Application and Development of New Energy Power Generation in Electric Power Construction

Feng ZHOU

Anhui Urban Construction Design Institute CORP., Ltd., Hefei, Anhui, 230000, China

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Abstract: At present, China's electric power construction is confronted with the dual tasks of traditional energy constraints and low-carbon transformation. On one hand, for a long time, China has relied on coal-fired power generation and other fossil fuel-based power generation methods. Although the proportion of coal-fired power generation dropped below 55% in 2024, the non-renewability of coal resources, along with the carbon emissions and air pollution issues during the mining and combustion processes, remain prominent. Additionally, China's dependence on imported crude oil and natural gas exceeds 70% and 40% respectively, posing external risks to energy security. On the other hand, the "dual carbon" goals have set clear low-carbon requirements for electric power construction. New energy power generation methods such as wind power, photovoltaic (PV) power, and energy storage rely on domestic renewable resources and offer the advantages of zero carbon emissions and self-sufficiency. Based on this, this article systematically reviews the core role of new energy power generation in electric power construction, predicts future development trends, and proposes targeted countermeasures from both policy and technological perspectives, aiming to provide references for promoting the deep integration of new energy power generation and electric power construction and achieving a clean transformation of the power system.

1. Introduction

Energy is the cornerstone of a country's economic development. As the core part of the energy system, electric power construction has a direct impact on energy security, environmental quality, and sustainable economic growth. For a long time, China's electric power construction has focused on coal-fired power generation. Although this has supported rapid economic growth, it also faces triple pressures: fossil fuel shortages, high carbon emission intensity, and a high degree of dependence on foreign energy sources. Against this backdrop, the proposal of the "dual carbon" goals has pointed the way for the transformation of electric power construction. New energy power generation, which utilizes local renewable energy sources such as wind and solar power, with its characteristics of zero carbon emissions and distributed supply, has become a key solution to the problems faced by traditional electric power construction.

2. The Core Role of New Energy Power Generation in Electric Power Construction

2.1 Promoting Energy Structure Transformation

Renewable energy power generation, with its zero-carbon or low-carbon energy attributes, has become a core force in promoting the transformation of China's energy structure during the process of electric power construction. For a long time, China's power structure has mainly relied on fossil fuel-based power generation such as coal. This structure not only faces problems such as the limited nature of coal resources and high carbon emission intensity during the mining and utilization processes but also leads to a high degree of dependence of the power system on traditional fossil fuels, which is not conducive to the sustainability of energy supply. However, by continuously expanding its application scale in electric power construction, renewable energy power generation

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has, on one hand, continuously increased the total supply of clean electricity. As of 2024, the installed capacity of wind power, PV power, and other new energy power generation methods has exceeded 1.3 billion kilowatts [1], accounting for more than 45% of the country's total installed power capacity, and is still growing at a rate of over 100 million kilowatts per year, continuously filling the power supply gap left by the withdrawal of traditional fossil fuel-based power generation. On the other hand, it has actively replaced the share of fossil fuel-based power generation. Against the backdrop of increasing power consumption demand, the incremental part of renewable energy power generation has effectively squeezed the power generation space of coal-fired power and other fossil fuel-based power generation methods. By 2024, the proportion of coal-fired power generation in China has dropped below 55%, a decrease of more than 15 percentage points compared to 2015, directly reducing the power system's dependence on fossil fuels.

