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Power System Optimization Dispatch for Energy Conservation and Emission Reduction

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Abstract: This paper examines the optimization of power system dispatching with a focus on energy conservation and emission reduction. Through analyzing current situations and challenges, it aims to propose effective strategies and methods to achieve efficient power system operation while protecting the environment. The article commences by detailing China's advancements and obstacles in energy conservation and emission reduction within its power system. It addresses issues such as the variability of renewable energy sources, efficiency constraints in thermal power generation units, the intricate nature of the power grid infrastructure, and the novel challenges introduced by reforms in the electricity market. Subsequently, the paper presents four major strategies: priority dispatching of clean energy, flexible dispatching of thermal power units, power grid structure optimization, and market mechanism introduction. Research findings, when integrated with practical case studies, demonstrate that the utilization of virtual power plants and advanced dispatching systems can markedly enhance the capacity for clean energy consumption, decrease the operational duration of thermal power units and the intensity of carbon emissions, while simultaneously improving the overall efficiency of power systems. This research holds significant importance for promoting green and sustainable development in the power industry.

Keywords: Power system, Optimization dispatching, Energy conservation and emission reduction, Clean energy, Thermal power units

1. Introduction

As the global energy crisis escalates and the ecological environment worsens, energy conservation and emissions reduction have emerged as critical areas of international focus. The power system, as a crucial domain of energy production and consumption, directly impacts national energy security and environmental protection through its operational efficiency and emission levels. Consequently, the optimization of power system dispatching focused on energy conservation and emission reduction has gained paramount importance. China has achieved notable advancements in energy conservation and emission reduction within its power system, evidenced by a consistent rise in the share of clean energy generation. Hydropower, as a traditional clean energy source, has become China's second-largest power source, particularly prominent in the southwestern region. Nuclear power technology continues to mature, with steady progress in coastal nuclear power plant construction, making important contributions to carbon emission reduction. The advancement of wind and solar energy generation has accelerated significantly in recent years, particularly in the "Three North" regions

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(North China, Northeast China, and Northwest China). In these areas, the grid-connected capacity of extensive wind farms and photovoltaic power stations is consistently on the rise. This progress in clean energy technologies has substantially contributed to the reduction of carbon emission intensity within the power system.[1]. Thermal power units, as the backbone of the power system, have also achieved significant improvements in energy efficiency. The widespread application of ultra-supercritical units has substantially improved thermal power plants' efficiency. The comprehensive promotion of desulfurization and denitrification technologies in coal-fired units has greatly reduced sulfur oxide and nitrogen oxide emissions. Additionally, the application of intelligent technologies in thermal power plants has optimized unit operation parameters, further improving energy utilization efficiency. Nevertheless, the swift economic advancement in China has resulted in an ever-increasing demand for energy. The acceleration of industrialization and urbanization processes, along with improvements in living standards, have driven increases in electricity consumption. Although energy intensity has decreased, overall electricity consumption continues to show an upward trend. Given the current conditions, the power system is under significant strain to achieve energy efficiency and reduce emissions, particularly in economically advanced areas where the increase in electricity demand frequently surpasses the progress in clean energy initiatives, thereby rendering the objectives of energy conservation and emission reduction particularly daunting[2, 3].

2. Power system optimization dispatching strategies and methods

2.1. Priority dispatching of clean energy

Priority dispatching of clean energy is a key strategy for achieving energy conservation and emission reduction in power systems. Renewable energy sources, including hydropower, wind energy, solar energy, and nuclear energy, offer substantial benefits for environmental conservation and sustainability. Therefore, they should be given precedence in the management of power system operations. In specific implementation, dispatch centers need to accurately forecast clean energy generation based on weather forecasts and historical data, and incorporate it into day-ahead and intraday dispatching plans. In the context of real-time dispatching, it is imperative to optimize the utilization of clean energy to enhance its generation share to the fullest extent possible.[5]. Priority dispatching of clean energy also requires supporting policy support and technological innovation. The government can introduce relevant policies, such as renewable energy power quotas and priority grid connection, to create favorable conditions for clean energy development. To enhance the integration and utilization of clean energy, it is imperative to bolster the research and development of innovative energy generation forecasting technologies and advanced smart grid systems. Through these measures, the proportion of clean energy generation can be effectively increased to achieve energy conservation and emission reduction goals in the power system.

2.2. Flexible dispatching of thermal power units

The maintenance and management of thermal power units are equally crucial for achieving flexible dispatching. Regular inspection and maintenance can ensure efficient unit operation and reduce the probability of failures. In the interim, by implementing robust management frameworks, including equipment condition monitoring systems and preventive maintenance protocols, potential issues can be detected and addressed swiftly to guarantee consistent operational performance of the unit[8]. The application of intelligent technologies has provided new possibilities for flexible dispatching of thermal power units. By introducing advanced technologies such as artificial intelligence and big data analysis, real-time optimization of unit operation parameters can be achieved, improving dispatching accuracy and efficiency. Utilizing machine learning algorithms to forecast power demand and renewable energy generation can enhance the precision of thermal power unit operational strategies,

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thereby attaining an optimal equilibrium between economic efficiency and environmental sustainability.

