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Transformation of Uzbekistan's energy sector: development of scada systems, challenges and prospects for automation and digitalization

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Abstract. This article presents an analysis of the processes of digital transformation in the electric power sector of Uzbekistan, with particular attention to the development and implementation of Supervisory Control and Data Acquisition (SCADA) systems [1]. The importance of automation and real-time monitoring for ensuring stability and efficiency of power systems is highlighted. The study examines the main challenges associated with the integration of SCADA technologies—technological gaps, limited human resources, regulatory and financial constraints—and evaluates the results of pilot projects implemented within the framework of the Digital Uzbekistan 2030 program [3,4,5]. Based on analytical and practical data, recommendations are presented for improving the efficiency of SCADA systems, their integration into a unified energy infrastructure, and strengthening the technological sustainability of the sector.

INTRODUCTION

In recent years, Uzbekistan has intensified efforts to modernize its electric power infrastructure, placing special emphasis on the introduction of SCADA/EMS technologies as part of the national digitalization agenda [4]. In 2023, the Ministry of Energy and JSC "National Electric Grid of Uzbekistan" (NEGU), with support from the Asian Development Bank (ADB) and the World Bank, launched SCADA/EMS/RTU pilot projects at substations of 110–500 kV in the Tashkent and Navoi regions. The pilot stage includes modernization of more than 100 substations and construction of over 3,000 km of fiber-optic communication lines to integrate power facilities into a unified dispatching system [1]. Implementation of SCADA elements at production sites, such as the Turtkul and Navoi thermal power plants, has already demonstrated increased monitoring efficiency and improved transparency of technological processes [2]. These initiatives lay the foundation for large-scale integration of automated control systems into the national energy network until 2026 in accordance with the Digital Uzbekistan 2030 strategy [1]. Modernization of transmission networks, expansion of control centers, and introduction of intelligent software complexes determine the strategic direction of the development of Uzbekistan's electric power sector.

EXPERIMENTAL RESEARCH / ANALYTICAL FRAMEWORK

A significant stage in the modernization of the industry was the adoption of regulatory acts defining strategic priorities for reforming the energy system [4]:

Table 1. Regulatory basis for digitalization.

№	Document	Date	Issuing authority	Description
1	PU-166	28.09.2023	President of Uzbekistan	On measures for the next stage of energy sector reform
2	PP-39	03.02.2025	President of Uzbekistan	On regulation of electricity procurement
3	PP-145	21.04.2025	Cabinet of Ministers	On privatization of large enterprises with state participation

Digitalization directions

TABLE 2. Digital transformation projects of NEGU within 2022–2026

Direction	Project goal	Duration	Financing	Cost (million USD)	Expected results
SCADA	Implementation of a centralized Automated Dispatch Control System for transmission networks	2022–2026	World Bank	125.0	Reduction of emergency outages; improved reliability; real-time control and optimization of grid operation
ERP	Creation of an integrated resource and asset management system	2022–2026	World Bank	69.6	Unified accounting; increased transparency; reduction of operational costs; improved financial planning

RESEARCH RESULTS

Historical development of SCADA systems in Uzbekistan. The first SCADA elements appeared in dispatching centers, enabling centralized operation of transmission networks. Gradually, manual monitoring was replaced by automated data collection and visualization tools. However, legacy equipment and fragmented communication channels limited the effectiveness of early SCADA systems [2]. Research by Kamaev and others shows that modernization efforts were constrained by low interoperability between old and new technologies, insufficient personnel training, and lack of unified regulatory requirements.

Current challenges of SCADA integration. Analysis of implemented pilots and national energy projects identified several structural obstacles:

1. **Technological incompatibility**.

Many substations operate on outdated platforms, complicating integration with modern SCADA and requiring costly hybrid modernization solutions.

2. **Human-resource constraints**.

Lack of qualified specialists in SCADA operation, cybersecurity, and data analysis limits functional capabilities.

3. **Regulatory and organizational barriers**.

Existing norms do not fully cover requirements for digital protection, integration of renewable energy, and real-time data exchange between producers and consumers.

4. **Financial limitations**

Large-scale SCADA deployment requires consistent investment and long-term support programs.

