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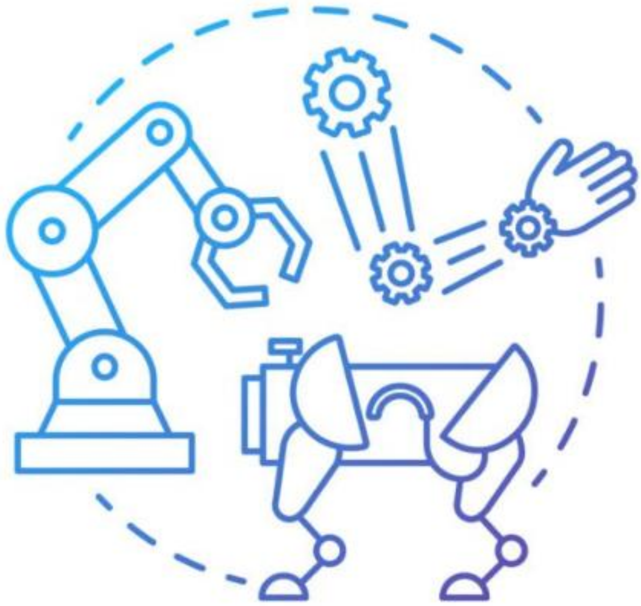

МАТЕРІАЛИ

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У збірник включені тези доповідей, які присвячені сучасним автоматизованим технологіям Industry 4.0 та їх впровадження; інформаційні управляючі системи технологічного призначення; математичні методи в системах автоматизації; розробка та програмування в робототехніці; штучний інтелект та машинне навчання в автоматизації; інтеграція технологій у виробництві та промисловості; сенсорні технології та взаємодія людини з роботами в Industry 5.0; ефективність використання роботизованих систем у виробництві; етика та правові аспекти в робототехніці; Інтернет речей та Інтегровані системи в комп'ютерно-інтегрованих технологіях, автоматизації та робототехніки; технологічні виклики та інновації у світі робототехніки.

Computer-integrated technologies, automation and robotics 2026: Proceedings of III st All-Ukrainian Conference, Kharkiv, May 14-15, 2026: Thesises of Reports / [Ed. I.Sh. Nevlyudov (chief editor).] .-Kharkiv .: [electronic version], 2026. - 97 p.

The collection includes abstracts devoted to modern automated technologies of Industry 4.0 and their implementation; information control systems for technological purposes; mathematical methods in automation systems; development and programming in robotics; artificial intelligence and machine learning in automation; integration of technologies in production and industry; sensor technologies and human interaction with robots in Industry 5.0; efficiency of using robotic systems in production; ethics and legal aspects in robotics; Internet of Things.

ЗМІСТ

EVOLUTION OF SCADA ARCHITECTURE: FROM CENTRALIZED MODELS TO CLOUD-BASED SOLUTIONS

V.I. Ievtushenko, S.V. Sotnik
Kharkiv National University of Radio Electronics
Ukraine, 61166, Kharkiv, Nauky av., 14
E-mail: vitalii.ievtushenko@nure.ua

Annotation: The work is devoted to the study of the transformation of SCADA system architectures in the context of the digital transformation of industrial enterprises. The historical prerequisites for the transition from centralized on-premise deployments to distributed and cloud-oriented solutions are identified. The role of edge computing as an intermediate layer that ensures fault tolerance and operational autonomy of remote facilities is characterized. The specifics of web-oriented human-machine interfaces based on HTML5, WebSocket and RESTful API technologies are outlined. It is shown that the hybrid architecture, which combines local real-time processing with cloud-based analytics and long-term data storage, represents the most balanced approach for modern industrial automation within the Industry 4.0 paradigm.

Keywords: SCADA, cloud technologies, web-based systems, IIoT, edge computing, microservice architecture, industrial automation, information management systems.

ЕВОЛЮЦІЯ АРХІТЕКТУРИ SCADA: ВІД ЦЕНТРАЛІЗОВАНИХ МОДЕЛЕЙ ДО ХМАРНО-ОРІЄНТОВАНИХ РІШЕНЬ

В. І. Євтушенко, С. В. Сотник
Харківський національний університет радіоелектроніки
Україна, 61166, Харків, пр. Науки 14
E-mail: vitalii.ievtushenko@nure.ua

Анотація: Робота присвячена вивченню трансформації архітектур SCADA-систем у контексті цифрової трансформації промислових підприємств. Виокремлено історичні передумови переходу від централізованих локальних рішень до розподілених та орієнтованих на хмарні технології. Охарактеризовано роль edge-обчислень як проміжного рівня, що забезпечує відмовостійкість та операційну автономність віддалених об'єктів. Наведено особливості веб-орієнтованих інтерфейсів «людина-машина» на базі технологій HTML5, WebSocket та RESTful API. Показано, що гібридна архітектура, яка поєднує локальну обробку даних у режимі реального часу з хмарною аналітикою та довгостроковим зберіганням даних, є найзбалансованішим підходом для сучасної промислової автоматизації в рамках парадигми Industry 4.0.

