DOI: 10.54254/2755-2721/59/20240805

A review on application and innovation of wind-solar power generation technologies based on dual carbon targets

Jinghao Huang

Electrical and Electronic Engineering, North China Electric Power University, Baoding, Hebei, China, 071066

837745263@qq.com

Abstract. With the increasing depletion of traditional energy sources, the greenhouse effect is becoming increasingly serious, mankind is in urgent need of clean and renewable new energy demand is increasing, in order to support the “carbon peak&carbon neutral” goal, in the future a longer period of time, the improvement of wind power age innovation is the principal procedure for the advancement of numerous nations today, many countries and international organizations to vigorously promote the development of wind power and photovoltaic power generation system will also continue to accelerate the development of new energy generation systems in China. China’s renewable power age framework, which is basically founded on wind power and will keep on progressing, is being fiercely promoted by many nations and international organizations. This thesis mainly exemplifies the many applications of wind power generation technology in China based on the dual-carbon target through the approaches of literature reviews, and incorporates the inventive innovation model of wind power age innovation and different methodologies. Combined with domestic and international cases, this review summarizes how to solve the dilemmas faced by renewable energy technologies and how to optimize the operation and improve the efficiency of power generation by using innovative technologies, which can provide technical support for the realization of the “dual-carbon” goal.

Keywords: Peak Carbon, Carbon Neutral, Wind Power, Photovoltaic Power, Green Electricity

1. Introduction

Global energy-related carbon dioxide emissions hit a record high in 2022, further increasing by 0.9% to over 36.8 billion tons. Nearly 90% of China’s carbon emissions come from the energy sector, and the electricity sector has the highest carbon emissions, with over 40% of all national emissions coming from this sector [1]. Therefore, the development of green power cannot be delayed. Green power ordinarily alludes to wind power, photovoltaic power age and other environmentally friendly power. Wind power generation technology generally refers to wind power technology. This refers to the technology that utilizes wind energy to generate electricity by converting wind energy into electricity. Photovoltaic power generation technology is a technology that directly converts solar energy into electrical energy, which can utilize the photovoltaic effect at the semiconductor interface and directly convert light energy into electrical energy, and the key component of this technology is the solar cell [2]. As wind energy and light energy are renewable and environmentally friendly renewable energy, the advancement of wind power age innovation is the principal improvement procedure of numerous nations today, which can provide technical support for the realization of the “dual-carbon” goals. This paper reviewed a lot of literature based on the above research, this paper combines domestic and international cases to summarize the application and innovation points of wind power generation technology based on the dual-carbon goals, to help the development of renewable power energy technology, and to provide a case reserve for the future progress of wind power generation technology.

2. Photovoltaic power generation technology

2.1. The impact of photovoltaic grid-connected power generation system on the power grid

According to the PV grid-connected power generation system, there are two types of power generation: Distributed PV grid-connected power generation system and large-scale centralized PV grid-connected power generation system. Among them, a centralized PV grid-connected power generation system, i.e., PV grid-connected power station system, indicates that the power generated by the system directly enters into the power grid, but this approach cannot fully utilize the characteristics of solar energy such as wide distribution and wide geographical area. In addition, a distributed PV grid-connected power generation system, i.e. household PV grid-connected system, which is based on the “peak and valley arbitrage” activity method of the power framework, in which the power not fully consumed by the distributed PV grid-connected power generation system is connected to the transmission grid at the peak tariff, and the power generated by the power system is purchased at the valley tariff. Electricity not used during the day can be sold to the local utility grid through the inverter and then purchased back from the grid at night when electricity is needed.

As PV power generation and traditional thermal power generation, hydroelectric power generation in the inherent characteristics and the way of elimination of acceptance and so on, there is a big difference. Therefore, the grid typically contributes to concerns with grid stability and dependability, grid efficiency, and other issues, including the islanding effect and the influence of the problem produced by photovoltaic systems on the distribution network, the above problems are mainly by the photovoltaic power generation of stochastic power generation features randomness and intermittency [3].

2.2. Photovoltaic optimization model and prediction technology

2.2.1. Optimal power flow model based on second-order cone technique. Among all the algorithms of the power industry, heuristic algorithms such as Genetic Algorithm, Particle Swarm Algorithm, Artificial Neural Networks, Ant Colony Algorithm, Simulated Annealing Algorithm, etc., where Genetic Algorithm and Particle Swarm Algorithms are more suitable for High Resistance Distribution Grids and Low Resistance Distribution Grids. The comparison of common algorithms in power systems is shown in Table 1 below. Intelligent optimization of the above algorithms, although less constrained by the non-convexity of the model, needs to be less efficient due to its repeated iterations. Also, and due to its stochastic nature, it may fall into local optimal solutions.

