

Cause Analysis and Countermeasures of Wind Power Curtailment

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Abstract. The current world has numerous issues, such as insufficient electrical supply, excessive fossil fuel consumption, and environmental contamination. As a rapidly increasing renewable energy in recent years, wind energy plays a significant role in mitigating these issues. Nevertheless, the rapidly expanding wind energy business has led to the emergence of the problem of wind power delays. Using the existing state of wind power in China as a starting point, this article examines the causes of curtailment of wind power and the obstacles that must be overcome to improve the situation. The objective of this study is to examine the current problem of wind curtailment in China, its causes, and the problems it faces in order to give readers with further suggestions for solving wind power curtailment problem and promoting the wind power industry's continued progress toward low-cost, high-quality mature energy.

Keywords: Wind power, wind curtailment, China, wind energy.

1. Introduction

In order to reduce carbon emissions as a result of global climate change and worsening energy shortages, renewable energy generation, particularly wind and solar energy, has emerged as crucial elements in the construction of a clean power grid. However, as wind power has quickly developed, shortcomings and deficiencies of wind power are quickly exposed:

First, due to the intermittent nature of wind resources, wind power cannot independently support a system and requires peak-shaving power support; secondly, the number of hours of wind power utilization is low; third, the output power of wind power fluctuates significantly, and the quality of electrical energy is average; and fourth, in the distribution of wind power, areas with good wind resources are frequently located far from the load center. Therefore, when growing wind power, it is vital to enhance the capacity and electricity of wind power while maximizing the amount of peak-shaving power supply. The disparity between wind power distribution and load distribution dictates that the wind power consumption across the country must be taken into consideration for the large-scale growth of wind power; the limitations of wind power necessitate a larger load than its own capacity, a larger peak-shaving power supply, and a power supply that is suitable for wind power. In conjunction with more robust power networks for wind energy consumption, a power system suited for wind energy consumption is created.

This paper begins with the current situation of wind power consumption in some regions of China, analyses the current wind power industry development of China and the constraints of the objective environment, and then analyses the primary causes of the wind power curtailment problem as well as the challenges and obstacles that may be encountered if the issue is to be resolved. Combining the special objective conditions of China with three important parts of market technology policy, this article offers workable solutions to the wind power arrears problem. In the meanwhile, the future development of wind energy is anticipated.

2. Current status of wind energy consumption

The global wind energy business has been around for more than 40 years, and the technological and industrial development of the wind power industry originated in Denmark and led to its expansion throughout Europe. In the early stage of wind energy industry growth, European producers of wind

turbines and wind power producers dominated the market. In the process of long-term learning and catching up with European advanced enterprises, the Chinese wind power industry has developed from technology introduction, joint design, absorption, absorption, to the stage of independent research and development. At the same time, China's wind power business is booming. In 2000, the installed capacity of wind power in China was only 0.3GW. In 2002, China began mass production of domestic units. In 2012, Wind energy installed in China exceeded 60GW, making it the world's largest wind power country, and it has remained so to this day [1].

The optimization of the national energy structure has a positive effect on improving the quality of economic development. In the context of the global energy structure transition to low carbon and the continuous optimization of energy consumption structure, the demand for renewable energy will continue to increase. Due to its distinctive benefits, including its plentiful resources, environmental protection, high degree of automation in operation and administration, and declining cost per kilowatt-hour, wind energy has emerged as one of the most widely generated and used renewable energy sources. Its use is a crucial component supporting the optimization and decarbonization of the energy structure, and its development is progressively shifting from complimentary energy to alternative energy.

The "13th Five-Year Plan for Wind Power Development" published by the National Energy Administration in November 2016 states that, in order to reach the target of non-fossil energy making up 15% and 20% of primary energy consumption in 2020 and 2030, it is necessary to promote energy Transformation, China must accelerate the development of wind power and other renewable energy industries. The goal of "carbon peaking and carbon neutrality" has once again boosted China's wind power industry. China will see a greater than 65% reduction in carbon dioxide emissions per unit of GDP by 2030 compared to 2005, non-fossil energy will make up around 25% of primary energy consumption, and the combined installed capacity of wind and solar energy will top 1.2 billion kilowatts. Significant and extensive changes in the economic, social, and political systems will be necessary to reach carbon peaking and carbon neutrality. For ecological civilization to be built by 2030 as planned, carbon peaking and carbon neutralization must be incorporated into the overall design. Target carbon peaking and carbon neutrality by 2060. The wind energy industry will usher in an opportunity for rapid, long-term growth.