Ключові слова: SCADA, хмарні технології, веб-орієнтовані системи, IIoT, edge computing, мікросервісна архітектура, промислова автоматизація, інформаційні управляючі системи.

The current stage of industrial development, characterized by the Industry 4.0 concept and the rapid proliferation of the Industrial Internet of Things (IIoT), imposes fundamentally new requirements on Supervisory Control and Data Acquisition (SCADA) systems [1-5]. Traditional centralized SCADA systems, which for decades have served as a reliable foundation for the automation of energy, water supply, and manufacturing, are increasingly becoming a constraining factor for development today [6, 7]. Their architecture, focused on on-premise deployment and the use of "thick" clients, demonstrates limitations in the context of a growing number of distributed assets, the need for deep data analytics, and the necessity of close integration with corporate information systems (ERP, MES).

Thus, the relevance of this study is determined by the objective necessity of transforming the architecture of Supervisory Control and Data Acquisition (SCADA) systems to bridge the gap between established industrial standards and the demands of the digital economy. The transition to cloud-oriented and web-based solutions enables horizontal scaling, reduction of capital expenditures on infrastructure, provision of remote access, and implementation of predictive analytics tools based on machine learning [8-11].

This issue is particularly significant due to the fact that the industry is moving not toward the complete abandonment of local computing, but toward hybrid models, where critical real-time functions remain on edge devices, while resource-intensive tasks of data processing and storage are moved to the cloud. This approach requires a rethinking of SCADA design principles, the development of new methods for ensuring cybersecurity in open networks, and the creation of unified web-oriented human-machine interface (HMI) solutions.

MATERIALS AND RESEARCH RESULTS. SCADA is a class of systems for monitoring, data collection, process control, and remote supervision in distributed facilities (energy, water, manufacturing, transportation).

The transition from centralized SCADA models to cloud-based and web-oriented solutions is a natural stage in the development of industrial automation amid digital transformation and the proliferation of the Industrial Internet of Things [12-16]. Traditional SCADA systems were historically built on a centralized principle, where all data from field devices – sensors, actuators, Programmable Logic Controllers (PLCs), and Remote Terminal Units (RTUs) – was transmitted to one or several central servers. These servers performed data collection, processing, and archiving, and ensured interaction with operator workstations via HMI interfaces. This approach provided high predictability, controllability, and compliance with security requirements, which was particularly important for the energy, water supply, and other critical sectors.

Typical examples of classical centralized platforms are SIMATIC WinCC, Wonderware InTouch, and iFIX. They are oriented towards on-premise deployment, the use of «thick» clients, and often rely on closed or semi-open data exchange protocols. However, with the increase in the number of connected devices, the expansion of the geography of production facilities, and the need for integration with corporate information systems, the centralized model began to demonstrate limitations. Scaling required significant capital expenditures on server infrastructure, and remote access was complex and required specialized VPN solutions. Furthermore, integration with ERP, MES, and analytical platforms was often carried out through complex gateways or custom developments.

The next stage of evolution was the emergence of distributed and multi-tier architectures, in which part of the data processing was moved closer to the source, to the level of edge devices or local gateways. This made it possible to reduce the load on central servers, increase fault tolerance, and ensure autonomous operation of facilities in case of loss of communication with the central node. The concept of edge computing became an intermediate link between classical centralization and a full-fledged cloud model. Evolution of SCADA architectures: from centralized on-premise models to cloud-oriented solutions is shown in Fig. 1.

The further development of digital technologies, the proliferation of broadband internet, and cloud services have contributed to the formation of cloud-based SCADA architecture. In this model, data from field devices is transmitted through secure gateways to a cloud platform, where functions such as storage, analytics, visualization, and integration with other services are implemented. Cloud solutions provide horizontal scalability, high availability, and the ability to use machine learning tools for predictive analytics. Among the platforms that support such approaches are AWS IoT Core, Microsoft Azure IoT Hub, and Google Cloud IoT. They enable the construction of microservice architectures, the use of containerization, and API-oriented integration.

In parallel with cloudification, there is a transition to web-oriented interfaces. Whereas in the past, operator stations required the installation of specialized software, modern systems increasingly use the browser as a universal client. Web technologies such as HTML5, WebSocket, and RESTful APIs make it possible to implement a fully functional HMI in the form of single-page applications. This simplifies software updates, ensures cross-platform compatibility, and supports mobile devices. An example of a platform that actively develops a web-oriented approach is Ignition, which combines server-side logic with a flexible browser-based interface and support for modern data exchange protocols.