2.3. Power grid structure optimization

Power grid structure optimization is a crucial means to improve power system dispatching efficiency. A meticulously engineered grid framework can significantly improve the reliability of power transmission and economic efficiency, minimize energy losses, and facilitate the extensive integration and utilization of renewable energy sources[9]. During grid structure optimization, it is necessary to strengthen the monitoring and management of grid operations. Through establishing comprehensive grid monitoring systems, real-time grid operation status can be tracked, and potential risks can be promptly identified and addressed. In the interim, the application of big data analytics technology facilitates a comprehensive examination of grid operational data, uncovering optimization prospects and developing more empirical grid planning and operational strategies. These measures can ensure safe and stable grid operation, providing a solid foundation for power system optimization dispatching.

2.4. Introduction of market mechanisms

Market mechanisms play an important role in power system energy conservation and emission reduction. By implementing market-oriented regulatory approaches, the initiative of all stakeholders to engage in energy conservation and emissions reduction can be thoroughly activated, enhancing the efficiency of resource allocation and achieving a harmonious balance between economic and environmental advantages. Carbon trading is a typical example of a market mechanism application. By establishing a carbon emission rights trading market, prices can be set for carbon emissions, compelling enterprises to incorporate environmental costs into their business decisions, thereby encouraging them to actively adopt energy conservation and emission reduction measures. The green power certificate system represents an additional efficient market-based approach. Through issuing and trading green power certificates, additional economic incentives can be provided for clean energy generation. Power users can fulfill their clean energy usage requirements or environmental responsibilities by purchasing green power certificates. This system not only facilitates the advancement of renewable energy but also generates additional revenue streams for energy companies[11].

3. Case analysis of power system optimization dispatching

3.1. Application of virtual power plants

Virtual power plants (VPPs), as a new approach to power system optimization dispatching, have achieved remarkable results in one province's practice. In 2020, the province initiated a pilot project for a Virtual Power Plant (VPP), which aims to integrate distributed energy resources throughout the region. This includes harnessing photovoltaic energy, wind energy, and flexible load management from industrial and commercial consumers. Through advanced information communication technology and intelligent control systems, these dispersed resources were unified under centralized dispatching and management, forming a virtual large-scale power plant.

After project implementation, the province's clean energy consumption capacity significantly improved. Based on data provided by the provincial power utility, the contribution of renewable energy generation to Virtual Power Plant (VPP) dispatching amounted to 1.5 billion kilowatt-hours in 2021, reflecting a 30% increase compared to 2020. In contrast, the annual average operational hours of thermal power units declined from 4,500 hours in 2020 to 4,200 hours in 2021, representing

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a decrease of 6.67%. This not only increased the proportion of clean energy generation but also effectively reduced the operation time of thermal power units, making an important contribution to energy conservation and emission reduction.

Table 1: Comparison of key indicators before and after implementation of virtual power plant project in a province

Indicator	2020 (Before Implementation)	2021 (After Implementation)	Change Rate
Renewable Energy Generation (100 million kWh)·	11.54	15	30.00%
Annual Average Utilization Hours of Thermal Power Units	4500	4200	-6.67%
System Peak Regulation Capacity (10,000 kW)	200	250	25.00%
Carbon Emission Intensity (g CO2/kWh)	650	580	-10.77%

The application of virtual power plants also significantly improved the grid's peak regulation capability. By incorporating distributed energy resources and flexible load management, the system's peak regulation capacity rose from 2 million kilowatts in 2020 to 2.5 million kilowatts in 2021, representing a 25% enhancement. This significantly improved the grid's responsiveness to load variations and facilitated the integration of additional clean energy sources.

In terms of environmental benefits, the application of virtual power plants reduced the province's power system carbon emission intensity from 650g CO2/kWh in 2020 to 580g CO2/kWh in 2021, a decrease of 10.77%. This accomplishment not only surpassed the annual greenhouse gas reduction goals established by the provincial authorities but also significantly advanced the province's energy transition and sustainable development initiatives.

The successful application of virtual power plants has provided new ideas and methods for power system optimization dispatching. By consolidating distributed energy resources, virtual power plants have enhanced system adaptability and dependability while also fostering an environment conducive to extensive clean energy implementations.

3.2. Application of intelligent dispatching systems

A prefecture-level city implemented an AI-driven intelligent dispatching system in 2019, enabling real-time monitoring, analysis, and automated optimization of power system operations, which has led to substantial economic and environmental advantages. The system uses machine learning algorithms to analyze historical data, combining real-time meteorological information and load forecasting to accurately predict power demand and renewable energy generation for the next 24 hours, thereby formulating optimal dispatching strategies.

