Wind Power Systems Distribution and Optimization in Mainland China

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Abstract. With the fast development and technology evolution, the energy consumption in China has gradually increased, and energy depletion has become a main concern. In recent years, with the promulgation of new energy policies, wind power plant, as a clean energy source, has gradually attracted people's attention, and wind power generation technology has been progressed and developed. This paper will assess and summarize the wind capacities and results of this operation through observation and comparison of the outcome in different areas. Factors for the distribution of systems are analyzed, providing an explanation for the current state of capacity distributions in the provinces. Comparing the installed wind power systems in east and west China, east China was perceived to have a larger capacity. Further investigation into the reasoning has led to the high wind curtailment rate in different areas of China. Possible reasons were provided, and solutions were given. Wind curtailment and even energy distribution will also be discussed, as well as suggestions for future technology development and power generation planning.

Keywords: Wind power; Turbines; Install capacity; Distribution; Wind curtailment.

1. Introduction

The People's Republic of China, a country that has seen tremendous economic growth, has also surpassed all other nations as the world's greatest producer of carbon dioxide (CO_2) since 2006, accounting for nearly 30% of global CO_2 emissions [1]. China set national development objectives as a consequence to encourage the usage of clean energy. A 10,000 MW wind power base at Jiuquan, Gansu Province, was approved in 2008, ushering in a new era in China's development of new energy sources and establishing wind power as one of the top clean energy sources in terms of energy output, cost, and profit. Since then, the installed wind power capacity in China has increased steadily, indicating a "blowout" situation with construction serving as a manner of extensive, focused development and long-distance transmission. A record high wind power generation has been achieved in 2016 when 148,640 MW of wind energy's installed capacity was linked to the grid [2].

In order to analyze this "miracle", the outcomes must be observed through a comparison of different areas.

2. Geographical Division of China

Splitting the country into two different areas of investigation is more difficult than one would expect. Politically speaking, there are three main regions of China: West China, Central China, and East China, with the east being the most economically developed, the Centerless so, and the West being the least economically developed. As shown in Figure 1 (a), The western region includes the Guizhou, Sichuan, Gansu, Qinghai, Shanxi, and Yunnan provinces, as well as the Chongqing municipality and the Inner Mongolia, Ningxia autonomous regions, Tibet, Xinjiang, and Guangxi. The central region includes the Hunan, Shanxi, Heilongjiang, Henan, Anhui, Jiangxim and Jilin provinces. The eastern region includes the Liaoning, Hebei, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, and Hainan provinces and the Beijing, Tianjin, and Shanghai municipalities.

Other sources claim that there is a fourth, northeastern region of China, as shown in Figure 1 (b). This includes the provinces Heilongjiang, Jilin, and Liaoning, previously grouped under central China.

Aside from these political and economic distinguishments, one can consider the geographic and demographic factors. A popular way of doing this is the Heihe-Tengchong Line, also called the Hu Huanyong Line or the Hu line, as shown in Figure 1 (c). Connected by two border towns, It divides China's land area into two sections, the east and the West, with a polarizing difference in population densities. The eastern section consists of 94% of China's total population, while the West only has the remaining 6%, all while the surface areas only have a 14% difference [3]. Although this is a possible solution, it is simply too complicated, as it bisects provinces on multiple occasions, making it hard to collect data.

As that is the case, this essay will be utilizing the first proposed three-region division of mainland Chinese territory, as seen in Figure 1 (a), but with central China being grouped together with eastern China.

