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Overview of the Application of Artificial Intelligence in Intelligent Grid Dispatch Optimization

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ABSTRACT
With the global energy transition and the large-scale integration of renewable energy into the grid, the volatility and uncertainty of the power system have increased significantly, making traditional dispatch methods unable to meet these demands. Against this backdrop, artificial intelligence, with its advantages of autonomous learning, rapid iteration, and global optimization, has become a key driver of innovation in smart grid dispatch systems.This article systematically reviews the application of artificial intelligence (AI) in smart grid dispatching, categorizing it into three phases: introduction, growth, and maturity. It also categorizes and organizes research on support vector machines, genetic algorithms, deep learning methods, and multi-agent systems. It then argues that while AI demonstrates significant potential in smart grid dispatching, it still faces numerous challenges. It also points out that future efforts should focus on developing interpretable AI models, strengthening privacy protection, and fostering cross-disciplinary and cross-domain collaboration to promote the large-scale application of AI in smart grid dispatching.In general, artificial intelligence has brought new opportunities for the development of smart grid dispatching and has played a significant role in the realization of new power systems and the "dual carbon" strategic goals.

KEYWORDS
Smart grid; Dispatch optimization; Artificial intelligence; Machine learning; Deep learning; Product life cycle theory

1 Introduction

Driven by the global energy structure transformation and the "dual carbon" strategic goals, smart grids have gradually become important facilities for efficient energy utilization and sustainable development [1]. Through advanced communication technology, control and computer technology, smart grids have achieved real-time monitoring and high-speed optimization scheduling of power production, transportation, distribution and consumption. However, with the large-scale access of renewable energy, the volatility and power uncertainty of the power system have increased significantly. Traditional scheduling methods based on digital optimization and heuristic algorithms have difficulty in achieving efficient calculations when dealing with the highly complex grid operation problems after the large-scale access of renewable energy, resulting in low efficiency and poor real-time performance [2]. In this context, artificial intelligence technology, with its unique advantages in autonomous learning, rapid iteration and global optimization, has become a key driving force for the transformation of smart grid scheduling systems [3].

China attaches great importance to the integrated application of artificial intelligence and energy systems. As early as 2017, the government issued the "New Generation Artificial Intelligence Development Plan", which clearly proposed "developing smart grids" as one of the key application areas of artificial intelligence. Subsequently, it issued policy documents such as the "14th Five-Year Plan for National Informatization", the "14th Five-Year Plan for Modern Energy Systems" and the "Blue Book on the Development of New Power Systems", laying a national strategic foundation for the application of artificial intelligence in the field of smart grids [4]. The intelligence level of smart grids is directly related to the safety, reliability and economy of power systems. Studies have shown that the load forecasting, state estimation, optimal scheduling, and security protection capabilities of artificial intelligence technology are far superior to traditional methods [5]. It not only improves the system operation efficiency and response speed, but also demonstrates its potential in network security and human-computer interaction [6].

In recent years, domestic and foreign scholars have achieved a lot of results in the research on the integration and application of artificial intelligence technology and smart grid. For example, deep learning and robot learning methods have been widely used in load forecasting and renewable energy application prediction, effectively improving the accuracy and timeliness of predictions [7]; reinforcement learning and multi-agent technology have demonstrated superior flexibility in distributed scheduling optimization and demand response management [8]; the integration of artificial intelligence and blockchain technology has greatly improved data security, transaction transparency and user participation [8]. In addition, artificial intelligence also plays a huge role in the intelligent management of new energy systems such as hydrogen energy. This project combines the product life cycle theory to classify the development of artificial intelligence in the field of smart grid scheduling in recent years, aiming to establish a logically clear development context and application status, analyze the advantages and disadvantages of different methods at different stages, and reveal the key challenges they face in practical applications, so as to provide reference and guidance for the application and development of artificial intelligence technology in the field of smart grid scheduling.

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2 Background and technical basis

Smart grids integrate communications and power systems, with adaptive control and real-time monitoring capabilities as key features. Grid dispatch, a core area of smart grids, aims to ensure safe, economical, and stable operation of the power system. Specific tasks include load forecasting, renewable energy output forecasting, power generation and load balancing, frequency and voltage control, and emergency dispatch. Compared to traditional centralized power grids, smart grids incorporate a large number of renewable energy and distributed power sources, making dispatching more complex and uncertain. A key challenge that urgently needs to be addressed is achieving real-time optimization.