The application of the intelligent dispatching system significantly improved the overall energy efficiency of the power system. Based on the operational statistics provided by the municipal power utility, the average transmission loss rate has declined from 6.5% in 2018 to 5.8% in 2020, representing a decrease of 10.77%. This improvement was mainly attributed to the system's precise control and optimization of power grid flow. Simultaneously, the adoption of renewable energy sources has seen considerable enhancement, as evidenced by the reduction in curtailment rates for wind and solar power, which fell from 8.2% and 5.5% in 2018 to 3.1% and 2.0% in 2020, respectively.

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Table 2: Comparison of Key Indicators Before and After Application of Intelligent Dispatching System in a City

Indicator	Indicator | 2018 (Before Application)	2020 (After Application)	Change Rate
System Average Line Loss Rate	6.50%	5.80%	-10.77%
Wind Power Curtailment Rate	8.20%	3.10%	-62.20%
Photovoltaic Power Curtailment Rate	5.50%	2.00%	-63.64%
Thermal Power Unit Coal Consumption Rate (g/kWh)	310	295	-4.84%
System Peak Regulation Cost (yuan/MWh)	85	72	-15.29%

The intelligent dispatching system enhanced thermal power unit efficiency, reducing average coal consumption from 310g/kWh in 2018 to 295g/kWh in 2020, a 4.84% decrease. This led to lower fuel use and significant reductions in carbon and pollutant emissions. Additionally, peak regulation costs fell from 85 yuan/MWh in 2018 to 72 yuan/MWh in 2020, a 15.29% reduction, improving economic efficiency and supporting power market reform.

The successful application of the intelligent dispatching system has provided a new technical path for power system optimization dispatching, achieving economical, efficient, and green operation through the application of artificial intelligence technology.

4. Conclusion

This paper discusses the application of power system optimization dispatching in energy conservation and emission reduction. Firstly, the paper analyzes the current situation and challenges of China's power system in energy conservation and emission reduction. Despite the increasing share of clean energy and improved thermal power efficiency, rising power demand and the intermittent nature of clean energy create significant challenges for energy conservation and emission reduction in power systems. This paper highlights that prioritizing clean energy dispatch is essential for these goals. By accurately predicting clean energy output, optimizing peak regulation and frequency modulation, and developing ultra-high voltage transmission lines, we can enhance clean energy consumption. Additionally, flexible thermal power unit dispatch is vital for energy conservation and emission reduction. Upgrading technology and employing intelligent systems can boost thermal units' peak regulation and efficiency, thereby lowering carbon emissions. Furthermore, optimizing power grid structure is key to enhancing dispatch efficiency, reliability, and economic performance while minimizing losses and facilitating large-scale clean energy integration. Lastly, market mechanisms like carbon trading and green power certificates can energize participation in energy conservation and emission reduction, aligning economic and environmental benefits. This research offers a theoretical foundation and technical guidance for optimizing power system dispatch and outlines a clear path for the power industry's sustainable development.

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References

[1] *Liang, H. (2020). Intelligent optimization algorithms and their application in economic/emission scheduling of power systems (Master's thesis). Shandong University, Jinan.*

[2] *Ma, X., Shen, W., & Zhen, W. (2021). Research on optimization scheduling strategy of electrical comprehensive energy system based on low-carbon goals. Power Grid and Clean Energy, 37(12), 116-122.*

[3] *Hui, J., & Ling, Y. (2022). Optimization strategies for planning and operation of low-carbon power systems. Heilongjiang Science, 13(6), 140-142.*

[4] *Zheng, K. (2023). Efficient power systems support "green" data centers. China Excellent Data Center, (4), 12-14.*

[5] *Zhao, D. (2023). Analysis of line loss in power systems and discussion on energy-saving scheduling measures. Power System Equipment, (5), 44-46.*

[6] *Liu, C. (2020). Low-carbon economic scheduling of power systems considering wind power uncertainty and demand-side management. Journal of Chongqing University of Technology: Natural Science, 34(4), 38-39.*

[7] *Li, X. (2022). Comprehensive evaluation method for energy conservation and emission reduction of power grids under carbon neutrality goals. Electrical Technology, (2), 12-13.*

[8] *Wang, S. (2022). Research on optimization management system for power grid scheduling operation. Wenyuan (Middle School Edition), (7), 57-59.*

[9] *Ge, F. (2021). Analysis of energy-saving and consumption-reducing technologies in power transmission and distribution systems. Electronic Paradise, (5), 42-43.*

[10] *Gan, Z. (2022). Multi-objective scheduling optimization of power systems considering demand response under the dual-carbon background (Master's thesis). North China Electric Power University, Beijing.*

[11] *Tian, C. (2022). Construction of new power systems under the "dual-carbon" goal. Light Sources and Lighting, (11), 149-151.*