Operational effects of implemented SCADA solutions

A case study from Tashkent showed that the introduction of SCADA at a major distribution node reduced technical losses by **approximately 15% in two years** due to:[7]

- automated load balancing,
- faster emergency detection,
- improved communication between substations.

Another example is a natural gas processing plant where predictive maintenance using SCADA increased equipment uptime by more than **20%**. These cases confirm that SCADA significantly improves operational efficiency, reliability, and economic sustainability. The further development of SCADA systems in Uzbekistan's electric power sector should be considered not only as a technological upgrade, but also as a systemic transformation affecting operational management, institutional coordination, and long-term strategic planning. International experience demonstrates that the effectiveness of SCADA implementation significantly increases when it is embedded within a broader digital ecosystem that includes Energy Management Systems (EMS), Advanced Distribution Management Systems (ADMS), Geographic Information Systems (GIS), and Market Management Systems (MMS). One of the key prospects for the next stage of automation in Uzbekistan is the transition from classical SCADA architectures to intelligent, data-driven platforms based on Industrial Internet of Things (IIoT) technologies and cloud-based solutions.

Such an approach enables scalable data acquisition from geographically dispersed assets, real-time analytics, and the application of artificial intelligence algorithms for forecasting demand, detecting anomalies, and optimizing dispatch decisions. In the context of growing integration of renewable energy sources—solar and wind power plants in particular—SCADA systems must evolve to support flexible grid operation, fast response to variability, and decentralized control mechanisms. Cybersecurity represents another critical dimension of future SCADA development. As the level of digital connectivity increases, power systems become more vulnerable to cyber threats. Therefore, the introduction of standardized cybersecurity frameworks, including role-based access control, encryption of data channels, intrusion detection systems, and continuous security auditing, is an essential prerequisite for sustainable digitalization. The development of national regulations aligned with international standards such as IEC 62351 and ISO/IEC 27001 will enhance trust in digital control systems and ensure resilience of critical energy infrastructure. From an organizational perspective, the success of SCADA deployment depends on the coordination between generation companies, transmission system operators, distribution networks, and regulatory authorities.

The creation of a unified information space with standardized data models and communication protocols will facilitate interoperability and reduce duplication of digital solutions. In this regard, the role of NEGU as a central coordinator of dispatching and data exchange is of strategic importance. Human capital development remains a decisive factor. The transition to advanced SCADA and EMS platforms requires not only technical operators, but also system analysts, cybersecurity specialists, and data engineers capable of interpreting large volumes of operational data. Cooperation between universities, research institutes, and energy companies should be intensified to develop specialized educational programs, certification courses, and applied research projects focused on digital energy technologies. In the medium and long term, the integration of SCADA systems with national energy planning tools will allow Uzbekistan to move toward predictive and scenario-based management of the power sector. This will support evidence-based investment decisions, improve asset lifecycle management, and enhance the overall sustainability of the energy system. Ultimately, the consistent expansion of SCADA functionality will contribute to the formation of a smart, resilient, and economically efficient electric power sector that meets both national development goals and global decarbonization trends.

CONCLUSIONS

The analysis shows that the introduction of SCADA and EMS systems is a key factor in the digital transformation of Uzbekistan's electric power sector [4,8]. Despite notable progress in recent years, there remain systemic obstacles preventing full automation, including technological fragmentation, shortage of skilled personnel, and incomplete regulatory support [3,4,5].

Advantages of integrating SCADA systems include:

1. Increased reliability of power supply and reduced accident rates.
2. Improved efficiency of generation, transmission, and distribution processes.
3. Opportunities for predictive maintenance and reduction of operational costs.
4. Creation of an intelligent infrastructure supporting renewable energy integration.
5. Transition to transparent, data-driven energy management in line with global trends.

To achieve long-term sustainability, it is necessary to:

- intensify investments in digital infrastructure,
- modernize outdated equipment,
- introduce educational programs for SCADA specialists,
- develop unified national standards for automation and cybersecurity.

These measures will allow Uzbekistan to strengthen its energy independence, increase sectoral efficiency, and successfully transition to a modern digital energy ecosystem.