Traditional algorithms often face bottlenecks such as low computational efficiency and insufficient real-time performance when processing large-scale power systems and nonlinear data. Artificial intelligence, leveraging its advantages of self-learning and global optimization, offers a new technological path for power grid dispatching, providing strong support for smart grid dispatching at the prediction, optimization, and security levels.

3 Review based on product life cycle theory

3.1 Introduction period: initial exploration and research

The application of artificial intelligence in the field of smart grid dispatching began around 2010. At that time, researchers used artificial intelligence as an emerging computing tool to assist the application of traditional methods. During this period, the research focused on short-term load forecasting and small-scale dispatch optimization. However, due to the relatively limited scale of the power grid at that time, the computing power of artificial intelligence was relatively poor, so support vector machines (SVM), genetic algorithms (GA) and early artificial neural networks (ANN) became the main research methods. For example, genetic algorithms have global search capabilities and are therefore preferentially applied to small-scale dispatch problems. They can obtain better solutions within a limited number of iterations, which is more flexible than traditional linear programming methods [2].

Furthermore, SVM and ANN have also achieved certain results in short-term load forecasting tasks. Compared with statistical models based on regression analysis, SVM can better capture the nonlinear fluctuation characteristics of power load [5]. However, these methods are more dependent on data scale and features, and their generalization performance is insufficient, resulting in obvious limitations in large-scale power grid applications. Overall, the research at this stage basically remains at the laboratory level and lacks actual testing and promotion in the power grid.

3.2 Growth stage: deep learning and expanded applications

In the following years, with the increase in data acquisition methods, the continuous increase in data volume, and the gradual improvement in computing power, the research on artificial intelligence in the field of smart grid dispatching has rapidly entered a growth period. Deep learning has gradually become the core of research in this stage, especially in load forecasting, forecasting of energy generation after the connection of wind power and photovoltaic power generation, and distributed dispatching problems. Many studies have shown that long short-term memory networks (LSTMs) have excellent performance in processing typical time series data such as power load and renewable energy output, which can reduce the challenges caused by randomness and intermittency after large-scale access of renewable energy to the grid [6]. When processing power data, convolutional neural networks (CNNs) can automatically capture the potential laws in the input data by extracting local and multi-level features, making the dispatch model more adaptable when facing complex and multi-dimensional data structures [7]. For example, in the prediction of renewable energy output, the CNN mechanism can effectively identify the local fluctuation characteristics in the power series, and therefore significantly outperforms traditional recognition methods in terms of prediction accuracy. However, it still has certain limitations, such as insufficient long-term capture capabilities, which leads to poor performance in some tasks.

To make up for the lack of application environment of a single model, scholars have also proposed a variety of hybrid model architectures, combining deep learning with traditional learning and other different models, thereby improving the prediction accuracy and generalization ability of the model. The hybrid architecture based on CNN and LSTM is a typical example. CNN can capture short-term energy fluctuations, while LSTM performs better in the long term. The combination of the two provides more reliable data support for power grid scheduling [9]. Based on the combination of multiple models, artificial intelligence has gradually expanded to the demand response field of the power market, and combined deep learning with Internet of Things technology to form a new framework for real-time monitoring and dynamic scheduling [10]. These studies have significantly promoted the transformation of the smart grid scheduling field from the original single prediction task to systematic scheduling optimization.

3.3 Maturity: reinforcement learning, multi-agents, and fusion innovation

In recent years, as the complexity of the power grid operating environment has gradually increased, research has gradually entered a mature stage. Researchers continue to develop the application of artificial intelligence in the field of smart grid scheduling. The research in this stage is no longer limited to load forecasting, but is moving towards more complex and challenging real-time scheduling, distributed optimization and multi-objective collaboration. Reinforcement learning (RL) has become one of the core methods in this stage because it can continuously update decision-making strategies in continuous interaction with the environment. It can ensure the flexibility and robustness of scheduling in highly uncertain operating environments. In particular, models based on deep reinforcement learning (DRL) have been applied to fields such as real-time power grid scheduling and demand response control, and have shown better performance than traditional static optimization [8]. However, DRL training usually requires a large number of samples and computing power support, and the model still has uncertainties in terms of convergence and stability. This problem is still in urgent need of solution.

