BBChina

Master Program
on Bio-Based Circular Economy

Course of Renewable Energy Technologies

Wind energy in China

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Catalog

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1. Background

Since the beginning of the 21st century, the global population and economy have continued to grow, the world's energy demand has grown strongly, the competition for oil and gas resources is fierce, the pressure on the ecological environment has increased, and global climate change has attracted much attention. Green, low-carbon and sustainable development have become the science of the continued prosperity of human civilization. Rational choice. Humanity has entered the era of knowledge networks, and energy as the cornerstone and driving force of human modern civilization is also facing new changes. The energy field has a development law of large investment, long cycle, multiple connections and strong inertia. Energy is not only an economic resource, but also a political resource and a strategic resource. The issue of energy security is highly valued by the state. The next two to three decades will be a crucial period for the reform and transformation of energy production and consumption patterns and energy structure. People will work to build a sustainable energy system that is green, low-carbon, efficient, intelligent, and diversely shared. Renewable energy sources such as wind energy will grow rapidly, thus forming a new energy structure with five pillars as natural gas, oil, coal, nuclear energy, and renewable energy [1].

Wind is a phenomenon of airflow caused by solar radiation. It is a gift from nature. It is one of the earliest energy consciously used by humans. As early as 2000 years ago, ancient Egypt, China, Babylon and other regions had begun to use the wind to lift water, irrigate, grind, and transport. In the 2nd century AD, the ancient Persians invented the wind tower whose axis of rotation was perpendicular to the ground, which greatly improved the efficiency of workers' labor. When the time came to the 11th century AD, a modified rotating vertical windmill was introduced into Byzantium. Later, with the Crusades, it was introduced to European countries along the Atlantic coast in the 13th century AD. Since then, windmills have also appeared in various parts of the world, playing different roles. When the time came to the 18th century, the advent of the Industrial Revolution was accompanied by the emergence of steam engines. Since then, efficient steam engines have completely replaced windmills. In the 1880s, an American named Charles F. Brush created the world's first automatic fan for generating electricity, which also opened the era of "three steps" from wind energy to mechanical energy.

Wind energy is a rich and clean new energy source. Its biggest feature is renewable, pollution-free, large reserves and wide distribution. Except for routine maintenance, it does not need to consume other energy, which is an ideal new energy. Since the birth of the world's first wind turbine in 1888, after more than a century of development, wind power technology has become more mature. China has a vast territory, and its energy endowment is characterized by "more coal, lean oil, and less gas." Wind energy and other renewable energy sources will play an important role in promoting the optimization of energy structure. Through reading some documents, China's wind energy resources are very rich and widely distributed, and the total amount is sufficient to meet the needs of China's social production and life. As the main form of wind energy application, wind power generation has become the first choice of renewable energy-power-generation technology in recent years, and its position in the national energy development strategy has become increasingly prominent. Wind power generation has the advantages of low carbon, clean, high efficiency, etc., and it has an important help for the country to optimize the energy structure and improve energy security, so it is widely used worldwide [2]. After decades of development, the current wind-power-generation technology has matured and costs have fallen rapidly. In the near

future, the technology and economics of wind power generation will reach the level of conventional energy, and promote the development of energy reform and transformation.

Any human activity will have an impact on the ecology. From the perspective of magnitude, wind power has little impact on the ecology, and compared with fossil energy, wind power is a clean energy friendly to the environment. For the construction of wind power plants, the cost is lower than other energy wind power plants, and in the process of operation, no other energy consumption is required, and it will not cause changes to the surrounding geographical environment. Wind power has been valued by various countries. In China, it has become one of the important components of China's sustainable development strategy.

2. A short description of the technologies

2.1 Principles of wind power generation

The process of wind power generation is the process of converting wind energy into electrical energy through mechanical energy. The wind wheel realizes the process of converting wind energy into mechanical energy, and the wind generator and its control system realize the process of converting mechanical energy into electrical energy. After the wind enters the power generation system, it is used as the input signal of the power generation system, and the pitch angle signal is output through the wind controller to adjust the mechanical torque and output power. The mechanical power is then transmitted to the generator converted into electrical energy and finally transmitted to the grid. Completing the entire process from wind energy to electrical energy conversion [3]. The generator plays a vital role in the process of wind power generation. It not only affects the efficiency of energy conversion at this stage, but also affects the operation efficiency and mechanical structure of the wind turbine. Improving the level of wind power generation, making the conversion efficiency of wind power generation higher, operating more reliable, and providing higher quality of electrical energy is a main direction of the development of wind-power-generation technology [4].