China is the largest wind power market in the world and has abundant wind energy resources. Over the past few decades, the expansion of China's wind power market has also contributed to the growth and development of Chinese wind power manufacturers. In addition, China's wind power industry has long been widely supported and promoted by legislation. The wind energy business is developing rapidly. The product technology level of industry-leading companies is getting closer and closer to the international advanced level.

However, Although the Chinese Three North regions have abundant wind energy resources, they are frequently far from the eastern and central regions, where there is a high demand for electricity. Reverse the regional distribution of wind energy resources and electricity consumption. The existence of the phenomenon of "abandoning wind and limiting electricity", the short-term integration of wind power into the grid, and the existence of "abandoning wind and limiting electricity" are still the most challenging issues in the industry. The reasons for this will be analyzed below.

3. The causes and challenges of wind power curtailment

3.1. Transmission wind energy operation level is relatively low

The dispatch of wind power must be carefully handled, and the operation of other energy sources within the system must be appropriately planned, in order to achieve maximum permissions and maximize wind power consumption. The construction of a technique for predicting wind power generation capacity and a system for monitoring wind power generation operations are crucial components of optimal scheduling. Currently, China's wind power forecasting results are great, but the coverage of wind power forecasting systems is severely lacking. Although wind power forecasting

systems can be developed to optimize planning based on forecast data, the majority of wind farm forecasting systems are inadequately configured, and wind farms are maximizing wind output. Consumption, which restricts optimal scheduling.

Secondly, Chinese coal-dominated power supply system is determined by the features of Chinese coal-dominated energy resources. China's coal-fired power installed capacity accounted for 73% of the country's total power production capacity at the end of 2008, while heat supply units with insufficient peak shaving capability accounted for more than 20% of the coal-fired power installed capacity. In addition, runoff hydropower accounts for a considerable share of Chinese installed hydropower capacity, while hydropower with strong control performance accounts for a modest portion. The peak shaving capacity of Chinese power system has been insufficient for a long time due to the structure of its power supply. The burden on the system caused by peak regulation is increasing as wind power production increases, and the anti-peak regulation properties of wind power make peak regulation in the electricity grid and the clean energy network even more challenging. Currently, insufficient peak shaving capacity of the system is limiting wind power output in certain regions of Northeast China, North China, and Northwest China during the heating season system load trough.

In 2008, due to the limitation of the system's peak shaving capacity, Jilin Power Grid experienced 3 instances of limited wind power output operation, with a maximum output limit of 80,000 kW; East Mongolia Power Grid experienced a total of 7 instances of limited wind power output operation, with a maximum output limit of 100,000 kW.

3.2. The limited scale of interregional grid connectivity is not conducive to the widespread consumption of wind energy.

Chinese power growth has been governed by local provincial balance for a very long period, with relatively limited interconnection between areas.

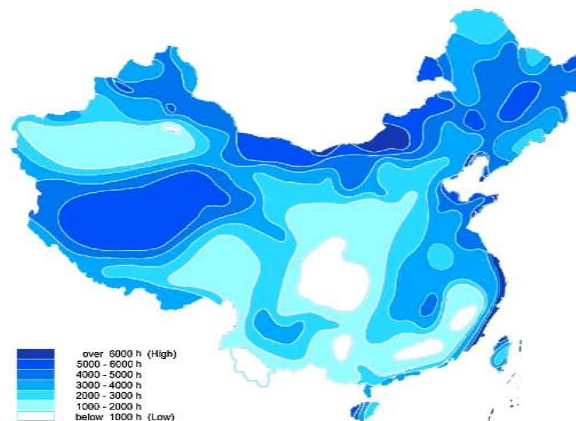


Figure 1. Distribution of effective wind power in China [2]

The main regions for the development of wind power in China are North China, Northeast China, and Northwest China. The majority are located at the end of the electrical grid. The local load level is low, the scale of the system is modest, and the wind power consumption capacity is quite limited. It is challenging to transport wind energy to the load center location where it is consumed. Figure 1 shows the distribution of wind energy resources.

