DOI 10.34185/1562-9945-4-159-2025-01
UDC 004.832

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DISTRIBUTED COMPONENT-ORIENTED PRODUCTION SYSTEM FOR CONTROLLING OF HIERARCHICAL OBJECT

Annotation. Existing methods of controlling industrial dispatching control systems (IDCS) lose their effectiveness due to the increase in their complexity. Therefore, research for the implementation of a distributed component-oriented production control system for dynamic IDCS is relevant and has practical significance. The purpose of the work is to present the architecture of a distributed component-oriented production control model for dynamic IDCS for controlling an object in real time. Conclusions: 1) a four-level IDCS architecture is proposed, which allows implementing the functioning of complex hierarchical automation objects; 2) a production system architecture for the system level of automation is proposed, which consists of low-level, complex and system levels, and a production system architecture for automated control at the main server level, which consists of complex and system levels; 3) the presented models are tested on the IDCS test problem with three systems. Based on the results of comparing the control indicators according to the proposed production model and the finite state machine, the advantages of the proposed method were determined: an increase in correctness by 16% and an increase in the share of fully automated actions by 15%.
Key words: production system, distributed control system, industrial dispatching control system, inference engine, CLIPS.

Problem statement. Generally accepted methods of control of industrial dispatching control systems (IDCS) are based on linear mathematical algorithms or on algorithms of finite automata. The rapid development of hardware has allowed to reduce the cost of building complex hierarchical automated complexes, which has led to their implementation in many areas of science and technology. The increase in the number of operations that are subject to automation has led to more complex scenarios of operation of these systems. At the same time, existing control methods are losing their effectiveness. One of the key areas of research in control automation is the application of artificial intelligence methods. Depending on the scope of application, various software tools based on neural networks or fuzzy logic methods are currently used. However, in the case of controlling an object with strict logic of operation, it is most advisable to use systems based on production models of knowledge. These models allow for high accuracy of the system operation with a sufficient level of its flexibility. However, implementation using basic models does not provide sufficient speed of determining control action. That is why further research for the implementation of a distributed component-oriented production control system for dynamic IDCS is relevant and has practical significance.

Analysis of recent research. The creation of an IDCS is a complex task, the main stages of which are the development of the general architecture of the automation object, the implementation of software algorithms for control and management, testing of the software and hardware complex and its implementation. In work [1], the authors considered modern architectures for building complex technological objects and presented intelligent methods for their modeling. The work defined the concept of a dynamic system and showed that most existing systems belong to this class. The method of controlling such systems was based on differential equations and provided high accuracy and speed of operation. One of the industries where hierarchical distributed models are widely used is control systems in the energy sector. In work [2], the authors considered a control system in a power system based on wind and solar energy. They determined the advantages of building hierarchical systems based on microgrids and presented mathematical algorithms for controlling them. However, the application of mathematical methods to large hierarchical systems is not always possible, since it requires the solution of higher-order differential equations.

Another option for implementing control of automated systems is the use of neural networks. In work [3], a complex hierarchical system for managing groundwater resources under climate change conditions based on the CNN-Bi LTM network was presented. This approach showed high accuracy in solving the problems under conditions of uncertainty of the input data boundaries. However, the proposed algorithms are not practical to use in systems of strict automated control.

Another approach to implementing control and management algorithms for complex hierarchical complexes is the use of production systems. In [4], the authors presented the use of CLIPS to assess the feasibility of using solar energy in the field of residential and commercial electricity supply. In [5], the problem of traffic light control was considered. The authors argued that the use of traditional methods to solve this problem does not give an optimal result due to the increase in traffic, which leads to a complication of the road situation. A production system based on the rules of the Traffic Lights Expert System (TLES) was proposed. The results obtained showed the feasibility of using the proposed system based on the data obtained to reduce the level of traffic congestion on the roads. At the same time, the control process met the time requirements, which is critical for real-time systems.