Table 1. Comparison of common algorithms in power systems.

	Genetic Algorithm	Particle Swarm Algorithm	Ant Colony Algorithm	Artificial Neural Networks (ANN)	Simulated Annealing Algorithm
Advantages	1. The variation mechanism to avoid the algorithms to fall into the local optimum; 2. The introduction of probabilistic ideas; 3. Expandable, easy to combine with other algorithms.	Simple and easy to implement without too many parameters to adjust.	1. Fewer parameters, simple setup; 2. Reliable, with strong global search capability.	1. Self-learning function; 2. Associative storage function; 3. Finding the optimized solution at high speed.	1. Simple description, flexible use, widely used, high efficiency; 2. Less constrained by initial conditions
Disadvantages	1. Complex programming, involving genetic coding and decoding; 2. The setting of parameters depends on empirical determination; 3. Strong dependence on the merit of the initial population.	1. Performance to be improved. 2. Selection of genetic operators is more troublesome	1. Slow convergence speed; 2. Poor optimization ability; 3. Contradiction between population diversity and convergence speed.	1. Unable to explain the reasoning process and basis; 2. Easy to lose information	1. Slow convergence and long execution time; 2. Algorithm performance related to initial value and parameter sensitivity

2.2.2. Mixed time-scale reactive power/voltage control strategies for distribution networks. The second-order cone relaxation technique can obtain the global optimal solution. In the optimal tidal current calculation of distribution networks, based on the power balance relationship between solar arrays, gas turbines, storage batteries, local loads, network losses and other factors, Ref. established a dynamic optimal tidal current modelling framework based on second-order cone planning [3]. Continuous reactive power compensation (SVC) and intermittent reactive power compensation (CB) devices are introduced. The model transforms the original non-convex distribution network model into a second-order cone planning problem and gives a better solution.

2.3. Application of new energy solar power generation

In terms of application characteristics, due to the wide distribution of solar energy and photovoltaic power generation has a preliminary scale, and in the use of renewable energy photovoltaic power generation process, the direct use of light energy and relying on semiconductor materials will be converted to solar energy resources, in the form of electrical energy. In terms of necessity, photovoltaic power generation technology can guarantee the security of the energy supply and solve the problem of resource constraints. In the economic field, photovoltaic power generation equipment operation and maintenance costs are not high, the total cost is low, and the economic performance is superior, with strong market application prospects [4].

DOI: 10.54254/2755-2721/59/20240805

2.4. China's solar power generation development based on the dual-carbon target

2.4.1. The current situation and predicament of photovoltaic power generation in China. The research status of PV power generation in China is reflected in the following three points: (1) Distributed PV power generation accounts for one-third of all PV power generation grid-connected installed capacity, exceeding 100 million kilowatts and reaching 110 million kilowatts; (2) Centralized PV power generation and distributed PV power generation parallel development. 2021 distributed PV power generation added 29 million kilowatts, accounting for about 55% of the total amount of new installed PV power generation; (3) Household PV power generation rapid development, 2021 new household distributed PV power generation reached about 21.5 million kilowatts [5]. Household photovoltaic power generation has become an important force in China to achieve the carbon peak carbon neutral goal and the implementation of the rural revitalization strategy as scheduled [5].

2.4.2. Solutions to photovoltaic power generation dilemma. Therefore, in the context of the "carbon peaking and carbon neutrality" era, it is necessary to accelerate the construction of the energy system with photovoltaic power generation as the main body. For example, at the government level, we should design and formulate scientific rules and regulations, and increase the support for the PV power generation industry; in the metropolitan and country regions, we ought to zero in on tapping the capability of PV power age and increment the composite PV power generation; At the level of technological innovation, we should vigorously push forward the development of the smart grid, and promote the realization of the PV grid-connected [6].

2.5. Existing deficiencies in photovoltaic power generation technology

Although photovoltaic power generation is gradually popularized, there are still some problems. First of all, the energy transition difficulties, China's power energy consumption structure is still overwhelmed by fossil energy; Secondly, the degree of PV power generation promotion still needs to expand, which involves the capital and market supply and demand relations are still contradictory and the maturity of the technology needs to be improved and so on.

3. Wind power generation technology

3.1. Existing problems of wind power generation technology

China's wind power industry at the beginning of the development of the industry scale is small, the market demand is not high, and China's wind power cooperation has not formed a technology-oriented cost advantage. The advantages of emerging technologies and innovation are not fully reflected. As low-carbonization is encouraged, the amount of wind power technology is also increasing. As a result, technology and innovation mechanisms that can adapt to the new sector have emerged as crucial drivers of the wind power industry's growth.