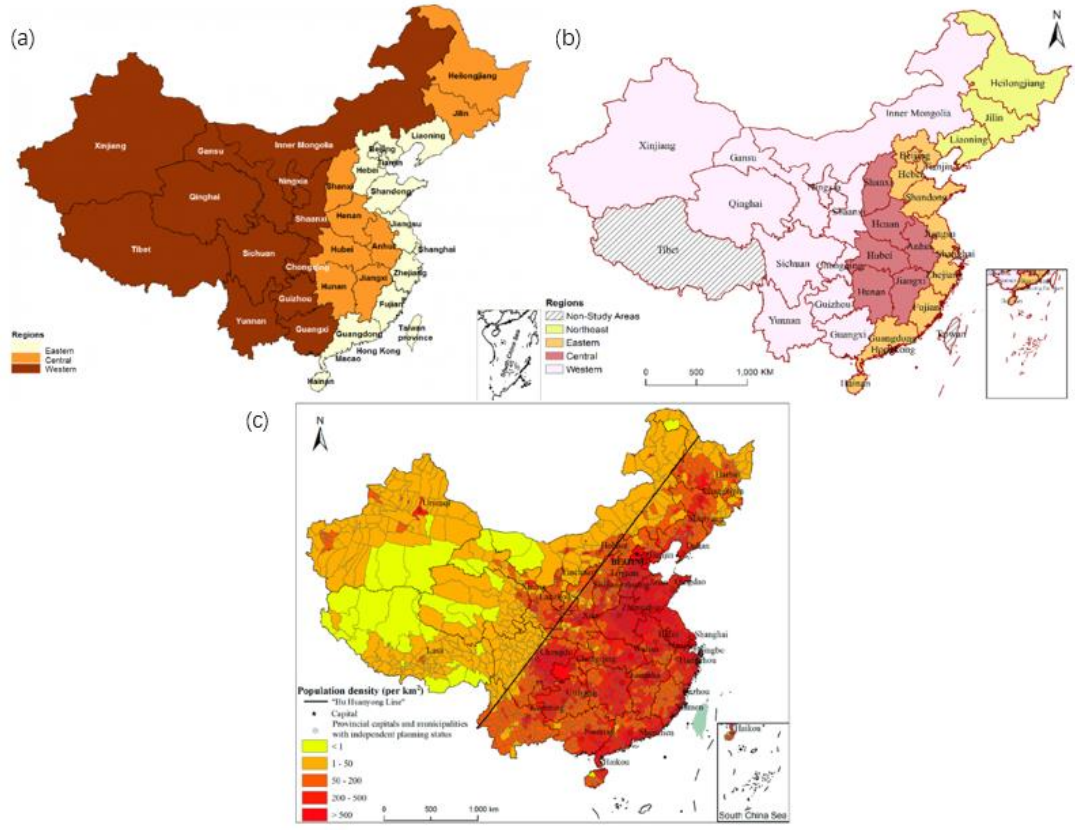


Fig 1. (a) Proposed division of China in three main parts [4]; (b) Proposed division of China in four main parts [5]; (c) The Heihe-Tengchong Line [6];

3. Distribution of Systems

3.1. Influence Factor Analysis

3.1.1 Wind speed

First and foremost, there are many factors that determine where wind power systems will be built and how large the capacity of said systems will be.

For the most part, the most obvious action to take before deciding whether or not to, for all intents and purposes, build wind power systems in a certain location is taking a look at wind speeds in the area. Wind speed is a direct, effective, and convincing method of demonstrating if the systems will generate electricity, how much they will produce, and the amount of profit one can gain from the investment in these systems. Obviously, there are many other factors, but this species is a good start.

Figure 2 displays annual mean wind speed distribution from the year 1995 to the year 2016 in China. This numerical simulation incorporates data from more than 2400 ground weather stations, more than 160 sounding meteorological stations, the global atmospheric circulation mode lattice reanalysis, and more than 2400 ground weather stations using four-dimensional data assimilation techniques [7]. The open plains and water, tops of smooth, rounded hills, and mountain gaps are all favorable sites for wind turbine positions. Wind resources are usually more advantageous for the generation of electricity at higher altitudes.

From Figure 2, it could be visually observed that the areas with the highest wind speed in mainland China are the southern regions in Tibet and parts of Inner Mongolia, Xinjiang, and southern parts of China seem to have; as far as this map is concerned, the lowest wind speeds, presumably as the landscape, for the most part, is relatively flat, which is quite significant compared to the terrain of Tibet and Inner Mongolia.