2.2 Wind power generation technology

At present, the relatively mature wind-power-generation technology is divided into two categories: constant speed constant frequency power generation technology and variable speed constant frequency power generation technology [5]. Here are the differences between the two technologies: (a) the constant-speed constant-frequency power generation technology mainly consists of a generator, a variable-speed gearbox and a transformer. When the wind speed changes, the speed ratio of the variable-speed gearbox is adjusted to keep the wind turbine generator at a constant speed and achieve a constant frequency of the generated electrical energy. This structure is relatively inefficient due to the presence of gearboxes and other equipment. At the same time, wind induction generators of this structure generally choose induction asynchronous motors, so a reactive power compensation device needs to be installed and the output power is also uncontrollable. Therefore, the wind-power-generation technology of this structure has been gradually reduced. (b) At present, the variable speed constant frequency-power generation technology is mostly used, which has become the key technology of domestic research. Wind energy is random and non-directional. The variable-speed constant-frequency power generation technology can adjust the rotation speed of the generator as the wind speed changes to achieve maximum power. At the same time, due to the maximum power tracking, the system can better adapt to sudden changes in wind speed and the system is more stable. The speed of the motor is further controlled by means such as vector control, and finally, through the

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adjustment of power electronic equipment, a constant frequency current is obtained. This technology not only can achieve higher power conversion efficiency, but also suppress harmonics in a certain sense, and increase the stability of power grid connection. Although this power generation technology uses relatively complicated power electronic devices in the wind-power-conversion device, which increases part of the cost, it accounts for a very small proportion in the entire wind power generator set. Therefore, variable-speed constant-frequency power generation technology is highly feasible for the development of wind power. Scholars should study the variable-speed constant-frequency power generation technology in more depth. At present, the variable speed constant frequency-power-generation system is mainly divided into three types of multi-speed increase, semi-direct drive, and direct drive according to the speed. The corresponding gearbox types are high-speed gearbox, medium-speed gearbox, and no gearbox. The direct-drive wind power system has attracted the attention of many scholars at home and abroad. In the wind-power-generation system of this structure, the complicated variable speed gearbox is eliminated, the generator is directly connected to the shaft of the wind generator set, and the rotor speed changes with the wind speed [6].

2.3 Key issues of wind power technology

1) Wind power quality issues

On the one hand, although natural wind resources have greater energy, their properties are more variable, mainly represented by unstable wind direction and speed. In the traditional way, people use the inertia of the wind wheel to analyze the stability of the output power of the wind turbine. However, this method will form harmonics and reduce the power output to the grid. On the other hand, when the integrated capacity in the power grid meets the rated capacity, the voltage stability will be reduced. If there is a problem in the power grid, the unstable voltage will prevent the unit from effectively delivering energy to the power grid and cut off the protection action. The power grid directly causes the instability of the power grid.

2) The wind turbine cannot be developed

Compared with western developed countries, China's wind turbine components still have a large gap. For example, parts such as slip rings need to be imported from abroad, which makes it difficult for China's wind turbines to be installed and designed locally. . At the same time, in the management and consultation of wind turbines, it has not formed an industrial chain, and the system is not perfect, which has a greater impact on the development of wind power generation [7].

3) Low security

At present, due to the poor management of wind power enterprises, the lack of understanding of employees' ideas and the lack of professional level, etc., no attention has been paid to the safety of wind power operations. In the maintenance and inspection of wind turbines, over speed tests, emergency shutdown tests, and vibration tests have been ignored. Such contents make the unit lack of maintenance and inspection, and its reliability is reduced.

4) Defects in control technology

In mechanical control, the blades of China generally use the NANC series of the United States. Although it has good power performance, due to the effect of the wind speed and working conditions of the wind wheel, the uneven force of the wind wheel is rotating. Instability and

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repeated changes will occur during the process, causing the wind turbine to vibrate and form a large noise.

2.4 Solutions to problems

1) Improve the quality of wind power

In order to improve the quality of wind power, superconducting energy storage technology can be used to keep the frequency and output voltage of wind turbines stable. This technology is a brand-new flexible AC transmission technology, which has the advantages of no pollution, high power and long life. It has the effect of releasing and absorbing reactive or active power, which in turn makes it meet the requirements of the power system [8].

2) Improve the mechanical structure

To improve the mechanical structure, we can start from the following two aspects: First, we can use advanced driving equipment to combine the gearbox with the main rotating shaft, etc., reduce the use of unit components, and thus greatly enhance the work efficiency of the system, safety, stability, and reduce the economic expenditure of component installation and maintenance. Second, it can optimize the structural dynamic design of the machine, prevent the load of the mechanical structure from being affected by the change of wind, and reduce the stress on the components, reduce the weight of the entire unit and components, and greatly reduce the cost.