At the same time, the research on multi-agent systems (MAS) has received increasing attention and has been widely used in the field of coordinated dispatching of distributed power grids and microgrids. Different agents can learn independently and perform local optimization, and then achieve global coordination and realize dispatching and cooperation through interaction, thereby significantly improving the overall economy and stability of the system [9]. In addition, with the gradual rise of the integration of artificial intelligence and emerging technologies such as blockchain, the boundaries of smart grid dispatching are constantly expanding, and the security and transparency of data transmission and market transactions have been greatly improved by smart contracts and encryption technology, which effectively addresses issues in network security and privacy protection [11]. In some more cutting-edge research, artificial intelligence has also been applied to the dispatching and management of hydrogen energy and integrated energy systems, achieving optimization across energy systems [12].

In summary, research in this phase is increasingly showing a trend toward interdisciplinary, multi-technical integration, rather than the traditional single-method approach. The application of AI in smart grid dispatching has gradually moved from experimental verification to practical application, addressing increasingly complex problems. In this process, researchers need to further address bottlenecks such as low data standardization, poor model interpretability, and insufficient system integration, and achieve truly large-scale, systematic application.

4 Challenges and problems

Although artificial intelligence technology has shown great potential in smart grid dispatching, its reasonable application still faces huge challenges. First, at the data level, the operation of the power grid depends on real-time information from various sensors, weather stations, and user terminals, but these data often have problems such as noise, missing information, and information inconsistency [6]. In areas such as wind power and photovoltaic power generation, their data is greatly affected by the environment and has obvious randomness and volatility. The prediction results of artificial intelligence are easily disturbed, affecting the overall stability [9]. In addition, the data standards of power grids in different regions are not unified, and the sharing mechanism is insufficient, resulting in the emergence of "data islands", which greatly limits the generalization ability and cross-regional application potential of artificial intelligence [4]. At the same time, as user data is introduced into the dispatching field, the problems of privacy protection and data security are gradually emerging. It is necessary to use technologies such as blockchain or differential privacy to alleviate these problems [10].

In terms of models, although methods such as deep learning and reinforcement learning have performed well in prediction and optimization, their promotion is still limited due to their lack of interpretability. Existing deep neural networks are basically "black box" models that lack transparency, making it difficult for staff to determine the logical basis of their predictions and optimizations, which reduces trust [5]. At the same time, artificial intelligence models have poor generalization. Most studies only perform well in specific scenarios or regions, but when running under new conditions, their performance will drop significantly [11]. Moreover, power grid dispatching generally requires real-time response in seconds or milliseconds, while deep neural networks and reinforcement learning often require a lot of computing power support and long training times. The contradiction between this high consumption and real-time requirements remains unresolved [8].

In practical applications, although researchers have conducted many experiments and achieved considerable success, when actually used on actual dispatching platforms, they often encounter difficulties in compatibility with existing power grids [1]. Grid dispatching systems often have strict standards, and the lack of interface standardization of artificial intelligence models has become a huge obstacle to their application in the field of smart grid dispatching [2]. Moreover, the stability and reliability of artificial intelligence models in extreme weather conditions remain to be verified [7].

In summary, artificial intelligence in the field of smart grid dispatching still faces problems such as poor data quality, weak model interpretability, and low real-time performance. These challenges not only illustrate the shortcomings of existing research, but also point out the direction for future research.

5 Future development trends

The development direction of artificial intelligence in the field of smart grid dispatching mainly focuses on optimizing safety, enhancing explainability, and improving low-carbon performance. Although deep learning and reinforcement learning have outstanding performance in prediction and optimization, their practical application is still limited due to their "black box" characteristics, and there is an urgent need to improve explainability and transparency [5]. In addition, with the rapid development of blockchain and the Internet of Things, the deep integration of artificial intelligence and these emerging technologies also has broad prospects. While improving dispatchability, it is also necessary to reduce the computing power requirements and energy consumption level of artificial intelligence itself. In addition, it is also necessary to strengthen the integration with electricity market mechanisms and policies, promote interdisciplinary collaboration, and truly serve the construction of new power systems [1].

