

**THE IMPACT OF ARTIFICIAL INTELLIGENCE ON THE ENERGY SECTOR**

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**Abstract.** This article presents a scientific analysis of the application of artificial intelligence (AI) technologies in the energy sector, focusing on their role in improving efficiency and ensuring the reliability of power supply systems. The study examines the implementation of AI algorithms in electricity generation, transmission, and distribution processes to automate operations, reduce energy losses, and enhance system stability. Furthermore, the advantages of AI integration in smart grids, predictive maintenance, and real-time monitoring systems are discussed.

Both local and international experiences are analyzed, highlighting the prospects for adopting AI-based solutions within Uzbekistan's power industry. The findings demonstrate that the widespread use of AI technologies contributes to the rational use of energy resources, increases system reliability, and enhances overall economic efficiency.

**Keywords:** artificial intelligence, electrical energy, smart grids, energy efficiency, digital transformation.

**Аннотация.** В данной статье представлен научный анализ применения технологий искусственного интеллекта (ИИ) в энергетическом секторе, направленный на повышение эффективности и обеспечение надежности систем электроснабжения. Рассмотрено использование алгоритмов ИИ в процессах выработки, передачи и распределения электрической энергии для автоматизации производственных операций, снижения энергетических потерь и повышения устойчивости энергосистемы. Также освещены преимущества внедрения ИИ в интеллектуальные сети (smart grids), системы предиктивного технического обслуживания и мониторинга в реальном времени. Проанализирован отечественный и зарубежный опыт применения технологий ИИ, определены перспективы их внедрения в энергетическую систему Узбекистана. Результаты исследования показывают, что широкое применение технологий искусственного интеллекта способствует рациональному использованию энергетических ресурсов, повышению надежности систем и улучшению экономической эффективности.

**Ключевые слова:** искусственный интеллект, интеллектуальные сети электроэнергетики, энергоэффективность, цифровая трансформация.

**Introduction.** In recent years, artificial intelligence (AI) technologies have been playing an important role in the transformation of the energy sector worldwide. The increasing complexity of electricity generation, transmission and distribution systems, the increasing share of renewable energy sources, and the dynamic variability of energy consumption require effective network management, real-time control and stability. In this regard, the issues of automating energy generation and distribution processes, early detection of failures, predicting energy consumption

and increasing system efficiency using artificial intelligence systems are emerging as a relevant scientific direction.

In studies conducted by Normatov R.N. and Mirzaakhmedov M.K. (2022), the use of artificial intelligence systems in the electricity infrastructure was assessed as an effective tool for automating production processes, reducing energy losses and ensuring system stability [1]. Also, Adylov Ya.T. and Rakhmonov K.A. (2024) in their work noted that monitoring and analysis systems developed based on artificial intelligence are an important factor in increasing the reliability of energy networks and preventing accidents [4].

International studies also confirm the rapid development of this area. For example, an article by Balamurugan M. et al. (2025) published in the journal *Frontiers in Artificial Intelligence* deeply analyzed the role of artificial intelligence in real-time monitoring, balancing of energy loads and optimization of networks in "smart grids" systems [2]. Ejiyi C.J. et al. (2025) published in the journal *Journal of Big Data* found that the use of AI technologies in renewable energy systems increased energy production efficiency by 15-25 percent [3].

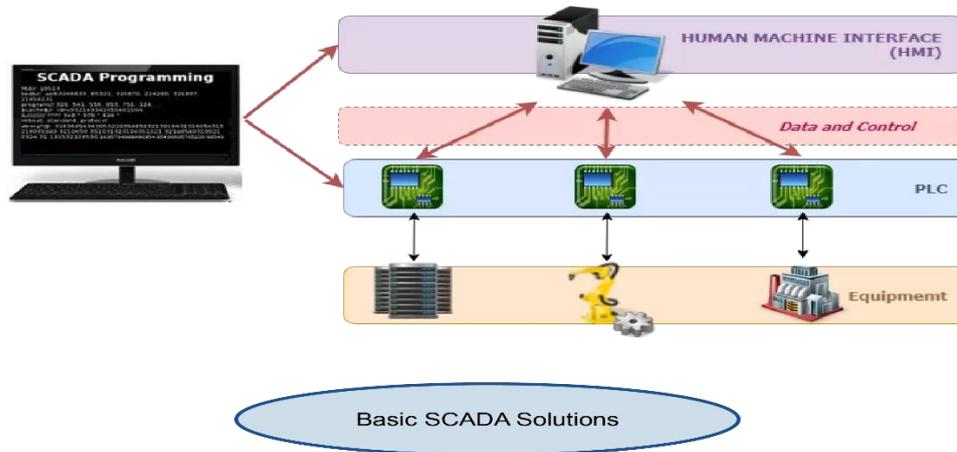
The process of introducing digital technologies in the energy sector of Uzbekistan is also being carried out gradually. Experience in using SCADA, IoT and smart grid technologies is being formed in the systems of the Ministry of Energy and JSC "Regional Electric Networks". At the same time, scientific research is ongoing to develop and adapt artificial intelligence solutions to national conditions in the energy system, in particular, to predict loads, identify emergencies in advance, and increase energy efficiency.