3) Improve safety performance

In order to enhance the safety of wind turbines, it is necessary to carry out over speed tests on wind turbines to detect over speed protection actions, over speed channels, over speed modules, and over speed sensors. At the same time, it is also necessary to carry out an emergency shutdown test on the wind turbine to test whether the mechanical brake, backup power supply, and slurry circuit can work normally. In addition, it is necessary to conduct a vibration test on the wind turbine to check whether the protection actions, protection channels, and protection measurement components are working properly to ensure the safety of the unit [9].

4) Improve control technology

For the problem of easy interference and instability of wind-power-generation system, it is generally solved by the method of system model control, but this method has certain limitations, so it is limited to a specified period of use of a system, and it is difficult to effectively prevent energy convert the changes produced in multiple processes. Under the environment of wind farm operation, wind turbines have unattended operation, so they have higher requirements for system control. The use of an adaptive controller allows the wind turbine to be optimized for its power factor within the maximum range. Its working principle is to measure the input and output of the system, analyze the parameters needed in the control process, and use the control system to start the control. Compared with the original controller, the performance of the adaptive controller is better optimized, and the performance is greatly increased. It constructs an accurate mathematical model to control the electrical power of the wind turbine, thereby controlling it more efficiently and saving costs.

2.5 Development trend of wind power technology [7]

1) Power generation by offshore wind turbines

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The focus of wind turbine technology is on offshore installations. The offshore wind energy resources are abundant, and the wind speed is relatively large, which is suitable for the installation of high-power wind turbines. Choose to install wind turbines in shallower waters. Offshore wind turbines can produce greater energy, more than double the power generated onshore. If you want to better solve the connection problem between the wind farm and the electric valve, you need to adjust the power transmission system through the air circulation of heat, which can better transfer the electricity to the load center.

2) Intelligent operation and maintenance wind farm in deep sea

The operating environment of wind turbines in deep-sea areas is very special, lacking experience in operation and maintenance, high cost of operation and maintenance, and high potential failure rate of the unit, which requires an integrated wind-farm-climate environment. Comprehensive analysis is carried out from various aspects such as ship scheduling, personnel scheduling, spare parts management, equipment status monitoring and so on. Guided by lean thinking, carry out intelligent and centralized operation and maintenance management. The intelligent wind farm in the deep-sea area mainly lies in the following two aspects:

- Intelligent and centralized wind farm equipment monitoring

The monitoring of wind farms in deep-sea areas uses centralized and remote monitoring methods. Through intelligent monitoring methods, scientifically using the advantages of big data, there are few duty workers at the centralized control headquarters, and the centralized control department commands to manage the wind farms. Costs and waste of operation and maintenance time due to unscientific staffing and decision-making errors.

- Transparent, online spare parts, equipment, operation and maintenance personnel control

Equipment data is very important in the operation and maintenance management of wind farms. Using information technology and big data thinking methods, it is possible to develop transparency, update management and control of equipment maintenance, inspection and other information, and share it with other information to carry out the full life cycle management of wind turbines. Spare parts management will have a direct impact on the availability and operation and maintenance time of wind turbines. Scientific spare parts reserve can prevent the loss of wind turbine generating capacity due to lack of spare parts. Through the intelligent operation and maintenance platform, the transparent and online transmission of spare parts information is carried out, the number of spare parts stored is determined according to the actual wear and tear status of spare parts, and unified management is carried out.

In summary, the development of wind power quality, mechanical structure and unit control technology is an important development direction of wind-power-generation technology. In addition, based on the status of power grid operations and the long-term benefits of large-scale development of wind power, the improvement of wind-farm-output power controllability is also an important factor affecting wind power technology. To better, solve the problems, in the future we need to strengthen the research of wind power technology, and promote the better application of wind power technology in the commercial development according to the renewable energy development policy [10].

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3. Overview of wind energy resources in China

3.1 Overview of Chinese wind resources

China has a vast territory and a long coastline, with a land area of about 9.6 million square kilometers and a coastline (including islands) of 32,000 kilometers. It has rich wind energy resources and has huge potential for wind energy development [11]. Wind energy resources depend on the wind energy density and the annual cumulative hours of available wind energy. The wind energy resources are greatly affected by the terrain. According to estimates from more than 900 meteorological stations across the country, the height of the ground is 10m above the ground. The national average-wind-power density is 100W/m^2, and the total reserves of wind energy resources are about 3.226 TW, which can be developed and used. The onshore wind energy reserves are 253 GW, and the offshore wind energy reserves that can be developed and utilized are 750 GW, totaling about 1 TW. If the annual on-grid electricity of onshore wind power is calculated at an equivalent full load of 2000h. It can provide 500 TWh of electricity per year, and the annual on-grid electricity of offshore wind power is calculated at an equivalent full load of 2500h, which can provide 1.8 trillion kWh of electricity each year, a total of 2.3 trillion KWh power. China is rich in wind energy resources and has huge development potential, which will surely become an important part of the future energy structure [12].