In work [6], the problem of mixing drilling fluids was considered. Within the framework of the work, the authors determined the structure of the production complex, described a set of rules according to which the fluids are prepared, and showed the interfaces of the system operator, which is part of the overall automation system. The system was tested in a real production process, and the obtained data showed that the solution meets all the necessary standards.

In article [7], the process of modeling functional processes between components of a hierarchical control object was considered, which allows simulating the system operation during

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

testing. It was determined that the modeling process allows you to detect and correct errors in the logic of work, some of which are critical for the operation of the automated complex.

However, the presented methods do not reflect the specifics of a control object with a complex distributed hierarchical structure. Therefore, it is necessary to take into account the specified specifics at the level of the control object representation model.

The purpose of the work is to present the architecture of a distributed component-oriented production model for a IDCS for controlling an object in real time.

To achieve this goal, it is necessary to perform the following **tasks**:

1. Determine the IDCS architecture for implementing a production control system.
2. Determine the architecture of a distributed component-oriented production control system.
3. Test the presented architectures on a test IDCS.

1. IDCS architecture for production control system

To implement a distributed component-oriented production system, the IDCS architecture is used, presented in Fig. 1.

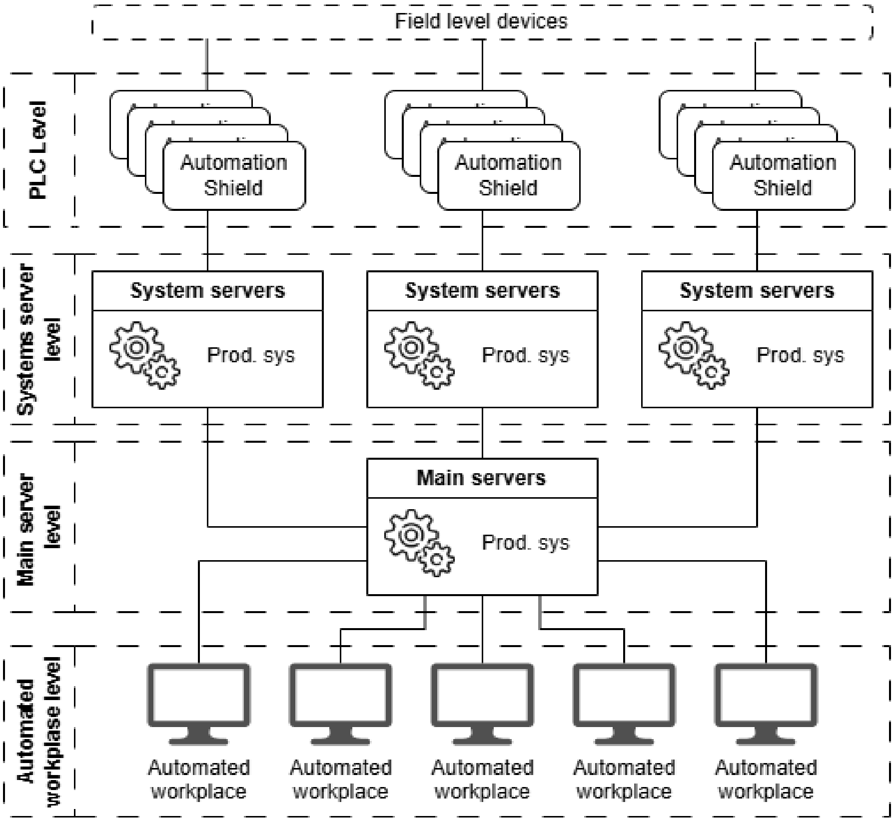

Figure 1 – IDCS architecture

At the programable logical controllers level (PLC level), direct control of the equipment and receipt of data from sensors are implemented. Each control panel, depending on the complexity of the system, can contain one or more PLCs. Communication of controllers with server equipment of the system level occurs using standardized protocols, most often TCP/UDP Ethernet. In addition to standard protocols, internal protocols offered by the hardware manufacturer can also often be used.