For instance, wind power from Mengdong must be sent to the Liaoning load center for consumption, but the size limits of the network restrict wind power transmission. In extreme circumstances, only efforts to limit wind power output are implemented, which is not beneficial to the widespread development and use of wind power and other forms of renewable energy.

3.3. Adjust power system functionality

Wind energy has unpredictable, variable, and intermittent qualities. Moreover, the analysis of the Annual output of wind power characteristics reveals that the output of wind power is particularly high in spring and winter in many regions of China, whereas the analysis of the annual output

characteristics of wind power in summer and autumn reveals that the annual output power of wind energy has more opportunities to obtain wind energy, and the frequency regulation of the power system Band peaks is also becoming more complex.

3.4. Grid-connected engineering

After substantial access to wind energy, the safety and stability of the system are unaffected, which is crucial for efficiently absorbing wind energy elements.

In China, the wind energy industry was slow to develop, and there are no mandated wind energy and wind energy technical requirements. The majority of equipment manufacturers have adopted European wind turbine manufacturing and assembly techniques. Due to a lack of independent research and development capabilities, the majority of manufacturers have already implemented low-voltage conversion with relatively limited regulation capacity, high efficiency, and low efficiency, which negatively impacts wind power. The inability to improve the manufacturing automation level of generators poses a threat to the regular operation of the power system.

If we wish to alter the existing condition of forsaking wind and power, it will be faced with several obstacles.

Challenge 1: ensuring electricity delivery during periods of low wind power.

In order to secure enough power supply, sufficient dispatchable power production capacity (such as gas turbine units or flexible coal-fired units) is necessary, or additional cross-border energy imports and exports can be accomplished by strengthening grid coupling with adjacent nations. Corresponding measurements Particularly, the value of is dependent on the duration of its use.

Challenge 2: Ensure the value of wind energy, which means when wind resources are abundant, ensure the price of wind energy and its efficient utilization.

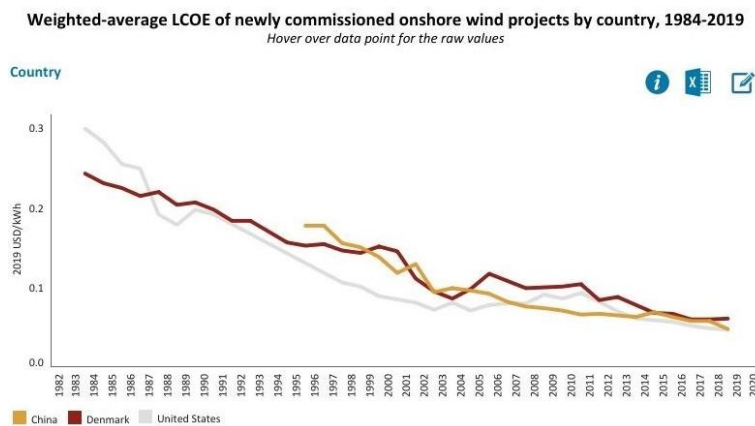


Figure 2. Global onshore wind power bidding versus coal power [4]

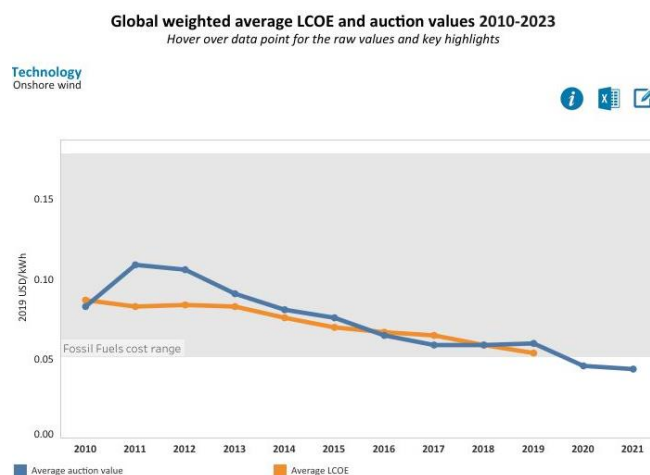


Figure 3. Compare the ratio of onshore wind power to global power in recent years [5]