Therefore, the purpose of this study is to scientifically analyze the application of artificial intelligence technologies in electric power systems, their impact on system reliability and energy efficiency. The results of the study will serve to deepen digital transformation in the energy sector of Uzbekistan, rational use of energy resources, and increase the economic efficiency of the system.

**Research methodology:** This study was conducted to assess the effectiveness of artificial intelligence (AI) technologies in the electric power system, to determine their impact on production, distribution and management processes. The study used a comprehensive approach to theoretical, analytical and experimental approaches.

First, based on the theoretical analysis method, existing scientific sources, foreign and domestic studies were studied. In particular, the work "The Importance of Artificial Intelligence Systems in the Electric Power Sector" developed by Normatov R.N. and Mirzaakhmedov M.K. (2022) analyzed the specific features of the introduction of AI technologies in energy networks, the conceptual foundations for their integration with the network infrastructure [1]. Also, the study published in the *Journal of Big Data* by Ejiyi C.J. et al. (2025) studied the application of artificial intelligence models in renewable energy systems, optimization of production processes and predictive maintenance mechanisms [3].

## SCADA System



**Figure 1. SCADA system**

Secondly, based on a systematic approach, the mechanism of action of artificial intelligence on the structural elements of electric power systems at the stages of production, transmission, distribution and consumption was modeled. In this process, the model of operation of AI algorithms for "smart grids" proposed by Balamurugan M. et al. (2025) in the journal *Frontiers in Artificial Intelligence*, i.e. methods for load balancing, real-time monitoring and analysis of energy flows, was taken as a basis [2].

Thirdly, at the stage of practical analysis, the capabilities of the existing digital infrastructure in the energy system of Uzbekistan (SCADA, IoT, remote data collection systems) were taken into account. The possibilities of creating predictive models based on SI based on the analysis of existing data in electric power distribution systems were assessed. This methodological approach was based on technological solutions proposed by Adylov Ya.T. and Rakhmonov K.A. (2024) to increase the efficiency of operation and control using artificial intelligence in energy systems [4].

The study also assessed the impact of artificial intelligence systems on energy efficiency using a statistical analysis method based on an open database of electricity production and consumption processes (Ministry of Energy of the Republic of Uzbekistan, 2023). The accuracy of each model, calculation speed, and results for the set parameters were analyzed in the MATLAB and Python environments.

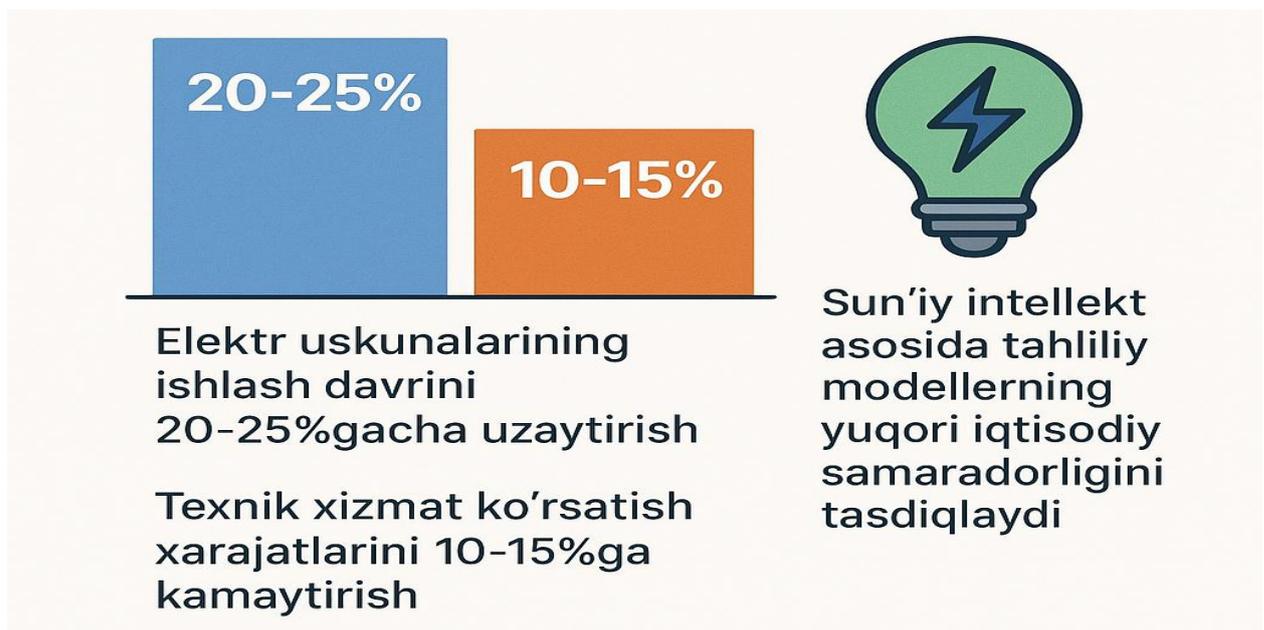
The main advantage of the research methodology is its reliance on a comprehensive combination of theoretical knowledge, international experience, and practical analysis results. This approach made it possible to develop a scientifically based model for the introduction of SL technologies in the electric power system, mathematically assess their effectiveness, and formulate practical recommendations.