REFERENCES

1. Otamurodov, A. *Energy in Central Asia: Status Quo and Prospects (2025–2030).* Journal of Interdisciplinary Sciences and Innovation, 2025, Vol. 1, No. 2, pp. 505–510. Available at: https://inlibrary.uz/index.php/jmsi/article/view/89499
2. Kamaev, A. *Infrastructure Projects in Uzbekistan: Analysis of Opportunities and Risks in the Context of the 2030 Strategy.* Doctoral dissertation, Turin Polytechnic University, 2025. Available at: https://webthesis.biblio.polito.it/35600/
3. Norkulov, D. *Designing the Energy Transition: Innovations in Renewable Energy, Their Applications, and Future Trends in South Korea and Uzbekistan.* World Scientific Research Journal, 2025, Vol. 43, No. 1, pp. 61–76. Available at: http://journalss.org/index.php/wsrj/article/view/666
4. Khakimdjanova, S. Kh. *Digital Transformation, Technological and Economic Sovereignty on the Example of Uzbekistan's Energy Sector.* 2024. Available at: https://rep.bntu.by/handle/data/155483
5. Memmedov, E. F., & Muradova, R. E. *Automatic Power Supply System and Its Functional Role.* Bulletin of Science, 2025, Vol. 2, No. 5 (86), pp. 1174–1183. Available at: https://cyberleninka.ru/article/n/automatic-power-supply-system-and-its-functional-role
6. Yuldoshev, Z., & Akmuradov, B. *Energy Efficiency Management in Smart Devices* [Electronic resource]. Available at: https://devos.uz/files/856.pdf
7. Gafurov, S. *Prospects for the Development of the Gas Processing Industry in Uzbekistan.* Journal of Theoretical and Applied Econometrics, 2025, Vol. 2, No. 1, pp. 16–24. Available at: http://economicjournals.org/index.php/jtae/article/view/50
8. Ushakov, V. Yu., Rakhmonov, I. U., Askarov, A. B., & Nikitin, D. S. *Testing and Monitoring Systems for Electrical Networks.* In: *Digitalization of Electric Power Industry: Scientific and Technical Foundations and Achieved Advantages*, ed. by V. Yu. Ushakov. Cham: Springer Nature Switzerland, 2025, pp. 27–43. Available at: https://link.springer.com/chapter/10.1007/978-3-031-95705-5_4
9. Gulchekhra Allaeva, Gulchekhra Yusupkhodjaeva, Kamola Mukhitdinova, Methodology for calculating sustainable development of fec enterprises based on consolidated integral indices. AIP Conf. Proc. 3331, 030006 (2025) https://doi.org/10.1063/5.0308133
10. Gulchekhra Yusupkhodjaeva, Gulchekhra Allaeva, Kamola Mukhitdinova, Sustainable development of transport enterprises in the context of the formation of the digital economy. AIP Conf. Proc. 3331, 030087 (2025) https://doi.org/10.1063/5.0306872
11. Kamala Mukhitdinova, Gulchekhra Yusupkhodjaeva, Gulchekhra Allaeva, Econometric modeling of investment potential of industrial enterprisess. AIP Conf. Proc. 3331, 050026 (2025) https://doi.org/10.1063/5.0308123
12. Gulchekhra Allaeva, Main directions of sustainable development of fuel and energy enterprises. AIP Conf. Proc. 3152, 050012 (2024) https://doi.org/10.1063/5.0220851
13. Gulchekhra Allaeva, The role of energy security in forming the foundations for sustainable development of fuel and energy complex enterprises. In E3S Web of Conferences 461, 01061 (2023), https://doi.org/10.1051/e3sconf/202346101061
14. Gulchekhra Allaeva, Sustainable development methodology of fuel-energy complex of the republic of Uzbekistan. In E3S Web of Conferences 289, 07033 (2021) https://doi.org/10.1051/e3sconf/202128907033
15. Gulchekhra Allaeva, Fiscal instruments of taxation improvement as a factor of sustainable development of enterprises of the fuel and energy sector. In E3S Web of Conferences 216, 01173 (2020) https://doi.org/10.1051/e3sconf/202021601173
16. Gulchekhra Allaeva, Priority directions of development "Uzbekneftegas" jsc in the conditions of globalization of the world economy. In E3S Web of Conferences 139, 01008 (2019) https://doi.org/10.1051/e3sconf/201913901008
17. Saodat Ibragimova, Khilola Bakhodirova, Formation of investment activities of energy enterprises. E3S Web of Conferences 461, 01074 (2023) https://doi.org/10.1051/e3sconf/202346101074
18. Ravshan Xusainov, Otabek Begmullaev, Problems of ensuring the electricity supply system in Uzbekistan. In AIP Conference Proceedings. 3331, 030002 (2025) https://doi.org/10.1063/5.0305927
19. Ravshan Xusainov, Barno Tillayeva, Nigina Sayfutdinova, Development of ecology and energy in Uzbekistan. AIP Conf. Proc. 3331, 030010 (2025) https://doi.org/10.1063/5.0306384
20. Gulchekhra Yusupkhodjaeva, Development of a unified digital transport and logistics intelligent platform based on the National Operator. E3S Web of Conferences 461, 01055 (2023) https://doi.org/10.1051/e3sconf/202346101055