At the system level, the system is controlled as a single unit. The basis of this level is server equipment, in particular servers for processing and storing information. Depending on the architectural features of the logical controller level and the overall complexity of the system, the system level can be implemented both on the basis of one local hardware server and on the basis of a group of servers, both local and remote. Within the system level, there is no exchange of information between servers of different systems. This allows to ensure the safety and reliability of each individual system.

At the main server level, from a hardware point of view, communication between servers of the system level occurs. At the same time, access to the physical equipment at the PLC level is unavailable to guarantee correct control of field-level devices. From the point of view of business logic, this level ensures the interconnection of all systems with each other, as well as the connection with automated workplaces. An automated workplace is a set of software and hardware that implements the interaction of personnel with some part of the overall system.

2. Architecture of a distributed component-oriented production system

Production systems implemented to manage a hierarchical object have a three-level distributed architecture, which is presented in Fig. 2.

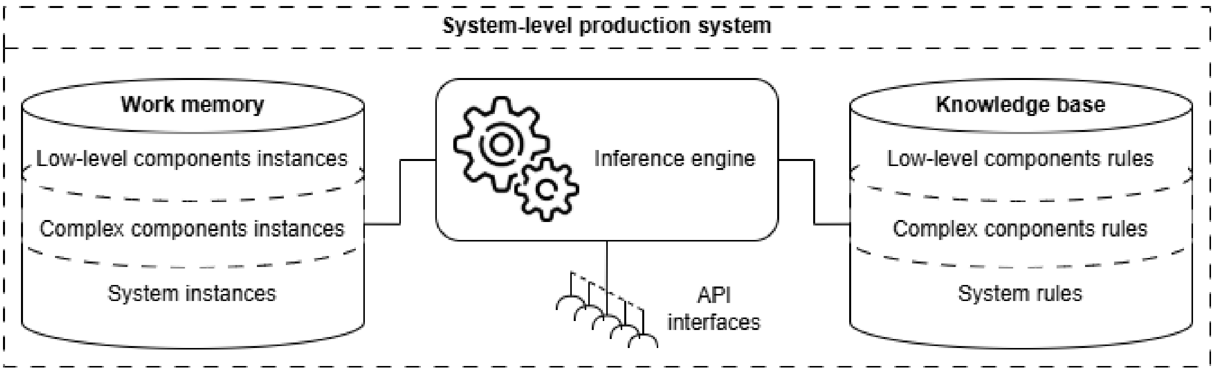

Figure 2 – System-level production system architecture

The implementation of a production system for controlling equipment within a separate industrial system of a general complex takes place on system-level servers. A three-level distributed hierarchy [7] is chosen for it, which consists of:

1. Work memory, divided into 3 segments depending on the level. The first segment reflects the state of specific low-level interfaces that directly interact with field-level equipment. The second segment, which is the middle level, reflects the state of components that aggregate field-level equipment and act as a single mechanism. The third segment reflects the state of high-level complex nodes that consist of structural components of the middle-level system.

2. A knowledge base, similarly divided into three segments, each of which contains rules for processing information at a specific level.

3. A logical inference engine that works in the direction from the lower to the upper levels.

The control of various systems as a single complex is carried out by the production system of the main server level. At the same time, its hierarchy is similar to that of production

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

systems at the system-level. The difference is that there is no lower level of segmentation, since interaction with physical equipment at the main server level is unavailable for security reasons.

3. Computational experiments

The presented approach to the implementation of a hierarchical object was tested on a complex system consisting of separate emergency lighting systems, emergency power supply and access control and management system of data center. CLIPS [8] was chosen as a production model. Interaction with the Schneider Modicon M241 PLC at the system level was configured through driver programs written in C. Dell Precision Tower 7810 workstations were used as servers. The implementation of the operator control software and general business logic was performed in C#. The graphical interfaces of system operators are implemented using WPF technology.

6 sets of emergency scenarios were defined for testing the software-hardware complex:

1. Failure of a non-critical component of one of the systems.
2. Failure of 10% of the components of one of the systems.
3. Failure of a critical component of one of the systems.
4. Failure of 10% of the critical components of one of the systems.
5. Conflict in the operation of components of one system.
6. Intersystem conflicts.

