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Review of developments and insights into an index system of wind power utilization level

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ABSTRACT

With the rapid development of wind power, countries not only pay attention to wind power quantity, but also to quality or utilization efficiency. Therefore, establishing a set of complete systems and suitable conditions to evaluate the wind power utilization level of China is necessary. The present study summarizes the development status of wind power in China, and then compares the domestic and foreign wind power utilization levels. The results show that the wind power total utilization level of China is equal to that of the United States, the regional "Three North" grid wind power utilization level is commensurate with that of Germany, and "East Mongolia" reaches the world-leading utilization level along with Denmark. In the present study, the diversifying index system of wind power utilization level is also constructed in consideration of the basic indices, development scale indices, and utilization efficiency indices of wind power. The developments in Chinese wind power are reviewed and the future wind power utilization level of China is analyzed using power system integrated optimization model. Research results show that the wind power utilization level must measure many aspects rather than a single index, and we should focus on the coordinated development of wind power and the entire power system. China must improve the overall planning and operation level of the power system, which is the key to developing its wind power industry, to scientifically and orderly promote wind power as well as ensure healthy development while improving the wind power utilization level.

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1. Introduction

As urgent global issues, such as population, energy security, environmental protection, and climate change, become increasingly serious, utilization of renewable energy, especially wind power, becomes highly significant [1–3]. In recent years, wind power generation has been the most mature global issue with large-scale development conditions and commercial prospects for renewable power production. Furthermore, wind power plays a crucial role in improving the power structure of a country, reducing the greenhouse effect, and maintaining ecological balance. Wind power generation, as a strategic emerging industry, has been growing rapidly because of the inexhaustible and clean nature of wind energy [4–6]. Consequently, governments all over the world, including those in China, India, Europe, and the United States, have set wind power development as a priority. The study of wind energy and wind development has been a topic of great interest for developers and researchers in many countries [7–9].

The wind power utilization level of the overall power system is not only closely related to wind energy resources and wind power installed capacity, but also to power structure, grid structure, load characteristics, and other factors. Different countries have different wind power utilization levels because of the different basic conditions for the development of such power [10,11].The evaluation utilization level indicators of wind power include wind power installed capacity, installed capacity account, annual utilization hours, power generation, and power generation capacity that represents power proportion [12,13]. Wind power scientists have not formed a comprehensive and unified approach to deal with various types of wind power utilization level indicators and scientifically evaluate wind power development and utilization level. In evaluating the level of wind power development, what should be considered is not only the development scale but also the development quality of wind power [14–17]. Overall, evaluating wind power utilization levels is a systematic and global issue.

A high utilization level of wind power should ensure that the annual utilization hours of wind power approximates or meets the designed annual utilization hours and can respond flexibly to the increased difficulty of a wind power system operation [10]. The rapid development of wind power across the world has led to a series of issues, including wind turbine quality problems, scattered layouts of wind farms, small-scale power generation capacity, lack of commercial operation mechanisms that overlap wind farm developments, and poor reliability [18,19]. Clearly, a number of internal and external factors affect the sustainable development and utilization level of wind power in China, which calls for a comprehensive industry analysis to highlight these factors. Therefore, this analysis provides useful operational strategies, management measures, and inputs to both government authorities and private developers.

In the present study, a diversification utilization level indicator comparison system of wind power is built to ensure a comprehensive comparison of wind power utilization levels and a reasonable evaluation of wind power development. The installed wind power capacity and wind power generation account for the proportion of annual electricity consumption, the instantaneous output of wind power accounts for the same proportion of the maximum load point, and years of wind power utilization hours are selected as evaluation indices for the diversification system. Furthermore, the wind power utilization levels of domestic and international locations are analyzed comprehensively. Based on the system-integrated optimization model, the future wind power utilization level of China is discussed and analyzed.

2. China wind power development overview

In recent years, the wind power industry in China has developed rapidly. The newly installed capacity of wind power increased by 3.13–16.089 GW in 2013 from the previous year's figure. The total installed capacity reached 91.413 GW, the new grid capacity reached 14.49 GW, and the total grid capacity reached 77.16 GW. China continues to be the first wind power market in the world. Wind power in the country accounts for the third largest supply after thermal power and hydro-power [8,9].

China has abundant wind energy resources, especially in the “Three North” (northeast, north, and northwest) and eastern coastal areas. The total reserves of wind energy resources in China are estimated to be 3.23 TW, which ranks third in the world. According to the China Wind Energy Association, the “Three North” regional wind power grid capacity accounts for 83.6% of supply in the country. The Inner Mongolia wind power grid capacity reached 18.33 GW, which ranked first in the country; the capacity of Hebei and Gansu reached 7.75 GW and 7.03 GW, respectively, which ranked second and third [16]. The wind power capacity increased sharply in Xianjiang, and the newly installed capacity reached 3.15 GW, which was the largest installed area in 2013. These results are mainly attributed to improvements in the wind power delivery conditions. Grid wind power and wind power consumption conditions had a significant effect on the development rate. An ultra-high altitude test of wind farms was conducted in Nagqu of Tibet that was marking China's wind farms throughout the country provinces [9]. In nearly two years, the offshore wind power in China made breakthrough progress. By the end of 2013, the national offshore wind power project approved a total size of approximately 2.22 GW; a grid of 390 MW was built, which distributed power to Jiangsu, Shanghai, and Zhejiang. This grid ranks second in the world in terms of production after a similar grid in Britain, and is ahead of a similar grid in Denmark.

Reviewing the overall development of the wind power industry in recent years, we can see that the Chinese government policy on developing the wind power industry serves an important purpose. In 2012, the “Wind Power Development Twelfth Five-Year Plan” confirmed the goal that the installed wind power capacity would reach 200 million kilowatts by 2020. In 2013, the National Energy Board merged with the SERC and proposed the concept of “big energy” (coal, electricity, oil, natural gas, new energy), which was in favor of improving the energy structure [9,19,20]. Then, this group published “the work on how to strongly control air pollution by the energy industry,” which proposed “safe, efficient, and economical” advanced transmission technology, 12 advanced electric power transmission channels, as well as expansion of the send scale from north to south and from west to east. All these factors are expected to solve the problem of wind power consumption in the country. During the 18th National Congress of the CPC, the concept of “Beautiful China” was proposed to “vigorously promote the construction of ecological civilization, the positive development of low-carbon energy industry and new energy, renewable energy.” Overall, with strong policy guidance, wind power can help improve the national energy structure. Wind power is also expected to minimize haze and contribute to national green sustainable development together with PV(Photo-voltaic power), hydro-power, gas, and other types of clean energy [9,21].

3. Basic conditions for domestic and international wind power development

Understanding the influence of basic wind power development conditions is necessary to study the domestic and foreign wind power utilization levels. In countries all over the world, different energy structures, different wind energy resource distributions, and different power grid constructions lead to different utilization levels of wind power generation.