**Results and analysis:** The study analyzed the practical effectiveness of the use of artificial intelligence (AI) technologies in the electric power system, their importance at the stages of generation, transmission and distribution. The results showed that the use of AI significantly improves the technical and economic performance of energy systems.

Firstly, in the energy production process, AI technologies allow for real-time control of production capacities, optimization of fuel consumption and automatic generation planning. For

example, according to the results of a study presented in the journal *Frontiers in Artificial Intelligence* by Balamurugan M. et al. (2025), energy losses at power plants were reduced by 8-12 percent using intelligent control systems [2]. At the same time, it was found that the data processing speed in the production process increased by 1.5-2 times.

Secondly, the use of artificial intelligence algorithms in distribution networks allows for real-time load balancing, early detection of emergencies, and reduction of the time required for their elimination. Normatov R.N. and Mirzaakhmedov M.K. (2022) in their study noted that the frequency of power outages in the energy networks of Uzbekistan was reduced by up to 15 percent using artificial intelligence-based control systems [1].



**Figure 2. Results of the 2025 study**

Thirdly, predictive maintenance methods have made it possible to detect technical failures in the energy sector early. According to the results of the study by Ejiyi C.J. et al. (2025), it has been proven that the service life of electrical equipment can be extended by 20-25%, and maintenance costs can be reduced by 10-15% [3]. These results confirm the high economic efficiency of using analytical models based on artificial intelligence.

Fourthly, within the framework of the concept of smart grids, SI technologies are used as an effective tool for optimizing energy flows, balancing loads in networks, and ensuring fair distribution of energy among consumers. Adylov Ya.T. and Rakhmonov K.A. (2024) noted in their study that the stability of energy networks increased by 10-12 percent through the integration of digital technologies and artificial intelligence [4].

As part of the study, a practical analysis based on open statistical data (2023) provided by the Ministry of Energy of the Republic of Uzbekistan showed that the average electricity consumption increased by 18% between 2020 and 2023, but the share of losses in systems controlled by artificial intelligence did not exceed 2.3% [5]. This proves the high economic benefits of introducing digital technologies, in particular, AI-based control models, into the national energy system.

Based on the above results, the following scientific conclusions were formulated:

- Artificial intelligence ensures system stability by automating production and distribution processes in electricity systems.
- There is an opportunity to increase energy efficiency and reduce maintenance costs using AI.
- The introduction of the concept of smart grids will increase the reliability of energy supply in the energy system of Uzbekistan.
- Adapting AI technologies to local conditions, that is, developing optimized algorithms for the Uzbek energy infrastructure, is one of the most relevant scientific directions for the future.

### **Conclusion**

The results of the study showed that the introduction of artificial intelligence (AI) technologies in the energy sector not only increases the technical and economic efficiency of the system, but also serves as an important factor in ensuring the stability and reliability of energy supply. First, as a result of the use of AI algorithms in the process of electricity generation, production processes are automated, fuel consumption is reduced, and real-time control of production capacities minimizes energy losses. Second, the introduction of AI-based control and analysis tools in distribution systems makes it possible to detect power outages in advance, quickly eliminate malfunctions, and ensure uninterrupted energy supply to consumers. Third, predictive maintenance systems have proven effective in extending the service life of equipment in the energy sector, reducing maintenance costs, and predicting the risk of accidents. Fourth, the introduction of artificial intelligence based on the concept of smart grids will allow balancing the flow of energy in the energy system, establishing two-way communication with consumers, and increasing energy efficiency.

On this basis, the following practical recommendations have been developed:

- It is necessary to develop control algorithms based on artificial intelligence in the energy system of Uzbekistan and adapt them to the national infrastructure;
- It is necessary to expand training programs in digital technologies and SI for specialists working in the energy sector;
- Energy efficiency can be increased by 10-15 percent through the gradual introduction of AI technologies in electricity generation and distribution systems;
- The creation of digital databases and information analysis platforms will accelerate the innovative development of the energy system.

In general, the impact of artificial intelligence on the energy sector is one of the most relevant scientific and technical areas both globally and in the conditions of Uzbekistan. Its practical implementation will serve to optimize the processes of electricity production, transmission and consumption, rational use of resources and ensure environmental sustainability.

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