Journal of Artificial Intelligence Practice (2024)
Clausius Scientific Press, Canada
DOI: 10.23977/jaip.2024.070106
ISSN 2371-8412 Vol. 7 Num. 1

Comparative Analysis of Application Cases of Artificial Intelligence Technology in Smart Grid Dispatching

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Keywords: Smart grid, smart grid dispatching, artificial intelligence

Abstract: This study uses case comparison method to explore the technical requirements and challenges of smart grid dispatch, with a focus on the role of AI. The research results highlight the importance of AI in the development of smart grid, but solutions to technical, privacy and other issues need further exploration.

1. Introduction

As power system complexity grows, intelligent grid dispatching is essential for enhancing operational efficiency and reliability. AI technology presents both opportunities and challenges for intelligent grid dispatching. Through deep learning and big data analysis, AI can monitor the grid in real-time, optimize dispatching decisions, improve emergency response, and reduce environmental impact, aiding in building an efficient, safe, and environmentally friendly smart grid. This article examines the current application status and future development of AI in intelligent grid dispatching.

2. The Fit and Supplement of Artificial Intelligence And Smart Grid Dispatching Technology Demand

2.1. Connotation and Function of Smart Grid Dispatching

In 2006, IBM first introduced the concept of "smart grid", sparking global interest in power research institutions. Smart grid is the intelligence of the power grid, combining advanced sensing, measurement, communication, information, computer and control technologies with power systems [1]. Smart grid dispatching uses cutting-edge computer technology and intelligent management systems to manage power systems from generation to end users, aiming to improve grid efficiency, ensure system safety and stability, and provide high-quality power services.

2.2. Core technical requirements for smart grid dispatching

Compatibility, self-healing, security, intelligence, and automation[2] are the core technical requirements for smart grid dispatching, where compatibility is the foundation, self-healing and security are guarantees, and intelligence and automation are the keys to improving grid performance.

2.2.1. Compatibility

With the integration of renewable energy, various new power equipment and technologies are constantly emerging. Firstly, the smart grid dispatching system requires strong compatibility to achieve seamless docking between various equipment and systems. Secondly, with the gradual opening of the power market, the smart grid dispatching system needs to adopt an open architecture that supports multiple communication protocols and interface standards to integrate with other systems and equipment. At the same time, the dispatching system also needs to maintain scalability and flexibility to adapt to future developments and changes in power grid technology.

2.2.2. Self-healing

With the expansion of the scale of the power grid and the increase in operational complexity, the smart grid dispatching system automatically identifies, locates, and repairs faults in the power grid through real-time monitoring and data analysis, reducing power outages, improving power supply reliability, shortening fault recovery time, reducing maintenance costs, and reducing the impact on operations.

2.2.3. Security

The security of power grid equipment and data is one of the core requirements for smart grid dispatching. It includes preventing security risks such as hacker attacks, data leak, and physical damage, ensuring the physical and information security of the power grid, and ensuring the normal production of enterprises and daily safe power distribution for residents.

2.2.4. Intelligentization and automation

Smart grid dispatching should achieve high intelligence and automation. Through artificial intelligence, machine learning and other technologies, it can automatically make dispatching decisions, reduce human intervention and operating costs, improve the accuracy and reliability of dispatching decisions, and help dispatchers better cope with emergencies and optimize resource allocation, thereby improving the operational efficiency of the power grid.

2.3. The fit between artificial intelligence and the demand for smart grid dispatching technology

The concept of artificial intelligence was first proposed by American scientist John McCarthy at the Dartmouth Conference in 1956. It is a new technical science that studies, develops, simulates, extends, and expands the theory, methods, techniques, and application systems of human intelligence. The aim is to produce an intelligent machine that can respond in a similar way to human intelligence, allowing computers to have cognitive, reasoning, learning, and other abilities to achieve intelligent development[3]. The automation and intelligence of artificial intelligence, as well as the security protection and self-healing capabilities are highly compatible with the core technical requirements of smart grid dispatching.

2.4. Supplement of AI to the demand for smart grid dispatching technology

Artificial intelligence technology provides key supplements and improvements to the demand for smart grid dispatching technology, improving operational efficiency and stability. Specific applications are as follows:

2.4.1. Big data processing and analysis

In the daily operation process of smart grid dispatching, a large amount of real-time data including power loads, power demand, equipment status, etc. needs to be processed. With the help of powerful computing and understanding capabilities, artificial intelligence can quickly and efficiently analyze and extract useful information through various models, providing strong support for dispatching decisions. With the help of massive data processing and analysis technology, the smart grid dispatching system can more clearly grasp the operation and development trajectory of the power grid, make pre-judgment and corresponding countermeasures, and improve the stability and reliability of the power grid.

2.4.2. Machine learning

Machine learning is one of the core technologies of artificial intelligence. It automatically discovers patterns in large amounts of data and is used to predict power load, identify grid failures, and optimize energy distribution. By training the models with historical data, it can predict future power demands and provide a basis for scheduling. At the same time, it is used for fault diagnosis and repair to improve the stability and reliability of the power grid.

2.4.3. Deep learning

Deep learning is used to process large amounts of high-dimensional data and extract useful features. In smart grids, it can be used in image recognition, speech recognition, natural language processing, and other fields. For example, in the diagnosis of grid equipment faults, by analyzing the operating status and sound characteristics, it can quickly identify the fault location and improve the efficiency and accuracy of fault repair[4]. Users can also interact with the grid system through voice, providing more convenient services.