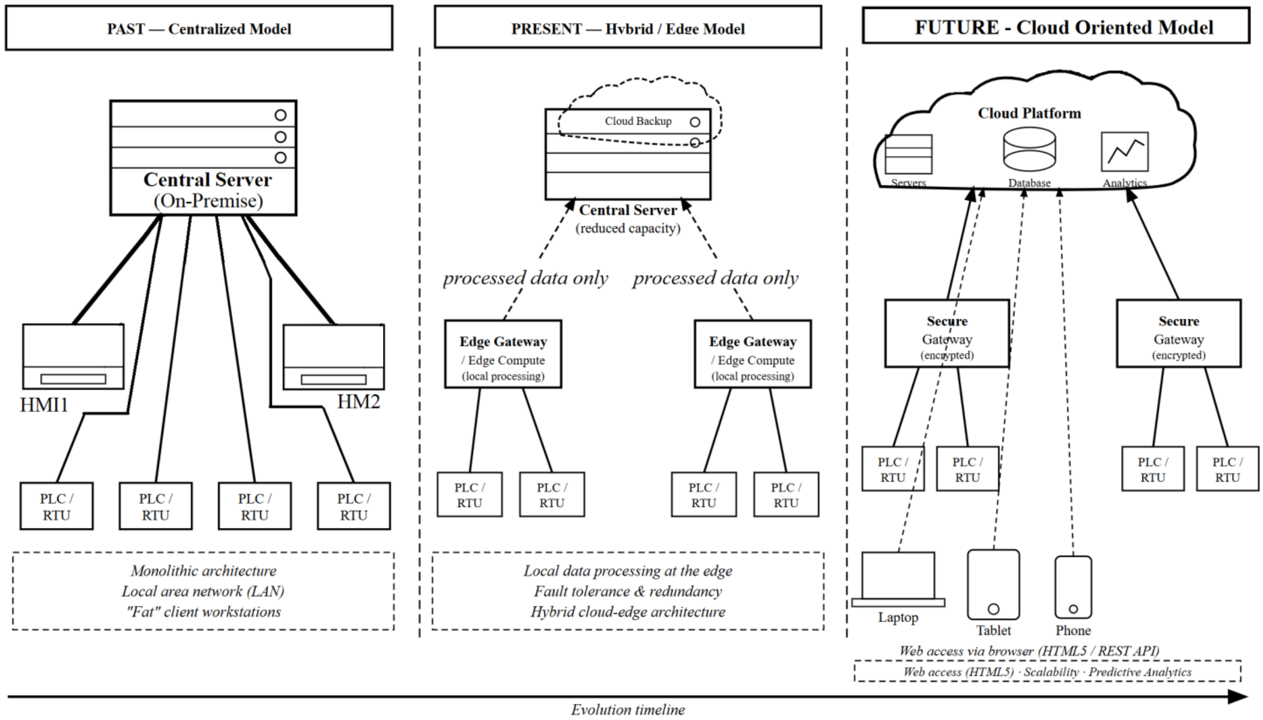

Figure 1 – Evolution of SCADA architectures: from centralized on-premise models to cloud-oriented solutions

Despite the active development of cloud technologies, a complete abandonment of local components in industry is still uncommon. The most prevalent approach is the hybrid model, where critical real-time functions remain at the local level, while long-term storage, analytics, and integration with business systems are moved to the cloud. This approach allows for maintaining high reliability while simultaneously leveraging the scalability and analytical capabilities of cloud services.

The transition from centralized SCADA systems to cloud-based and web-oriented solutions is not merely a technological upgrade but also a transformation of the production management concept. Modern SCADA is becoming distributed, service-oriented, integrated with corporate IT systems, and data-driven. It combines local autonomy with global accessibility, provides predictive analytics capabilities, and supports integration with the enterprise's digital ecosystems. This evolution defines the direction of industrial automation development within the context of Industry 4.0.

CONCLUSIONS. The evolution of SCADA systems from centralized to cloud-based and web-oriented architectures is a natural consequence of the digital transformation of industry. This paper analyzes the transformation of SCADA system architecture – from classical centralized models with on-premise deployment and «thick» clients to distributed hybrid and fully-fledged cloud solutions.