3.2 Regional distribution of wind energy resources [11]

China is a windy country, but the distribution of wind energy resources in China is not uniform. It is mainly affected by geographical location and terrain factors. Regions rich in wind energy resources are mainly concentrated in the southeast coast and nearby islands and in the north (northeast, north, and northwest) regions. There are also some relatively abundant inland wind energy resources. In addition, offshore wind energy resources are also very rich. The distribution map of China's wind energy resources is shown in Figure 1.

a) Wind energy resources on the southeast coast and nearby islands

The coastal and inland areas include Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi, and Hainan provinces (cities), nearly 10 kilometers wide, with an annual wind power density of more than 200 watts/square meter. The line is parallel to the coastline.

b) Wind energy resources in the northern region

The northern region is rich in wind energy, including three provinces in Northeast China, Hebei, Inner Mongolia, Gansu, Ningxia and Xinjiang. The wind power density is above 200-300 watts/square meter, and some can reach over 500 watts/square meter, such as Alashankou, Dabancheng, Huitengxile, Huitengliang, Xilinhot's gray beams, Chengde paddock, etc.

c) Inland wind energy resources

Wind power density is generally below 100 W/m2, but in some areas due to the influence of lakes and special terrain, wind energy resources are also abundant.

d) Offshore wind energy resources

The eastern coastal water area is 5-20 meters deep, but it is limited by marine function zones such as shipping routes, ports, and aquaculture. The actual offshore wind energy resources that can be developed by the actual technology are much smaller than those on land are. However, in places like Jiangsu, Fujian, Shandong, and Guangdong, offshore wind energy resources are abundant and very close to the power load center. Offshore wind power can become an important clean energy for the future development of these areas.

