis of the dynamics yi'(t) of its own i-th subsystem with the dynamics of yj' (t) of other j-th subsystems. The scientific novelty of the double logical algorithm lies in the correction of the dynamics of the subsystems together with the formation of additional artificial cross-links for the coordination of all subsystems of the MACS.

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КӨПФУНКЦИОНАЛДЫ ЭНЕРГЕТИКАЛЫҚ КЕШЕННІҢ АВТОМАТТЫ БАСҚАРУ ЖҮЙЕСІ ЖҰМЫСЫНЫҢ АЛГОРИТМДЕРІ МЕН ҚҰРЫЛЫМДЫҚ ДИАГРАММАЛАРЫН ДАМЫТУ

Аннотация. Перспективалы автоматты басқару жүйелерінің ішінде белгілі бір логикалық алгоритм негізінде қалыптасқан ажыратқыш арқылы басқару құрылғысының құрылымын да, параметрлерін де өзгертетін логикалық-динамикалық басқару жүйелері жақсы танылды. Логикалық алгоритмдерді АБКЖ ішкі жүйелерінің бөлігі ретінде күрделі техникалық объектілерге қолдану басқару сигналының мақсатты сапалы және сандық өзгеруіне байланысты басқарудың статикалық және динамикалық дәлдігін арттыруға мүмкіндік береді. Бұл тәсіл басқару жүйесінің табиғаты мен динамикасын толығымен ескеруге мүмкіндік беретін басқару жүйесіне принципиалды жаңа қасиеттер береді. Қолданыстағы логикалық басқару алгоритмдерін әзірлеу кезінде оларды көп байланыстырылған және көпфункционалды нысанды басқаруға қолдану мәселелері қарастырылмаған. Қолданыстағы логикалық алгоритмдерге тән нәрсе – құрылымды ауыстыру және/ немесе параметрлерді өзгерту кезінде тек өзіндік ішкі жүйенің динамикасы ескеріледі, бұл көп байланысқан динамикалық объектіні басқару жағдайында қолайсыз, өйткені айқас сілтемелер басқару сапасына айтарлықтай әсер етеді. Осылайша бірнеше байланыстырылған объектілерді басқарудың логикалық алгоритмдерін синтездеу мәселесі өзекті теориялық және қолданбалы мәселе болып саналады. Осы салада жүргізілген зерттеулердің едәуір көлеміне қарамастан, күрделі көпөлшемді объектілерді басқарудың логикалық алгоритмдерін қолдану жеткілікті деңгейде қарастырылмаған және түрлі жұмыс режимінде қажетті жұмыс сапасын негізге ала отырып, АБКЖ-ның осы типіне арналған бірыңғай жобалық тұжырымдама жоқ. Осыған байланысты АБКЖ барлық жеке ішкі жүйелерінің әрекеттерін жаңа сыртқы жағдайлар мен жұмыс режиміне сәйкес үйлестіру үшін басқару сигналдарын тудыратын, логикалық көбейтілген байланысты басқару алгоритмдерін синтездеу қажет болады. Қарастырылып отырған мәселе жұмысымыздың мақсатын айқындайды.

Түйін сөздер: блок-схема, алгоритм, модель, көпфункционалды энергетикалық кешен, автоматты басқару жүйесі, нысан, автоматика, зерттеу әдістері.

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РАЗРАБОТКА СТРУКТУРНЫХ СХЕМ И АЛГОРИТМОВ РАБОТЫ СИСТЕМЫ АВТОМАТИЧЕСКОГО УПРАВЛЕНИЯ МНОГОФУНКЦИОНАЛЬНЫМ ЭНЕРГЕТИЧЕСКИМ КОМПЛЕКСОМ

Аннотация. Среди перспективных систем автоматического управления хорошо зарекомендовали себя логико-динамические системы управления, изменяющие как структуру, так и параметры устройства управления с помощью переключателей, сформированных на основе определенного логического алгоритма. Использование логических алгоритмов в составе подсистем МСАУ для сложных технических объектов позволяет повысить статическую и динамическую точность управления за счет целенаправленного качественного и количественного изменения управляющего сигнала. Такой подход придаст системе управления принципиально новые свойства, позволяющие в полной мере учитывать характер и динамику объекта управления. При разработке существующих логических алгоритмов управления не рассматривались вопросы их применения для управления многосвязным и многофункциональным объектом. Общим для существующих логических алгоритмов является то, что при переключении структуры и / или изменении параметров учитывается только динамика собственной подсистемы, что недопустимо в случае управления многосвязным динамическим объектом, поскольку перекрестные связи оказывают существенное влияние на качество управления. Таким образом, задача синтеза логических алгоритмов управления многосвязными объектами является актуальной теоретической и прикладной задачей. Несмотря на значительный объем исследований, проводимых в этой области, применение логических алгоритмов управления сложными многомерными объектами недостаточно рассмотрено, и отсутствует единая концепция проектирования данного типа МСАУ, учитывающая требуемое качество функционирования в различных режимах эксплуатации. В связи с этим возникает необходимость синтеза алгоритмов логического многосвязного управления, формирующих

управляющие сигналы для координации действий всех отдельных подсистем МСАУ в соответствии с новыми внешними условиями и режимами работы. Рассматриваемая проблема определила цель данной работы и задачи исследования.

Ключевые слова: структурная схема, алгоритм, модель, многофункциональный энергетический комплекс, система автоматического регулирования, объект, автоматизация, методы иследования.

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