Currently, the majority of China's wind power is generated offshore. Nevertheless, the poll indicates that from 2019 to 2021, the bidding price for offshore wind generating equipment will fluctuate between 8,000 yuan/kW, 6,000 yuan/kW, and 3,800 yuan/kW. The yearly rate of fall is greater than 25%, while the development cost of offshore wind farms is maintained at approximately 16,500 yuan per kilowatt and the equipment cost has decreased from 50% to 25% [3]. The Figure 2 demonstrates that the global average cost of wind energy is significantly less than that of coal. The Figure 3 demonstrates that China's wind power market has expanded at an amazing rate in recent years.

Therefore, we must be aware of the price competition for wind power, and we might assume wind power price premiums to be slightly greater than wholesale electricity market pricing and wind power equipment investment. If the majority of wind power is sold at low or negative rates, this is detrimental to wind power operators and diminishes the incentive for investment and development in wind energy. Consequently, securing the socioeconomic value of wind power and encouraging the continuous growth of wind turbine investment are crucial. To properly utilize wind energy, the entire electricity infrastructure must be highly versatile. During periods of high wind output, several choices are available, including exporting electricity to neighboring nations, lowering generation from conventional dispatchable facilities, and encouraging end-use electricity consumption.

Challenge 3: Balancing wind power

Although wind forecasting systems are becoming increasingly precise, there are still obstacles to overcome in terms of real power generation, particularly during moderate to heavy winds. Due to projected deviations, power balancing becomes necessary. The power balance issue is solvable from both the supply and demand perspectives. On the supply side, gas turbines and other fast adjustable devices, such as energy storage, are suitable for meeting this need. On the demand side, electric boilers or heat pumps, as well as big industrial consumers and other flexible consumer units, can offer balancing services. In addition, grid connectivity between areas and integration with the energy systems of neighboring nations can give additional balancing opportunities.

Currently, these three obstacles are all economic in nature, and although the aforementioned problems can be solved entirely by existing technology, their economic efficiency cannot be guaranteed.

4. Countermeasures of Wind Power Consumption

China currently possesses an abundance of renewable energy resources. With the progressive development and improvement of new energy technologies, Chinese present new energy power installed capacity has been grossly unbalanced between the east and west due to regional limits. Large-scale new energy ground power stations are centered primarily in the northwest (mainly including Gansu, Ningxia, Xinjiang and Mengxi). Despite the fact that the installed capacity has expanded significantly over the past few years, the reduction of light and electricity has worsened annually due to the limited local consumption capacity. In the author's opinion, this issue must be addressed primarily from the following three perspectives:

The government must design effective regulations, establish a tax system to encourage wind power consumption, and aggressively direct the cross-border market coupling of wind power and the coupling with the heating system from a policy standpoint.

Currently, administrations at all levels in China have taken demonstrable action. In accordance with the requirements of the early warning and monitoring system for wind power investment, all wind power projects will be suspended and labelled as orange in 2016 if the area is designated as a red early warning zone. Each year, no new development projects are permitted in the area; only current ones may be constructed. It is designated as a green area, therefore wind farm building can proceed normally.

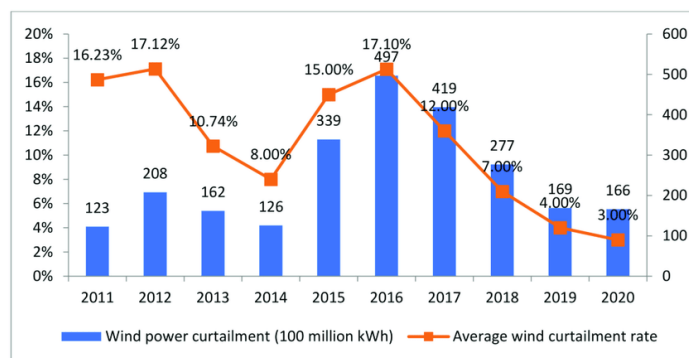


Figure 4. China wind curtailment statistics in recent years [6]

In recent years, the problem of wind power consumption in China has been substantially relieved thanks to the coordinated efforts of all levels of government, wind power developers, and investment monitoring and early warning systems. From Figure 4, it is evident that the proportion of abandoned wind farms has declined significantly since 2016 [7].