Typical representatives of centralized platforms (SIMATIC WinCC, Wonderware InTouch, iFIX) and their limitations in the context of a growing number of connected objects and the need for integration with corporate systems are considered. The role of edge computing as an intermediate layer between centralized and cloud models, which ensures fault tolerance and object autonomy, is substantiated. The capabilities of cloud platforms such as AWS IoT Core, Microsoft Azure IoT Hub, and Google Cloud IoT for implementing microservice architectures, predictive analytics, and horizontal scaling are analyzed. It is shown that the transition to web-oriented interfaces based on HTML5, WebSocket, and RESTful APIs ensures cross-platform compatibility, mobile access, and simplified software updates. It is established that the most promising approach is a hybrid architecture, where critical real-time functions are maintained locally, while analytics and long-term data storage are implemented in the cloud environment. The obtained results confirm that modern SCADA is evolving from an isolated industrial system into an integrated component of the enterprise's unified information space within the concept of Industry 4.0.

REFERENCES:

1. Sotnik, S. (2024). Integration of IoT into security systems: opportunities and risks. International Journal of Academic Engineering Research (IJAER). – Vol. 8, Issue 11. – pp. 56-61

2. Mandrykov, K., & et al. (2026). Comparative Analysis of Industrial Data Transmission Protocols (IIOT) in Automation Systems. All-Ukrainian Conference “Intelligent Civil Safety Technologies and Robotic Systems for Emergency and Rescue Operations” (ICSTRO-2026) February 12-13, 2026. – pp. 49-53

3. Marunich, R.V., & et al. (2025). Modern IoT technologies for creating automated access systems. Sustainable smart cities and communities: business and innovation solutions 2025: Proceedings of I st I International Conference, Kharkiv, April 21, 2025: Thesises of Reports. – pp. 38-39

4. Polikanov, K. A., & et al. (2025). Overview of modern technologies for residential automation. «Computer-integrated technologies, automation and robotics» CITAR-2025. – pp. 85-89

5. Vasylchenko, Y., & et al. (2025). Development of Security and Fire Alarm Integrated Automation System at Enterprise. WSEAS Transactions on Systems. – № 24. – pp. 642-664

6. Achkan, M. S., & et al. (2025). Integration of cloud technologies into modern SCADA systems: prospects and challenges. «Computer-integrated technologies, automation and robotics» CITAR-2025. – pp. 26-29

7. Danylenko, M.M., & et al. (2025). Comparative analysis of modern SCADA packages for production automation. International Journal of Academic Engineering Research (IJAER). – 9 (2). –26-34

8. Taran, A., & et al. (2026). AI as a Developer Tool: Github Copilot and Other Artificial Intelligence Assistants. All-Ukrainian Conference “Intelligent Civil Safety Technologies and Robotic Systems for Emergency and Rescue Operations” (ICSTRO-2026) February 12-13, 2026. – pp. 67-71

9. Taran, A., & et al. (2026). Low-Code/No-Code Web Platforms: Opportunities and Limitations. A. All-Ukrainian Conference “Intelligent Civil Safety Technologies and Robotic Systems for Emergency and Rescue Operations” (ICSTRO-2026) February 12-13, 2026. – pp. 96-100

10. Taran, A., & et al. (2026). WEB3 and Decentralized Applications. A Practical Look at Blockchain Development. All-Ukrainian Conference “Intelligent Civil Safety Technologies and Robotic Systems for Emergency and Rescue Operations” (ICSTRO-2026) February 12-13, 2026. – pp. 81-85

11. Taran, A., & et al. (2026). Impact of 5G/6G Networks on the Development of IOT, Robotics, and Autonomous Systems. Low Latest and Mass Connection of Devices. All-Ukrainian Conference “Intelligent Civil Safety Technologies and Robotic Systems for Emergency and Rescue Operations” (ICSTRO-2026) February 12-13, 2026. – pp. 114-118

12. Tverdokhlib, A., & et al. (2024). Intelligent tools for optimizing information and search engines. Manufacturing & Mechatronic Systems 2024: Proceedings of VIII st International Conference, Kharkiv, October 25-26, 2024. – pp. 28-31

13. Yechevskyi A., & et al. (2024). Methods Of Identification Of Objects On Industrial Lines. International Journal of Academic Engineering Research (IJAER). – Vol. 8, Issue 11. – pp. 48-55

14. Sotnik, S. (2025). Development of a range measurement module on an ultrasonic sensor with a GSM module. Radio Electronics, Computer Science, Control. – 2. – pp. 32-44

15. Nevludov, I. Sh., & et al. (2025). Application of artificial intelligence in additive manufacturing (3D printing). Information Technologies and Automation – 2025 / Proceedings of the XVIII International Scientific and Practical Conference. Odessa, October 30-31, 2025. – Odessa, ONUT Publishing House. – pp. 1006-1009

16. Sotnik, S. (2025). Evaluating relational database scaling strategies in web engineering. International Conference on Advanced Trends In Radioelectronics and Infocommunications (ATRIC-2025) (May 21–22, 2025), Lviv Polytechnic Publishing House, Lviv, Ukraine. – pp. 224-228