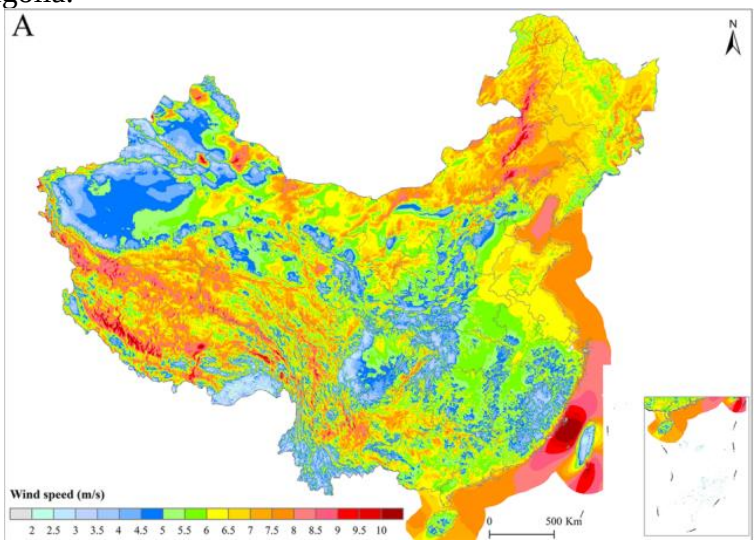


Fig. 2 China's land and offshore 100 m annual mean wind speed spatial distribution from 1995 to 2016 [7]

3.1.2. Types of turbines

Manufacturers of wind turbines create several models that are appropriate for a variety of wind speeds in order to maximize the utilization of wind resources. Four typical onshore types of wind turbines including the GW150-3.0, GW165-4.0, GW155-4.5 and GW 136-4.2 has been frequently used, in which the GW 150-3.0 has been designed for situations when wind speed is less than 5.5 m/s, and the GW136-4.2 has is suitable for use in harsh conditions when wind speed is larger than 9.2 m/s. Also, GW155-4.5 has the highest capacity of 4.5 MW [8].

This information was collected from Goldwind Technology Co., Ltd., one of the longest-leading contributors to the Chinese wind power system market. The theoretical wind power can be estimated using parameters such as the air density, the curve of the specific wind turbine, and the wind speed per hour. Figure 3 displays the distribution of turbine types.

They utilized data on the slope, yearly use hours, natural reservation areas, type of landform, and distance from an urban zone to filter data to find regions appropriate for onshore turbine sites. Based on government regulations and the practicality of the turbine site, each type of land has been endowed with a maximum utilization coefficient. It was found that the barren or sparsely vegetated lands have the highest utilization coefficient of 1, then followed by the grasslands, while the wet or frozen lands are not suitable for turbine construction at all. The Chinese Academy of Sciences (CAS) provided the land cover type data with a geographical resolution of 1 km.

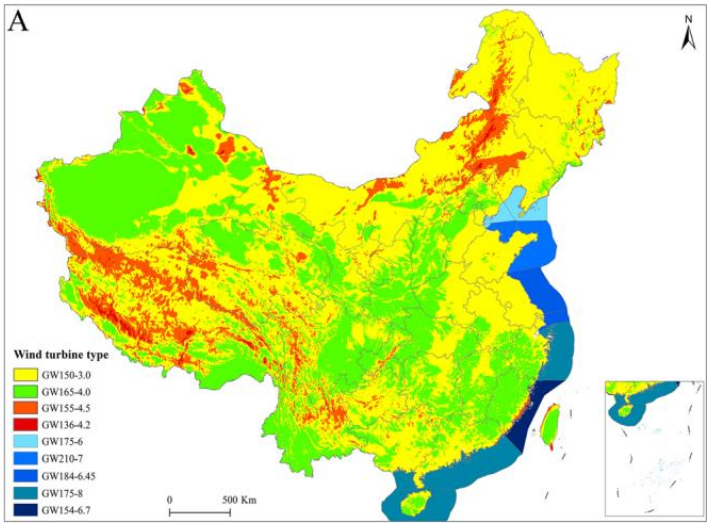


Fig. 3 Spatial distribution of onshore and offshore wind turbine types [7]

3.2. Current Status of Wind Turbine and Capacity Distribution

After determining the placement, one has to install it. Much past data is lost to time, but one can see the capacities increasing at almost an exponential rate. As seen in Figure 4, from the year 2013 to the year 2019, wind power installation in the provinces had been growing rapidly.