From the market level, and the active consumption and fluctuation balance of wind power may be promoted efficiently at the market level. During times of abundance, wind power can be exported to adjacent countries by taking advantage of market price advantages; during times of scarcity, relatively inexpensive power can be imported from abroad due to price disadvantages.

On a technical level, district heating and cogeneration have been successfully promoted, resulting in a strong coupling between the power system and the heating system, which effectively reduces the fluctuating load caused by wind power; additionally, seasonal energy storage technology is maturing to ensure the stability of the power supply. According to the analysis in the second section, the cost per kilowatt for wind power has decreased significantly, and compared to the same type of renewable energy, such as photovoltaics, it will have significant economic and geographical advantages, resulting in increased economic growth for wind energy. The centralized wind power plant with electrochemical energy storage is without question the best alternative for energy storage.

As a volatile renewable energy source, wind power is equipped with a different type of energy storage than photovoltaic energy storage. In contrast to photovoltaic power generation, which has more pronounced peak-to-valley characteristics due to day or night differences and short-term swings, wind power has poor accommodation matching, and there may be strong winds or no wind conditions for several days in a row. The key to the combined usage of wind and storage is the suppression of system shocks generated by volatility and intermittency by means of reasonable capacity allocation and suitable operation procedures.

In order to ensure a relatively stable power output, it is believed that some mainstream manufacturers in China have also adopted the fan paddle system, using high-power batteries or super capacitors as the power energy storage system to ensure that the fan is operational in the event of wind speed fluctuations. Maintain a generally consistent power output, and when the wind becomes excessive, the fan blades can be restored to neutral for a safe shutdown. However, the power-based energy storage system has the ability to regulate frequency, but not peak regulation. The optimal wind power distribution and storage peak management necessitates longer energy storage duration, with the continuous energy storage period possibly needing to reach 4 to 10 hours. Due to the unpredictability of wind power, the requirements for the kWh cost of the energy storage system will also be more stringent. If the wind energy utilization rate is pursued, the wind turbine's voltage and current output will unavoidably be unsteady. Historically, wind turbines were constructed to Instead of pursuing maximum wind energy utilization, stable energy output is designed for pursuing maximum wind energy consumption. Using energy storage equipment and wind turbines with energy storage equipment, it is possible to enhance output power under the same conditions, hence reducing costs and increasing profits. The determining factor is the cost of wind energy storage.

5. Conclusion

This paper covers the use of wind energy in China's wind power industry in terms of its advantages, problems, prospects, and risks. The answer is provided from three perspectives: policy, market, and technology, using wind energy storage as the focal point. The merits and disadvantages of the most relevant electrochemical energy storage systems currently available are explained, as well as their future development. The key advantage of the wind power sector, according to research findings, is that my country's enormous wind energy resources will have a long-term favourable effect on the environment, and the wind power equipment manufacturing industry is expanding rapidly. As a result of technological advancements, the cost of wind power generation has decreased dramatically. In addition, the energy-based economy has gained legislative backing, and there are numerous excellent growth potential in areas like offshore wind power development and clean development. In contrast, very high wind energy prices, transportation challenges due to wind energy's unequal distribution, hefty returns and tax burdens, a lack of critical technology, and unpredictability in quality and equipment are significant negatives. The company's long-term success is threatened by unanticipated supply chain expansion, difficulty connecting to the grid, a lack of marketing initiatives, and the development of a wind-power equipment manufacturer. The outcomes of these assessments can serve as a benchmark for the Chinese wind power sector, allowing it to become more competitive in the future and contributing to the industry's sustainable growth [8]. In a dynamic social and economic context, these factors are also real-time, and although the wind energy *curtailment issue* have been significantly improved, they remain the greatest barrier to the rapid and widespread development of wind energy, which requires more sustained and long-term efforts to overcome.

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