2.2 Ensuring Energy Security

New energy power generation plays a crucial role in ensuring China's energy security by reducing the country's dependence on external fossil fuels, achieving diversification of energy supply, and filling regional power supply gaps. Firstly, in terms of reducing dependence on external energy sources, China's traditional power production has long relied on fossil fuels such as coal and oil. The dependence rate on crude oil has long exceeded 70%, and that on natural gas exceeds 40%. Any fluctuations in international energy prices or disruptions in the supply chain can easily affect the stable supply of electricity [2]. However, the resources on which new energy power generation relies, such as wind, solar, and biomass energy, are locally distributed and renewable. Additionally, the northwest and north China regions have abundant wind energy resources, while the northwest and southwest regions have sufficient solar energy resources. By developing these local resources, new energy power generation can directly reduce the power system's demand for imported fossil fuels and mitigate the impact of international energy market fluctuations on domestic power security. Secondly, in terms of enriching the energy supply system, traditional power supply is highly dependent on coal-fired power generation. Problems such as a decline in coal production capacity or transportation disruptions may cause local power shortages. However, new energy power generation covers multiple types, such as wind, PV, biomass, and pumped hydro power. The peak power generation times of different types of new energy can complement each other. That is, PV power generation performs strongly during the day, while wind power generation has stable output at night. Distributed PV power generation can directly generate electricity on the rooftops of urban and rural areas, forming a "centralized + distributed" multi-supply model and avoiding power security risks caused by insufficient supply from a single energy source. Finally, in terms of ensuring regional power supply, power demand in load centers in the east, such as the Yangtze River Delta and the Pearl River Delta, is growing rapidly, but local fossil fuel resources are scarce, so electricity needs to be imported from other regions [3]. Remote areas in the west and north often face unstable power supply due to difficulties in grid construction and high costs of traditional power transmission. Distributed PV power generation can be developed in the east, while large-scale wind and solar power bases can be built in the west, equipped with special high-voltage transmission channels. This can not only supplement power for the load centers in the east but also replace diesel power generation in remote areas through "new energy + energy storage" microgrids. This can solve local power shortages and avoid regional power security risks caused by cross-regional power transmission failures or insufficient coverage of traditional power supply.

3. Development Trends of New Energy Power Generation in Electric Power Construction

In terms of technological upgrades, the efficiency and performance of new energy power generation continue to improve. By 2025, the proportion of China's new energy power generation capacity will exceed 45%. As the main types, wind and PV power generation have seen significant technological iterations. The conversion efficiency of PV silicon cells has increased year by year, and the application of high-efficiency modules has led to a continuous increase in power generation per unit area. The maximum single-unit capacity of wind power generation is constantly increasing, and large wind turbines have reduced the cost per kilowatt-hour of power generation and improved wind energy utilization efficiency [4]. Breakthroughs in energy storage technology have become a key support. Long-duration energy storage technologies such as compressed air energy storage and flow batteries have been applied in projects. For example, the compressed air energy storage system in the wind-PV-hydrogen integrated energy storage project in Yanqing County has not only improved the stability of power output but also provided heating services by utilizing waste heat, achieving multi-energy coordination. At the same time, intelligent technologies have been deeply integrated. The world's first annual forecasting system covering all types of new energy power generation has been put into use. By combining models such as meteorological factor prediction, wind farm and solar power station identification, and power generation capacity calculation, high-precision power generation forecasting has been achieved, providing scientific support for power system planning and operation.

In terms of grid cooperation, the popularization of flexible direct current (DC) transmission technology has become an important trend. This technology can independently regulate active and reactive power and has significant advantages in scenarios such as new energy grid connection and grid interconnection. The Tancha DC grid project has solved the problem of integrating large-scale wind power generation through flexible DC technology. For example, the offshore wind power grid connection project can transmit 2.4 billion kilowatt-hours of wind power per year [5]. According to national plans, during the 14th and 15th Five-Year Plan periods, large-scale PV and wind power bases in regions such as Inner Mongolia and Gansu will mainly rely on flexible DC technology for power transmission, while offshore wind power in regions such as Shandong and Fujian will be connected to the grid through flexible DC technology. It is expected that in the next 10 years, 1,400 megawatts of offshore wind power will adopt this technology, significantly enhancing the grid's ability to accommodate new energy.

4. Countermeasures and Suggestions for Promoting High-Quality Development of New Energy Power Generation in Electric Power Construction

4.1 Policy Level

Firstly, the government should take the lead in coordination and planning to break through planning obstacles that hinder the implementation of new energy projects. The National Energy Administration should collaborate with relevant departments such as the Ministry of Natural Resources and the Ministry of Ecology and Environment to formulate a unified national new energy development plan, clarify the layout principles of large-scale wind and solar power bases and distributed PV power stations, and ensure precise alignment between new energy plans and national land spatial planning and ecological protection red line planning. For example, special new energy construction areas should be designated in the "sand dunes and deserts" regions in northwest China to avoid conflicts with farmland, grasslands, and nature reserves [6]. Local governments should refine local implementation plans based on national plans, establish a green channel procedure for land use approval for new energy projects, simplify the approval process for unused land such as deserts and Gobi deserts, shorten the time from planning to project initiation, and strictly prohibit local authorities from arbitrarily stopping compliant new energy projects under the pretext of ecological protection to ensure the stability of plan implementation.