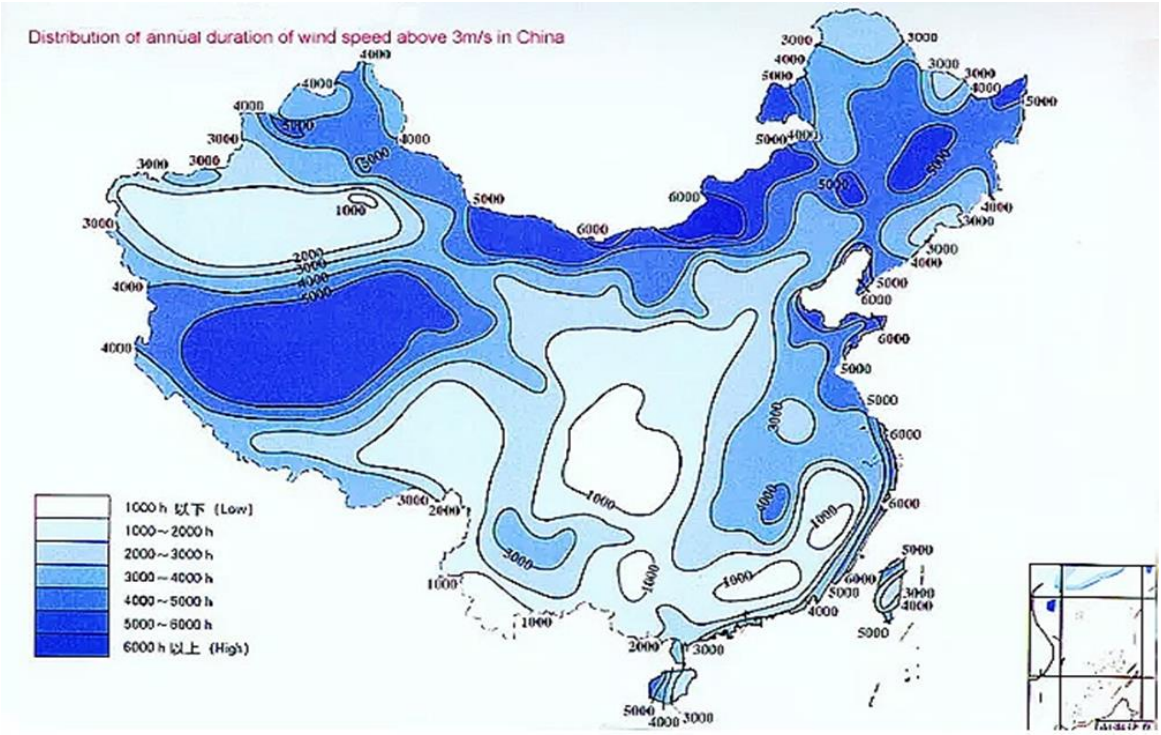

Figure 1. Distribution of wind energy resources in China

3.3 Development status of China's wind power industry

At present, China has become the world's largest and fastest growing market for wind power. The period of formal explosive growth of China's wind power industry is in the "Eleventh Five-Year and Twelfth Five-Year" phase (2006-2015). Domestic wind turbine manufacturers gradually mastering the design and mass production capacity of megawatt units and 2016 accompany this stage. The promulgation and implementation of the "Renewable Energy Law of the People's Republic of China" ushered in a golden development period for the wind power industry. By the end of 2015, the cumulative installed wind power capacity of the country reached 145GW, with a compound annual growth rate of more than 100%. Especially in 2015, the newly installed capacity of wind power nationwide reached 30.75 GW, and Gold wind Technology achieved the world's first new installed capacity that year. By 2016, the National Development and Reform Commission clearly put forward the 13th Five-Year Plan for wind power construction, requiring "by the end of 2020, the cumulative installed capacity of wind power will be guaranteed to exceed 210GW, of which the installed capacity of offshore wind power will be more than 5GW." [13] Following the record wind power generation in Europe and India in 2017, the two markets shrank in 2018, but several other regions and countries saw significant growth. In the past ten years of development, Asia is the largest market, accounting for about 52% of the global market, China is the fastest growing, and both onshore and offshore wind power is developing rapidly, followed by the United States, Germany, India, Brazil and the United Kingdom [14].

In 2019, the newly installed wind power capacity in the world exceeded 60 GW, ranking the top five in market share. Compared with 2018, it has increased by 19%, and the total installed capacity will reach 650 GW, a year-on-year increase of 10%. The five markets with the largest installed capacity in the world in 2019 are China, the United States, the United Kingdom, India and Spain. These five markets together accounted for 70% of global sales last year. as shown in picture 2.

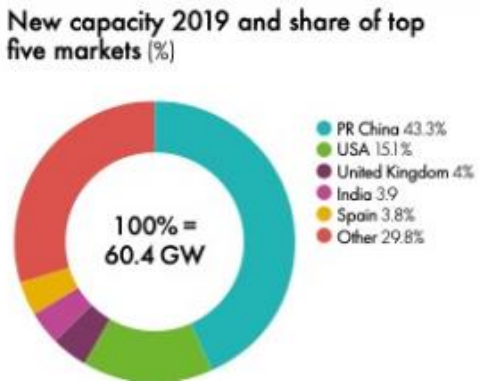

Figure 2. Top five market and proportion

The cumulative installed capacity of the global onshore wind power market reached 621GW. The newly installed capacity reached 54.2 GW; the cumulative installed capacity of the global offshore wind power market reached 29.1GW, and the newly installed capacity exceeded the milestone of 6 GW, accounting for 2019 global new installed capacity 10% of capacity is the highest level to date. As shown in Figure 3 [15].

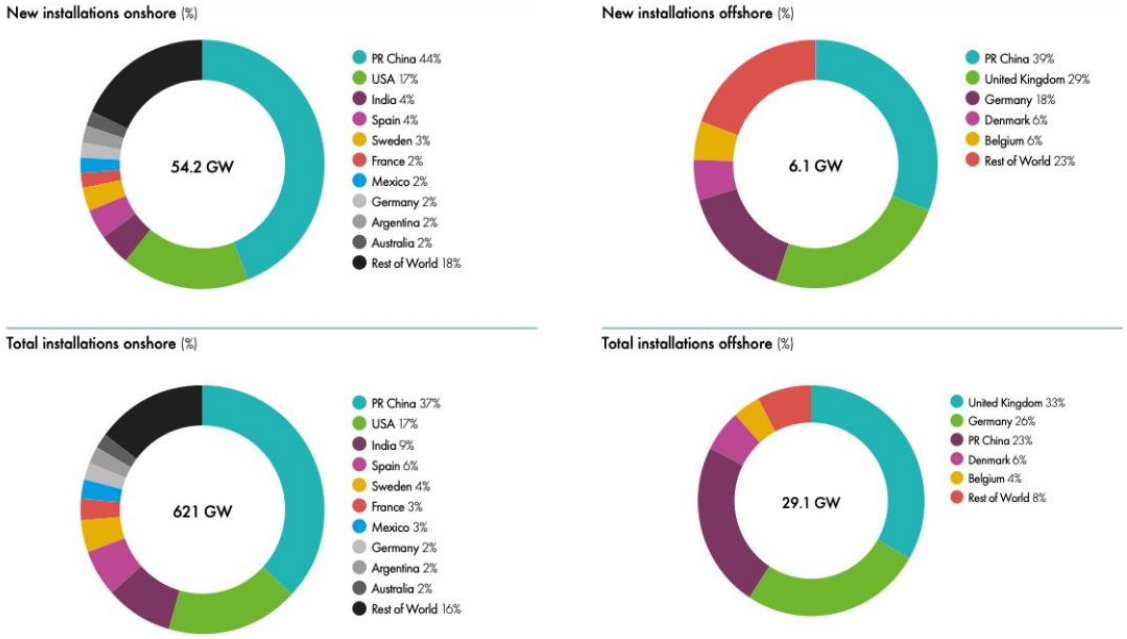

Figure 3. New installation onshore and offshore, total installation onshore and offshore

