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Перспективы внедрения технологий искусственного интеллекта в управление возобновляемой энергетикой

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Аннотация. *Статья представляет собой препринт исследования в области использования искусственного интеллекта (ИИ). Анализируется эффективность использования технологий искусственного интеллекта (ИИ) для управления нагрузкой на станции, выработки энергии за счёт возобновляемых источников энергии, а также оценивается использование ИИ в данных процессах. Проанализированы исследования текущего состояния и перспектив развития ИИ в разных отраслях и направлениях, сложность в многоаспектности использования Искусственного интеллекта на электростанциях в направлениях «зеленой энергетике».*

Ключевые слова: искусственный интеллект, управление нагрузкой, прогнозирование погоды, оптимизация, машинное обучение, нейронные сети, эффективность, безопасность, глубокое обучение, обучение с подкреплением

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Research article

Prospects for the implementation of artificial intelligence in renewable energy management

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Abstract. *The article is an attempt at research in the field of the use of artificial intelligence (AI). The efficiency of using artificial intelligence (AI) technologies to control the load at the plant, energy generation from renewable energy sources, and the use of AI in these processes is analyzed. The research of the current state and prospects of AI development in various industries and directions, the complexity in the multidimensional use of Artificial Intelligence at power plants in the areas of "green energy" are analyzed.*

Keywords: artificial intelligence, load management, weather forecasting, optimization, machine learning, neural networks, efficiency, security, deep learning, reinforcement learning

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Introduction. There is currently no clear and universal definition of artificial intelligence (AI), which is due to the constant development of this area in various countries of the world community, which makes AI terminologically difficult to accurately define, especially in the context of scientific research on “green energy”.

The use of AI will help energy companies transform. McKinsey research has shown that digitalization in energy companies will provide productivity gains of 2 to 10%, and profitability of 10 to 30% [1, 11].

A serious disadvantage of green energy is its dependence on weather conditions. Load management at a station that operates on renewable energy sources (RES) requires constant monitoring and optimization of the processes of distribution of the received energy [1, 2, 3, 4, 5, 6, 7, 8, 9].

The potential of using AI to optimize energy consumption contributes to energy efficiency and environmental protection, and stimulates economic growth in this industry. We present key aspects of AI applications in the field of energy consumption forecasting, energy production management and optimization, leak and fault detection, and the future development of green energy [1, 2, 3, 4, 5, 6, 7, 8, 9].

Materials and research methods. Renewable energy sources are not only clean, inexhaustible, but also environmentally friendly, powerful energy sources are capable of supplying large networks and isolated loads. The advantage of artificial intelligence AI is the ability to manage energy using data. As Bugorskiy I.A. notes, “…modern energy management systems require fast and accurate data analysis for decision-making, and artificial intelligence helps automate this process. Fuzzy logic and algorithms inspired by nature are among the artificial intelligence techniques that are used to improve the performance of renewable energy systems and green energy system technologies. These techniques help optimize the performance of green energy sources, improving their prospects for widespread use…” [10].

Research results and their discussion. To simplify and maximize these processes, artificial intelligence technologies can be used due to their potential for several reasons:

1. Artificial intelligence can be built into Smart grid » for efficient management of both energy production and consumption, making it easier to integrate multiple types of renewable energy sources with variable output.
2. Artificial intelligence analyzes large volumes of data in real time and makes decisions on energy redistribution to identify and then smooth out peak loads and avoid network overloads.
3. The use of artificial intelligence technologies to optimize the distribution of received energy leads to a reduction in the costs of energy production and transmission due to the rational use of resources.
4. Systems that incorporate artificial intelligence are highly flexible due to their ability to quickly adapt to changes in real time, such as changes in consumer behavior or weather conditions.
5. In addition, artificial intelligence technologies improve the stability and safety of the system because they predict potential problems and take measures to prevent accidents, which, accordingly, reduces their risk.

Among the artificial intelligence technologies that can be implemented in load management at renewable energy plants, machine learning, deep learning and reinforcement learning (DL, ML and RL, respectively) are particularly effective.

Machine learning is a subset of artificial intelligence that aims to create systems that learn and improve based on the data they have previously received.

Among the machine learning approaches, the following are worth highlighting:

1) A regression model that is used to predict variables such as energy consumption and production.

2) Classification model that helps predict equipment condition and failures.

A technique for regression and classification problems is gradient boosting, which allows for accurate prediction of energy production based on weather data. In addition, machine learning models such as decision trees and random forests are used to analyze a data set and identify aspects that have a direct impact on energy consumption.

Deep learning is a class of machine learning that uses neural networks to automatically learn from large amounts of data.

Deep learning techniques such as recurrent neural networks (RNN) and long short-term memory (LSTM) are suitable for time series analysis and forecasting changes in energy production or consumption based on historical data. In addition, convolutional neural networks (CNN) can analyze high-dimensional data, such as weather patterns that affect energy production and satellite images to determine solar radiation.

Reinforcement learning (RL) is another type of machine learning in which an agent is trained without information about the system, but with the ability to work in this system.

Deep Q-learning (an RL approach) is used to generate a real-time energy control strategy, where the agent learns by interacting with the environment and issuing a reward for the correct decision. This approach allows for the optimization of charging/discharging of battery systems at a specific point in time based on the load. In addition, Actor-Critic methods (another RL variant) provide the opportunity for adaptive energy management in smart grids.

To most effectively manage the load at a renewable energy plant, a combined approach should be used: machine learning to perform the forecasting process and reinforcement learning to improve energy management activities.

The implementation of a system based on the interaction of these methods will consist of the following stages:

1. Carrying out collection and organization of information:
- collection of recorded data on energy production and consumption, weather, the state of existing devices and information from sensors and other relevant and necessary equipment;
- implementation of data analysis.
2. Building an LSTM Prediction System :
- Organization of the data volumes required for training and testing the system;
- LSTM prediction system : building the LSTM architecture , performing the training process based on the recorded data, performing the system validation process, and tuning the hyperparameters;
- Conducting a system analysis.
3. Deep energy management optimization system Q - training:
- development of a modeling environment;
- implementing the process of training an agent to work with a modeling environment based on the predictions produced by the LSTM system for decision making;
- implementation of the system validation process;
- conducting a system analysis.
4. Combination with subsequent testing of the combined system:
- LSTM and Deep - Q systems ;
- development of an interface for working with the combined system and its monitoring;

– conducting testing;
5. Integration and usage:
– full implementation of the station,
– implementation of the process of training working personnel,
– monitoring and control of the system.

Conclusion. The implementation of a system based on a combined approach will allow achieving an economic effect, the main sources of which are in the following aspects:

– optimization of energy use;
– reduction of operating costs;
– reducing loads during peak hours;
– reliability and stability of energy supplies.

Thus, the introduction of artificial intelligence technologies into load management at a renewable energy plant, among which the most relevant are machine learning, deep learning and reinforcement learning, allows for automated load management and maximizes energy generation efficiency and reduces operating costs.

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