3.2. Development status of the global wind power industry

With the quick improvement of wind power innovation, the utilization of wind power age is turning out to be increasingly broad, the proportion of the power system is also gradually increasing, the environmental benefits and the availability of wind energy resources reserves gradually expand, and with the further advancement of the power system power electronic form of low-carbon, the high proportion of wind power of the power system operation of the uncertainty of the power system, the key is the advancement of the technology and the mechanism of the innovation can be adapted to the new industry, and the extension of the area of the offshore wind power is gradually expanding the proportion of the increase in the high proportion of the wind power power power of the control of the operation of the power system has become normal [7].

DOI: 10.54254/2755-2721/59/20240805

3.3. Direction of wind power technology innovation

3.3.1. Next-generation wind power generation technology. The development of wind turbine technology is still mostly focused on large-scale generators at this time. The annual power generation and revenue from power generation can both grow and the efficiency of wind energy resource usage can be considerably improved by selecting a plant with a bigger stand-alone capacity. How to further increase the plant's reliability and lower its manufacturing costs is the main technological issue today. A new generation of test platforms for wind turbines, a new generation of monitoring and control systems for wind farms, and some disruptive technological innovations like flexible tower and intelligent rotor technology are also crucial directions for technological advancement.

3.3.2. Offshore wind power technology. Compared with other renewable energy generation technologies, offshore wind power has played a significant role in the large-scale application of renewable energy technologies and energy transformation due to its high-capacity factor, low intermittency and the fact that seaward wind power is typically near power load focuses and doesn't possess land assets.

By the end of 2020, the world has built floating wind power projects, mainly in the United Kingdom, Japan, Portugal, Norway and France. China has no completed projects. Green Energy Donghai, Three Gorges Yangjiang, Haizhuang Zhanjiang, and Longyuan Nanri Island are expected to be completed in 2021 [8].

3.3.3. "Wind power +" technology. "Wind Power + is one of the "Power to X" (i.e., power diversification) technologies that use wind power to produce low-carbon gases or liquid fuels, thereby converting "excess" electricity that is difficult to dispatch through the grid into other energy commodities. This means that wind power can be used to produce low-carbon gases or liquid fuels, thereby converting "excess" electricity that is difficult to dispatch through the grid into other energy commodities. Water electrolysis media is one of the more mature and widely used technologies. The "Wind+" technology is geared towards onshore and offshore wind power, and integrates non-energy sectors such as sea farms and mariculture. Well-known projects include Westküste 100, VindØ Island in the North Sea, Bornholm Island in the Baltic Sea and TenneT Island in the North Sea.

3.4. Innovations in wind power technology in the power system

3.4.1. Design of active scheduling system with multi-time scale coordination for consuming large-scale wind power. The traditional grid operation and scheduling model and the capacity of conventional plants to regulate can no longer match the demand for large-scale wind power grid integration due to the intermittent and fluctuating nature of wind power output. The uncertainty of the day-ahead wind power output is described using a probabilistic simplified scenario set, and the day-ahead plant combination selection is made to accommodate the variation of wind power. Aiming at the constraining effect of the regulation capacity of conventional plants on wind power consumption, a dispatch model for the cooperative operation of high-load energy loads and conventional units is proposed. On this basis, a coordinated scheduling model for multi-timescale source loads with the objective of minimizing total system operating costs and pollution emissions is established. Day-ahead scheduling, daily rolling scheduling and real-time scheduling are coordinated and combined, and intelligent optimization algorithms are used to solve the problem step by step, providing an effective way for the grid to absorb intermittent energy [9].

3.4.2. Multi-time scale source-load coordinated scheduling model of power system containing large-scale wind power. The access of large-scale wind power poses a major challenge to the grid scheduling model and technology. By analyzing the stepwise growth of wind power prediction accuracy with time scale and the inherent characteristics of active scheduling, a multi-time scale coordinated active scheduling model and its key technologies are proposed. This planning model depends on the possibility of “multi-level coordination and step-by-step refinement”, and the residual deviation at the upper level is corrected by the lower level [10].

4. Co-operation of wind-solar power generation

4.1. Key technologies for the safe operation of wind and solar power generation equipment

To support the goal of reaching “peaking carbon and carbon neutrality”, China’s new energy generation systems based on wind and photovoltaic (PV) power generation will continue to see accelerated development for a long time to come. In this period wind and photovoltaic power generation developed rapidly, challenges posed by environmental factors have impacted the safe operation of the systems and have resulted in expensive operation and maintenance costs. Therefore, there are five key issues that need to be solved in terms of lightning strikes, ice coverage, dust accumulation, packaging issues, that wind power equipment must operate and maintain intelligently: The rotating wind turbine lightning flash mechanism under the influence of multiple climate factors, reliable encapsulation technology for perovskite solar cells, and other issues are yet to be resolved. Addressing these problems will enhance the adaptability of wind power generation equipment in complex environments, promote the safe operation of new energy generation systems based on wind power, reduce reliance on high-carbon emission fossil fuels, and contribute to achieving the “dual-carbon” goals [11].