According to the statistics of China's new and cumulative wind power installed capacity from 2008 to 2019, as of the end of 2019, China's cumulative wind power grid-connected capacity is close to 240GW (global cumulative installed capacity reached 621.3GW), while in 2008 China's cumulative wind power capacity in 2008 It is 12GW. The new and cumulative installed capacity of wind power in China from 2008 to 2019 is shown in Figure 4 [13].

China's installed wind power capacity has ranked first in the world for 10 consecutive years, and wind power has become the third largest source of electricity after thermal power and hydropower in China. It is estimated that the wind power industry will be affected by the deadline for onshore wind power subsidies in 2020, and the new installed capacity will reach more than 35GW [13].

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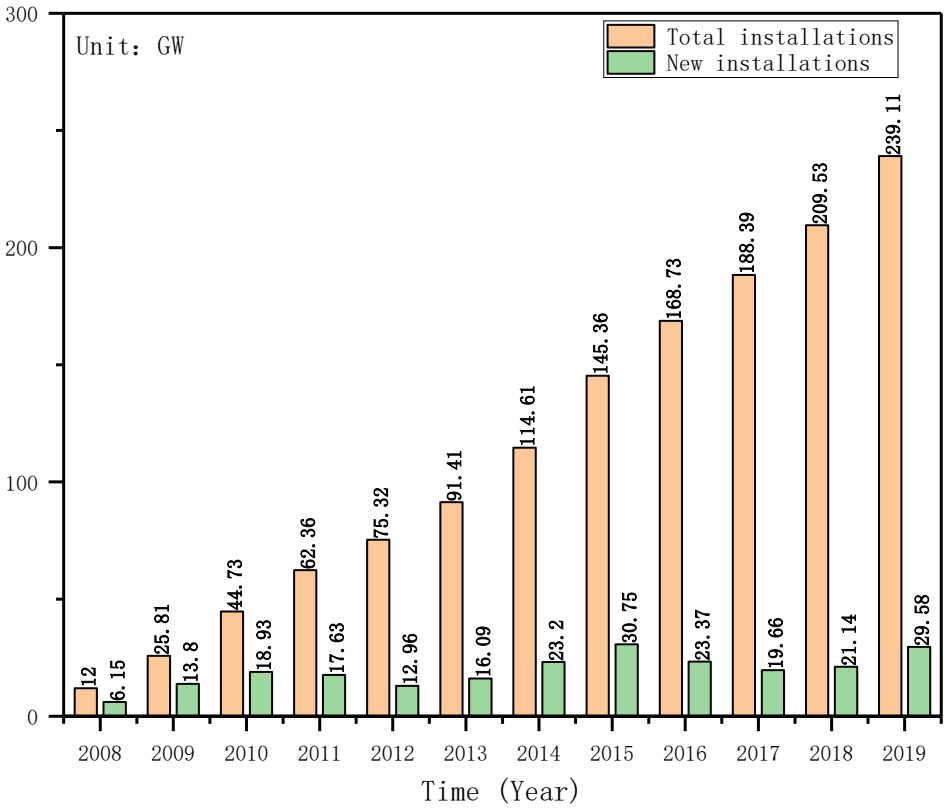

Figure 4. China's new and cumulative wind power installed capacity from 2008 to 2019

With the rapid development of China's wind power industry, the development speed of offshore wind power is faster than the overall development speed of the wind power industry. According to statistics from the China Wind Energy Association, in 2016, China's offshore wind power installed 154 new installations, with an additional installed capacity of 0.59GW, with a cumulative installed capacity of 1.63 GW, a cumulative increase of 56.73%. In 2017, China's offshore wind power installed capacity increased to 319 units, with a new installed capacity of 1.16 GW. The cumulative installed capacity reached 2.79 GW, and the cumulative installed capacity increased by 71.17%. In 2018, the newly installed capacity of offshore wind power in China was 1.65 GW, and the cumulative installed capacity was 4.44 GW. The cumulative installed capacity increased by 59.14%. The specific changes can be seen from Figure 5. According to the "13th Five-Year Plan for Renewable Energy" of the National Energy Administration, by 2020, offshore wind power will start construction of 10GW, and ensure that 5GW will be completed[16].