The main parameters considered in the testing process were the correctness of decision-making by the distributed production system, the time of information processing, the proportion of fully automated control actions. A comparison of the presented method with the traditional control algorithm implemented on a finite state machine was carried out. The averaged test results are summarized in Table. 1.

Table 1

Test results

Parameter	Method	Test set					
		1	2	3	4	5	6
Average time, ms	Fin. state mach.	320	415	350	820	1250	1325
	Prod. system	350	520	360	750	1300	1670
Correctness, %	Fin. state mach.	100	90	100	75	80	50
	Prod. system	100	90	100	90	85	85
Fully automated operations, %	Fin. state mach.	100	85	80	75	70	65
	Prod. system	100	100	100	90	80	75

The obtained data allow us to conclude that the average operating time of the production system is 10% longer. However, the results of its work are 16% more correct on complex tasks, in particular on intersystem conflicts. This is due to the fact that describing all possible scenarios of intersystem interaction for the operation of a finite automaton is a rather laborious process that is difficult to test. Therefore, in practice, a large number of scenarios are not prescribed, which ultimately leads to errors. The production system is able to build logical chains even without all the necessary information, which allows to increase the correctness of the obtained solution. The share of fully automated control actions of the complex built on the production system is also 15% higher for similar reasons.

Conclusions:

1. A four-level architecture of the IDCS is proposed, which allows to implement the functioning of complex hierarchical automation objects.

2. Architectural solutions for management at the system level and at the central server level are proposed.

3. The presented models are tested on a test problem of IDCS with three systems. Based on 6 test sets of emergency situations, the speed, correctness and share of fully automated actions of the software complex based on the production system are determined. According to the results of comparing the control indicators according to the proposed production model and the finite automaton model, it was determined that control according to the proposed method increases correctness by 16% and allows increasing the level of the share of fully automated actions by 15%.

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Received 28.04.2025.
Accepted 30.04.2025.

Розподілена продукційна система керування ієрархічним об'єктом

Існуючі методи керування автоматизованими системами диспетчерського управління (АСДУ), які базуються на математичних алгоритмах чи на моделях скінченних автоматів, втрачають свою ефективність через підвищення рівня складності об'єктів автоматизації. Застосування методів штучного інтелекту для таких систем дозволяє підвищити швидкість та коректність керуючої дії. Тому актуальною є задача вдосконалення методів керування складними ієрархічними об'єктами на основі підходів штучного інтелекту. Проведені дослідження показали, що існуючі методи дозволяють виконувати окремі задачі в загальній системі автоматизованого керування, однак їх коректність та частка повністю автоматизованих дій є недостатньо високою, для керування об'єктом в цілому.

Метою роботи є представлення архітектури розподіленої компонентно-орієнтованої продукційної моделі АСДУ для керування ієрархічним об’єктом в режимі реального часу.

Висновки: 1) запропоновано архітектуру АСДУ, яка дозволяє реалізовувати функціонування складних ієрархічних об'єктів автоматизації та складається з чотирьох рівнів: логічних контролерів, системних серверів, головного серверу та автоматизованих робочих місць; 2) запропоновано архітектурні рішення для управління на системному рівні та на рівні центрального сервера; 3) проведено апробацію запропонованих моделей на тестовій задачі АСДУ з трьома системами. Для апробації було визначено 6 наборів тестових даних, які відрізнялись за типом аварійних сценаріїв роботи. Тестова система була реалізована на основі апаратного забезпечення Schneider Electric та Dell. Засіб реалізації продукційної моделі – CLIPS. Мови програмування, використані для реалізації програмних систем – C, C#. За результатами порівняння показників керування за запропонованою продукційною моделлю та моделлю скінченного автомата визначено, що управління за запропонованим методом підвищує коректність на 16% і дозволяє збільшити рівень частки повністю автоматизованих дій на 15%.

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ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)