4.2. Suggestions for virtual power plant operation optimization

The environmental externalities generated during the construction and operation of virtual power plants affect the economic and environmental benefits of virtual power plant operation. First, the plant environmental externality costs of coal, wind power and photovoltaic power generation are separately accounted for and included in the unit power generation cost of the virtual power plant. On this basis, a two-stage blu-bar optimization model based on Wasserstein distance is constructed for the fuzzy set of wind power output prediction errors to minimize the operation cost, taking into account the uncertainty of wind power output. The scheduling decision problem of the virtual power plant is studied. Finally, the positive effect of considering environmental externalities on the economic and low-carbon operation of the virtual power plant, as well as the applicability and computational simplicity of the constructed two-stage blu-rod optimization model are verified through the arithmetic simulation and comparative analysis [12].

5. Conclusion

The “dual-carbon” aim is primarily discussed in this assessment along with the current state and innovative aspects of photovoltaic and wind power production technologies, and summarizes the following two points: (1) The optimization and strategy of photovoltaic power generation technology and application; (2) The innovation of wind power generation technology in multiple perspectives. To achieve the goal of solving the dilemmas faced by new energy technologies and the use of innovative technologies to optimize the operation and improve power generation more efficient, according to the summarized content of this review, it can help to provide a case reserve for the progress of wind power generation technology in the future. Due to the large number of innovative technologies, this review can not be completely covered, only selected part of the domestic and foreign cases to analyze, the follow-up can be improved in the innovation point, and can increase the biomass power generation direction of the summary.

References

[1] Chen Wei1, AI Xin1, WU Tao2, et al. Overview of research on the impact of photovoltaic grid-connected Power generation system on power grid Electric Power Automation Equipment DOI: 10.3969 / j.issn.1006-6047.2013.02.005

[2] Xu Heyong and Zhang Qian. Prediction technology OF photovoltaic POWER generation based on digital twin AND Improved LSTM JOURNAL of ENGINEERING FOR THERMAL ENERGY and Power, 2023:84-100.
[3] Huang Dawei, Wang Xiaoquan, Yu Na, et al. Hybrid time-scale reactive power/voltage control strategy for distribution network with PV output uncertainty. The Transactions of China Electrotechnical Society, 2021,10.19595 / j.carol carroll nki. 1000-6753. The tces. 211188
[4] Li Z. Research on application of new energy photovoltaic power generation technology. LOW CARBON WORLD, 2022:76-78, DOI: 10.16844 / j.carol carroll nki cn10-1007 / tk. 2022.08.054
[5] Zhao Wanming. The dilemma and solution of China's photovoltaic power generation under the dual-carbon vision. INDUSTRY,2022:41-44
[6] Han Mengyao 1,2,3, Xiong Jiao1,2,3, Liu Weidong 1,2,3. Spatial and temporal distribution, competitive pattern and emission reduction benefits of photovoltaic power generation in China. Journal of Natural Resources.2022, 37(5): 1338-1351,DOI: 10.31497/zrzyxb.20220516
[7] CUI Wei 1, Eskar 2. Status quo and development trend of wind power technology at home and abroad. Electrical Appliances and Energy Efficiency Management Technology,2019:1-5 DOI: 10. 16628 /j. cnki. 2095-8188. 2019. 13. 001
[8] Wang Q. Research on global wind power technology innovation in the context of carbon neutrality. China's energy, 2021:69-76. The Doi: 10.3969 / j.i SSN. 1003-2355.2021.08.012
[9] ZHANG Boming 1, WU Wenchuan1 , ZHENG Taiyi 2, SUN Hongbin. Design of active Power scheduling system for multi-time scale coordination of large-scale wind power. Automation of Electric Power System,2011:1-6
[10] Zhang Ya-Chao-1, LIU Kai-Pei-2, Liao Xiao-Bing-2, et al. Research on multi-time scale source load coordination scheduling model of power system with large-scale wind power. High Voltage Engineering,2019:600-608.DOI: 10.13336/j.1003-6520.hve.20190130034
[11] Li Qing-min, Yu Wan-shui, ZHAO Ji-yao. Key technologies for the safe operation of wind power generation equipment supporting the goal of "dual carbon". High Voltage Engineering, 202:3047-3060.DOI: 10.13336/j.1003-6520.hve.20211083
[12] SUN Jingqi1, Wang Wang1, GUO Xiaohui1, et al. Virtual power plant operation optimization considering environmental externalities and wind and landscape output uncertainties. Automation of Electric Power System,2022:50-59.DOI: 10.7500 /AEPS20210623005