21. Kamola Mukhitdinova, Gulmira Tarakhtieva, Ensuring sustainable future: The interconnectedness of food safety and environmental health. E3S Web of Conferences 497, 03037 (2024) https://doi.org/10.1051/e3sconf/202449703037
22. Hashimova, S., Yakubova, D., Tursunova, N. (2024). Possibilities of Expanding the Mineral Resource as a Base of Ferrous Metallurgy. In Lecture Notes in Networks and Systems, vol 733. Springer, Cham. https://doi.org/10.1007/978-3-031-37978-9_70
23. Sarvinoz Salomova, Matlyuba Saidkarimova, Latofat Karieva, Kamola Ibragimova, Gulnora Saidova, Ravshan Khikmatov, Improving the efficiency of energy enterprises AIP Conf. Proc. 3331, 040076 (2025) https://doi.org/10.1063/5.0305987
24. Otabek Begmullaev, Saidaxon Nabieva, Shakhnoza Mirsaidova, Classification of energy efficiency policies and their implementation Available to Purchase. In AIP Conference Proceedings. 3331, 030053 (2025) https://doi.org/10.1063/5.0305929
25. Otabek, A., Otabek, B. Alternative energy and its place in ensuring the energy balance of the Republic of Uzbekistan. In AIP Conference Proceedings, 2023, 2552, 050030 https://doi.org/10.1063/5.0117633
26. Akhmedov, O., Begmullaev, O. The ways ensuring energy balance in Uzbekistan. In E3S Web of Conferences 216, 01137 (2020), https://doi.org/10.1051/e3sconf/202021601137
27. Saidakhon Nabieva, Shakhnoza Atakhanova, Modern methods of investment activity in the development of industrial enterprises. AIP Conf. Proc. 3331, 050010 (2025) https://doi.org/10.1063/5.0308119
28. Sarvinoz Salomova, Increasing the efficiency of oil and gas industry enterprises in Uzbekistan. AIP Conf. Proc. 3331, 040075 (2025) https://doi.org/10.1063/5.0305986
29. Mukhitdinova, K.A, Vildanova, L.A Transport improvement of the method of assessing the attractiveness of investment in automotive enterprises. Published 2020 Engineering, Business, Economics, 171 Corpus ID: 218792573, https://DOI:10.31838/jcr.07.05.
30. Sultanova Sh.A., Safarov J.E., Usenov A.B., Muminova D. Analysis of the design of ultrasonic electronic generators. // Journal of Physics: Conference Series. International Conference "High-tech and Innovations in Research and Manufacturing" (HIRM 2021). 2176 (2022) 012007. doi:10.1088/1742-6596/2176/1/012007
31. Zulpanov Sh.U., Samandarov D.I., Dadayev G.T., Sultonova S.A., Safarov J.E. Research of the influence of mulberry silkworm cocoon structure on drying kinetics. // IOP Conf. Series: Earth and Environmental Science (AEGIS-2022). 1076 (2022) 012059. P.1-6. doi:10.1088/1755-1315/1076/1/012059