From the perspective of wind power structure, by the end of 2019, the cumulative installed capacity of wind power in the China is 233 GW, and the total installed capacity of onshore wind power accounts for 204 GW, accounting for 97.5%; the cumulative installed capacity of offshore wind power is 5.93 GW, accounting for 2.5%. China's offshore wind power development has made remarkable achievements, gradually narrowing the gap with the mature European market. At the same time, we must also be soberly aware that China's offshore wind power development is still in its infancy and growth stage. In the face of the vast offshore wind power market, we still need to continue to find gaps and continuously improve the quality of development.

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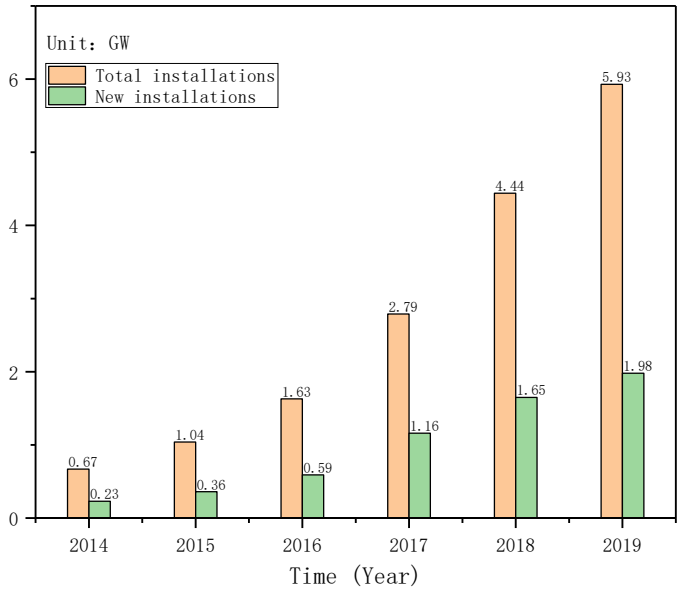

Figure 5. China's cumulative and newly installed offshore wind power capacity 2014-2019

3.4 Comparison of power generation capacity among China's power generation industries in recent ten years

In 2019, the power production and supply capacity will continue to improve, and the structure will be further optimized. From the perspective of electricity generation structure, China's wind-power-generation capacity was 135.7 TWh in 2013, and by 2019, it was 405.7 TWh, accounting for 5.4%. In just 6 years, it has grown three times as much as in 2013. In general, the proportion of wind power generation in the total composition of national electricity generation increased year-by-year.

The statistical chart of China's wind power generation from 2013 to 2019 is shown in Figure 6, and the composition of the national total power generation from 2009 to 2019 is shown in Figure 7.