6 Conclusion

This article reviews the development and current application of artificial intelligence in smart grid dispatching, applying it to the product lifecycle. Research is organized into three phases: introduction, growth, and maturity. In the initial exploratory phase, limited by data size and computing power, research remained largely experimental and verification, without widespread application. As deep learning technology matured, the focus of research shifted from single-point prediction to systematic dispatch optimization, marking a period of rapid development in smart grid research. After entering maturity, the integration of multiple fields further expanded the application of artificial intelligence in areas such as real-time dispatching, diversifying and increasing the complexity of its use cases.

Despite its immense potential, artificial intelligence still faces challenges such as low data quality, poor model interpretability, and excessive computing power consumption. These issues, to varying degrees, hinder its widespread adoption. However, these challenges also provide guidance for future research.

In summary, AI presents tremendous opportunities for smart grid scheduling, opens up new development paths, and plays a significant role in achieving the strategic goals of "dual carbonization." By continuously refining technical methods, improving model quality, and strengthening cross-domain collaboration, AI is expected to play an even more important role in smart grid planning and scheduling, becoming the core technical support for future grid planning and scheduling systems.

References

[1] M. A. Judge et al.: A comprehensive review of artificial intelligence approaches for smart grid integration and optimization, Energy Conversion and Management: X, Volume 24,October 2024, 100724.

[2] A. Mosavi: Machine Learning in Smart Grids: A Systematic Review, Novel Taxonomy, and Comparative Performance Evaluation, Pro Publico Bono – Public Administration, Volume 12, Issue 1, 2024, pp. 53–83.

[3] M. Balamurugan, K. Narayanan, N. Raghu, G. B. Arjun Kumar, and V. N. Trupti, "Role of artificial intelligence in smart grid – a mini review," Frontiers in Artificial Intelligence, vol. 8, Feb. 2025, Art. no. 1551661.

[4] M. M. Alam et al.: Artificial intelligence integrated grid systems: Technologies, potential frameworks, challenges, and research directions, Renewable and Sustainable Energy Reviews, Volume 211, March 2024, 115251.

[5] C. Xu, Z. Liao, C. Li, X. Zhou, R. Xie: Review on Interpretable Machine Learning in Smart Grid, Energies, Volume 15, December 2022, Article 4427.

[6] B. Biswal, S. Deb, S. Datta, T. S. Ustun, U. Cali: Review on smart grid load forecasting for smart energy management using deep learning and machine learning techniques, Energy Reports, Volume 12, December 2024, pp. 3654–3670.

[7] A. K. M. Rezown Mahmud and Waheduzzaman, "The Role of Artificial Intelligence in Advancing Smart Grid Technologies," European Journal of Science and Modern Technologies, vol. 3, no. 1, 2025.

[8] Xu N. et al.: A Review of Smart Grid Evolution and Reinforcement Learning: Applications, Challenges and Future Directions, Energies, Volume 18, July 2025, Article 1837.

[9] S. M. Hussain, A. S. Khan, and M. U. Aslam, "Smart grid dispatch powered by deep learning: a survey," Energy Reports, 2022. [Online]. Available: https://www.researchgate.net/publication/359138120_Smart_grid_dispatch_powered_by_deep_learning_a_survey.

[10] A. R. Singh, M. S. Sujatha, A. D. Kadu, M. Bajaj, H. K. Addis, and K. Sarada, "A deep learning and IoT-driven framework for real-time adaptive resource allocation in smart grids," Scientific Reports, vol. 15, 2025, Art. no. 02649.

[11] Y. Duan, Z. Xu, H. Chen, and Y. Wang, "Novel machine learning approach for enhanced smart grid operation," Scientific Reports, vol. 15, 2025, Art. no. 05083.

[12] M. Niraula, P. R. Ojha, S. Simkhada, and Y. Layalu, "Review on the application of machine learning algorithms on smart grid optimization," 2024. [Online]. Available: https://www. researchgate. net/publication/378346223_Review_on_the_Application_of_Machine_Learning_Algorithms_on_Smart_Grid_Optimization.