2.4.4. Reinforcement learning

Reinforcement learning enables computers to learn to complete specific tasks through trial and error without explicit instructions. In smart grid scheduling, it is applied to assist power systems in completing stability assessments and operational optimization [5], as well as intelligent control such as automatically adjusting parameters such as voltage and frequency to ensure stable power supply.

2.4.5. Human-computer interaction technology

Human-computer interaction technology, such as natural language processing (NLP) and speech recognition, enables computers to understand and respond to human language, enhancing the user's interaction experience with the power grid system. The application of this technology not only facilitates users, but also improves the availability and accessibility of the power grid system.

3. Comparison of application cases of artificial intelligence technology in smart grid dispatching

To gain a deeper understanding of AI technology's application in smart grid dispatch, this article selects four projects—in New York, Hamburg, Sydney, and Zhejiang—for comparison and analysis of their purposes, key technologies, and challenges.

As shown in Table 1, the common goal of these four smart grid projects is to improve the grid's scheduling decision-making and prediction capabilities through artificial intelligence technology, and enhance network operation efficiency and stability. However, there are some differences in the application of key technologies among the projects. The New York project mainly focuses on the application of sensor network and data analysis processing technology; the Hamburg project emphasizes intelligent sensing technology, automated scheduling system, and renewable energy access technology; the Sydney project focuses on renewable energy access, smart meters, and data analysis processing; while the Zhejiang project highlights intelligent sensing technology and automated scheduling system.

Table 1: Application of AI technology in smart grid in the United States, Germany, Australia and China

Project Name	Country	Initiating Organization	Key Technology	Purpose
New York City Smart Grid Project	United States	New York City government and utility companies	Sensor networks, data analysis and processing, automated dispatch systems	Artificial intelligence algorithms are used to process and analyze massive amounts of data to predict power demand and optimize dispatch decisions
Hamburg Smart Grid Project	Germany	Hamburg City Government and German energy company	Intelligent sensing technology, automated dispatch system, renewable energy access technology	Artificial intelligence algorithms are used to optimize the scheduling and distribution of renewable energy sources to improve the operational efficiency and stability of the power grid
Sydney Smart Grid Project	Australia	Sydney City Government and utility companies	Renewable energy access, smart meters, data analysis and processing	Artificial intelligence algorithms are used to optimize the dispatch and distribution of renewable energy, improving the operational efficiency and stability of the power grid
Zhejiang Smart Grid Project	China	Zhejiang Provincial Government and power companies	Intelligent sensing technology, automated dispatch systems, distributed energy access	Artificial intelligence algorithms are used to optimize scheduling decisions, combined with big data processing and analytics to achieve efficient grid operation and management

Data source: Collected from the Internet

In the implementation process, each project faces unique challenges. New York needs to install high-capacity sensors and equipment in a limited densely populated space, dealing with data privacy issues. Hamburg needs technological innovation in renewable energy and grid stability, which is expensive. Sydney faces policy risks and needs more innovation. Zhejiang must overcome grid/technical issues and gain user recognition.

By comparing these four smart grid projects, it's clear that AI technology plays a crucial role in smart grid dispatching in different countries and regions. Despite various challenges, the application of AI technology is vital for enhancing grid efficiency and stability, and optimizing dispatching decisions.

4. Conclusion and Suggestion

4.1. Conclusion

The results of this study show that artificial intelligence technology can effectively improve the operational efficiency and stability of smart grids. Specifically, artificial intelligence technology can achieve compatibility and scalability in smart grid dispatching, adapting to the development and changes of future grid technology; through machine learning and deep learning technology, it can predict power loads and optimize energy distribution, improving the operational efficiency and stability of the grid; reinforcement learning technology can assist power systems in completing stability assessment and operation optimization, ensuring a stable power supply; human-computer interaction technology can enhance the interactive experience between users and grid systems, improving the availability and accessibility of grid systems. However, artificial intelligence technology still faces technical challenges and data security issues in smart grid dispatching, which need further research and solution.

4.2. Suggestions

4.2.1. Continuous investment in research and development

The government and enterprises should continue to increase their investment in research and development of artificial intelligence in smart grid dispatch, encourage technological innovation and application exploration, and improve the operational efficiency and stability of the power grid.

4.2.2. Improve data security and privacy protection

The organization responsible for managing the smart grid dispatch process should establish and improve data security and privacy protection mechanisms to ensure that user data is not leaked or abused during this process. At the same time, the organization must strengthen the implementation of security measures such as data encryption and access control to mitigate any potential risks to the security and privacy of user data.

4.2.3. Strengthening international cooperation and technical exchanges

Governments, international organizations, technology companies, and relevant industry associations should strengthen international cooperation and exchanges, jointly address the challenges faced by smart grid dispatching, and share best practices and technological achievements. They should also collaborate to promote innovation and development of smart grid dispatching technology through research, technical exchanges, and experience sharing.

4.2.4. Focus on talent cultivation and skills improvement

Governments, educational institutions, and enterprises should strengthen talent cultivation and skill improvement, and cultivate interdisciplinary talents with knowledge of artificial intelligence technology and smart grid dispatching. At the same time, they should provide training and further education opportunities for existing technical personnel to improve their technical level and application capabilities.

4.2.5. Establish a feedback mechanism

The organization responsible for managing the smart grid dispatch process should encourage users to provide feedback and suggestions to optimize system performance, promptly identify and resolve issues, and thereby enhance user satisfaction and system availability.

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