Secondly, relevant departments need to improve market-oriented mechanisms to ensure the stability of revenue for new energy projects. On one hand, the National Development and Reform Commission and energy management departments should optimize green power trading rules, expand the coverage of green power trading to make it easier for industrial enterprises and data centers to purchase green power, and clarify the premium mechanism for green power. More enterprises should be encouraged to participate in green power consumption. On the other hand, they should establish an ancillary service market mechanism, including energy storage and virtual power plants, to incorporate peak load and frequency regulation services, and clarify the revenue distribution rules for new energy projects participating in ancillary services. For example, when the energy storage systems of wind and PV power stations provide peak load regulation services, they can obtain additional revenue based on the amount of peak load regulation, avoiding losses caused by unstable power generation, and transforming new energy projects from a single power generation revenue model to a diversified revenue model of power generation + ancillary services.

4.2 Technological Level

Firstly, research institutions need to collaborate with new energy enterprises to conduct research and development of core technologies and break through efficiency and cost bottlenecks. In the field of PV power, the focus should be on developing components with higher conversion efficiency, such as continuously optimizing the processes of top-contact and heterojunction high-efficiency PV cells, and promoting the commercial application of perovskite-crystalline silicon tandem cells to convert laboratory conversion efficiency into large-scale production capacity [7]. Additionally, low-cost PV materials such as silver-free pastes and thin silicon wafers should be developed to reduce the production cost of PV modules by 10% to 15%. In the field of wind power generation, they should overcome the core components of large-scale units, such as developing high-strength blades (using carbon fiber composites) suitable for wind turbines above 20 MW, high-reliability bearings (breaking import dependence), and intelligent control systems to reduce downtime caused by component failures and optimize the aerodynamic design of wind turbines to achieve efficient power generation in low-wind-speed areas. Moreover, they should develop more efficient combustion power generation and heat exchange technologies for small-scale new energy sources, such as gasification coupled power generation technology for biomass energy, to increase power generation efficiency from the current 25% to over 30% and reduce the cost of replacing traditional fossil fuels.

Secondly, new energy enterprises need to collaborate with technology enterprises to deepen the integration of intelligent technologies and improve power generation and operational efficiency. In the power generation forecasting stage, artificial intelligence algorithms and big data analysis technologies should be introduced. For example, a high-precision power forecasting model should be built based on historical power generation data, meteorological satellite cloud images, and real-time wind speed and solar radiation data to increase the short-term forecasting accuracy of wind and solar power to over 90% and the medium- and long-term forecasting accuracy to over 85%, providing precise basis for grid dispatching. In the power station operation stage, the application of digital twins and intelligent devices should be promoted. For example, digital twin systems should be established for PV and wind power stations to simulate the operating status of units in real time and warn of potential failures [8]. The use of unmanned aerial vehicles for wind turbine blade inspection and robots for cleaning PV panels replaces traditional manual operations, increasing operational efficiency by more than 30% and shortening fault handling time to within 2 hours. At the same time, the combination of new energy and Internet of Things (IoT) technologies should be promoted, such as installing smart meters and communication modules in distributed PV power stations to achieve real-time uploading of power generation and consumption data, facilitating precise settlement between users and grid enterprises, and avoiding data deviations in the grid connection of surplus power.

5. Conclusion

In conclusion, new energy power generation in China has gradually transformed from a supplementary power source to a main power source in electric power construction, and its core value in optimizing the energy structure and ensuring energy security has been verified in practice. In 2024, the proportion of non-fossil fuel power generation exceeded 30%, the output value of the new energy equipment manufacturing industry exceeded 3 trillion yuan, and the combined power generation from distributed PV in the east and wind-PV bases in the west filled regional power gaps by over 100 billion kilowatt-hours, providing solid support for the low-carbon transformation of electric power construction. Although new energy power generation still faces various challenges at present, with the iteration of high-efficiency PV modules, long-duration energy storage technologies, the construction of flexible DC transmission grids, and the improvement of green power trading and ancillary service markets, the integration of new energy power generation and electric power construction will gradually deepen. In the future, it is necessary to further promote the high-quality development of new energy power generation in electric power construction through policy coordination and planning alignment and technological breakthroughs in core bottlenecks.

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