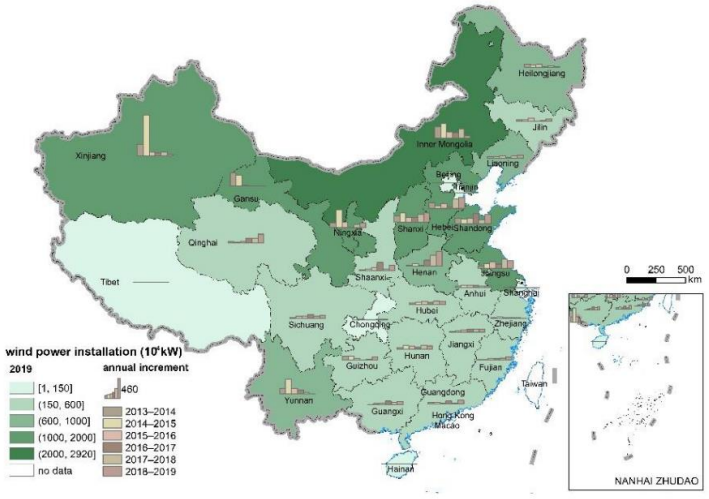


Fig. 4 Types of wind turbine installation in different areas in China [8]

3.3. Influence factor analysis

In conclusion, eastern China has the larger install capacity of wind power systems, with a staggering total of 184,470 MW, or 184.47 GW. On the other hand, western China has a reasonable 134,980 MW or 143.98 GW of install capacity. This mostly comes from Xinjiang and Inner Mongolia [9].

There are a few possible reasons for this conclusion. First, this essay's model of eastern China has more provinces (although there is less total area than western China). This may have benefited eastern China more, although there is really no other choice since if one goes too far east, the provinces cannot be anywhere near being called "western" anymore.

The more probable reason is the advantageous development of eastern China. There is a larger population with many large cities and abundant resources and wealth. As a result, a local government can spare more money on building wind turbines.

4. Wind curtailment in China and evolved wind power distribution

Taking a look at actual data as displayed in Table 3, it can be quite simple to tell that Inner Mongolia, Hebei, and Xinjiang are the top provinces by the capacity of wind turbines installed, with Beijing and Tibet being at the bottom. A handful of conflicts arise from this observation. First, although Tibet is a province with one of the most wind resources, demonstrated in Figure 4, it counterintuitively contains the smallest capacity of wind systems installed. Second, Xinjiang has one of the largest capacities installed, but its wind resources are relatively scarce. The reason for the above conflicts and the Wind curtailment in China will be discussed in this section.

Firstly, Tibet does have a high wind speed and a lot of resources, but the Qinghai Tibet Plateau's wind energy fluctuation should be taken into consideration as it may result in high storage capacity demands that are expensive. Its high elevation and difficult conditions make installing and maintaining wind power systems very difficult. Tibet is, on average, elevated to the point of being 4,380 meters above sea level, making it one of the highest areas in the world. Workers are prone to get altitude sickness at this level, preventing efficient work.

Secondly, Xinjiang is a very flat area of land, which makes it easier for large areas of wind turbines to be deployed. It also has a small population, meaning less architecture is in the way. Furthermore, the Chinese government has been promoting development in Xinjiang, which is one of the more underdeveloped provinces in China, leading to advancements in technology.

Although the statistics and logic support the positive achievements in Xinjiang, northwest China has continued to experience severe wind restriction since 2014, with the amount of wind curtailment being almost half of China's total. This includes Xinjiang and other provinces such as Gansu and Ningxia. It should be emphasized that the low population density, poorly built transportation and electrical transmission system, and significant space for improvement in other basic infrastructure of North-Western China that was implied earlier to be possibly beneficial might also impede the growth of wind energy, necessitating further investment in this area. The impacts of this situation are still an ongoing matter of debate. The rate of wind curtailment is shown in Figure 5.

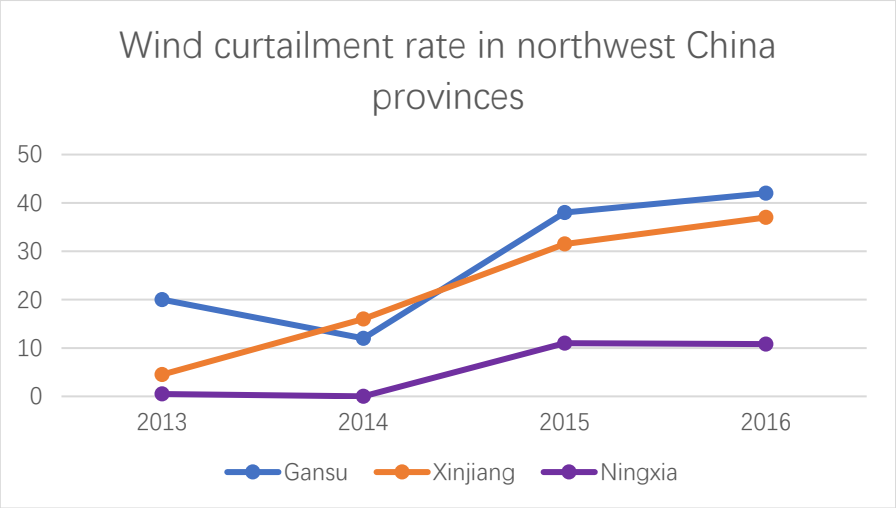


Fig. 5 The rate of wind curtailment in China's northwest provinces [2]

Wind curtailment, in general, is prominent in China and one of the biggest obstacles to China's "carbon neutral" future plans. China's total installed capacity in 2010 reached 44,733 MW, surpassing the total installation in the US, and moving China up to the leading position in the world. Unfortunately, China has subsequently begun to experience wind curtailment, and in 2010 the amount of wind power that was curtailed reached 3.94 billion kWh. Since 2010, the rise of China's wind power has been followed by unsettling wind curtailment [10].

An in-depth analysis of this issue came to the conclusion that the reason for the above problem was the fact that the distribution and supply of wind energy and the mismatch between the power

generated and the real local need. On the other side, the electrical industry is expanding slowly, and many regions of China are experiencing an excess of electricity.

5. Suggestions for future technology development and wind power distribution

Although China has come a long way in terms of its wind power technology, there are still many areas which it can improve in.

The omitting of wind resources in Tibet seems to be unavoidable for the foreseeable future, as the altitude and frequent extreme weather are detrimental obstacles in the way of possible mass installation of turbines. Until technology advances further, the situation in Tibet can only be accepted as reality by the observer.

The serious issue of wind curtailment, most prominently seen in north-western China, can only be solved once the demand and generation are sorted out between the investors and the local government. Market restrictions and geographical segregation are further challenges to wind energy export. It is important to emphasize further that the driving factor behind wind curtailment in northwest China is the low demand compared to the high supply. In such circumstances, it may be wise for the areas with a thriving wind industry to dramatically increase local renewable energy consumption. This might involve encouraging the use of home distributed power systems by creating new trade-in models and promoting the use of excess energy by imposing a negative electricity price. Additionally, more work may be done to strengthen the grid integration and wind power system, particularly by expanding the power transmission lines between different regions that bring wind energy to eastern China's power load core [11].

An interesting method of solving this issue can be the deployment of machine learning programs in wind turbines. They can regulate the wind power generated in order to meet demands and, in turn, control wind curtailment. Although possible, it is definitely costly to develop and deploy.

6. Conclusion

China has seen progression unlike almost any other country in this area of clean energy production in the last two decades. This study listed the different factors in the distribution of the installation of wind system capacities, including available wind resources and landforms. Eastern China was later found to be more extensive than western China, and possible reasons for it were given. These reasons might have been a fundamental problem with region division, or the environment in Tibet prohibiting progression in installation. Although many possibilities were considered, the problem of wind curtailment in provinces such as Xinjiang was brought up as the main candidate. Wind curtailment in northwest China is a serious problem mostly caused by the difference in supply and demand, which can be solved by creating new business models or developing a more advanced way of integrating the turbines into the electrical grid. Other relatively new possibilities are to be considered, but may not be pragmatic solutions considering cost efficiency.

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