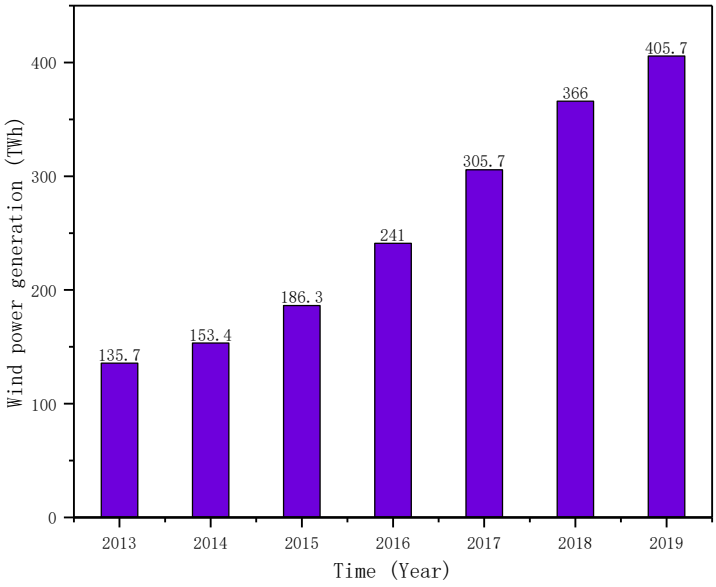

Figure 6. Statistical chart of Wind power generation in China from 2013 to 2019

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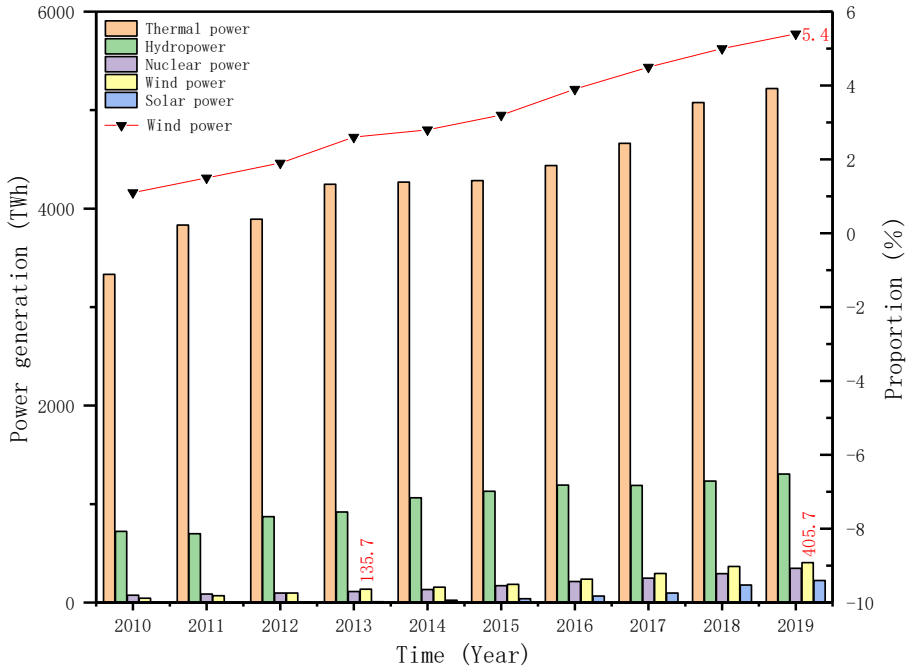

Figure 7. Composition of national Total power generation from 2009 to 2020[17]

3.5 Comparison of installed capacity among different regions in China

In 2018, the proportion of newly installed wind power capacity in the six regions in China is as follows: Central South China (28.3%), North China (25.8%), East China (23%), Northwest China (14.2%), Southwest China (5.5%) and Northeast China (3.2%).The "three northern regions" accounted for 43.2% of new installed capacity, and the southern Middle East for 56.8%.Compared with 2017, central and southern China had a faster growth in 2018, with a year-on-year growth of 33.2%. The main growth provinces in central and southern China are Henan, Guangxi and Guangdong. Meanwhile, the installed capacity of northeast China, North China and East China all increased with year-on-year growth of 29.9%, 8.2% and 9.3% respectively. However, the installed capacity of the northwest and southwest regions declined, with the southwest region dropping 33.8 percent and the northwest region dropping 1.5% year-on-year. Figure 8, 9, 10 shows the new installed capacity, the proportion and the distribution of each region in 2018[18].

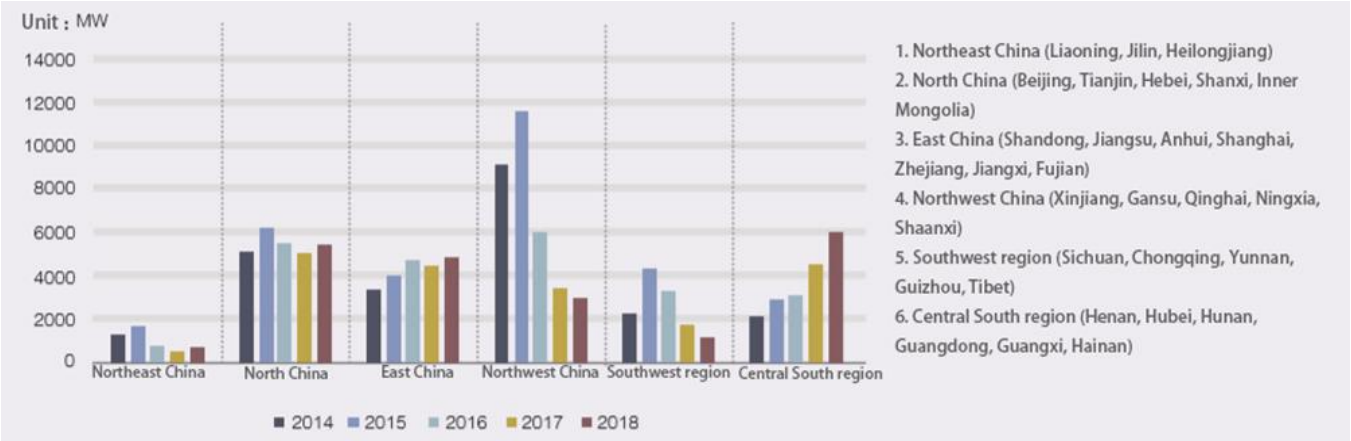

Figure 8. Trends in new installed wind turbine capacity in various regions of China from 2014 to 2018

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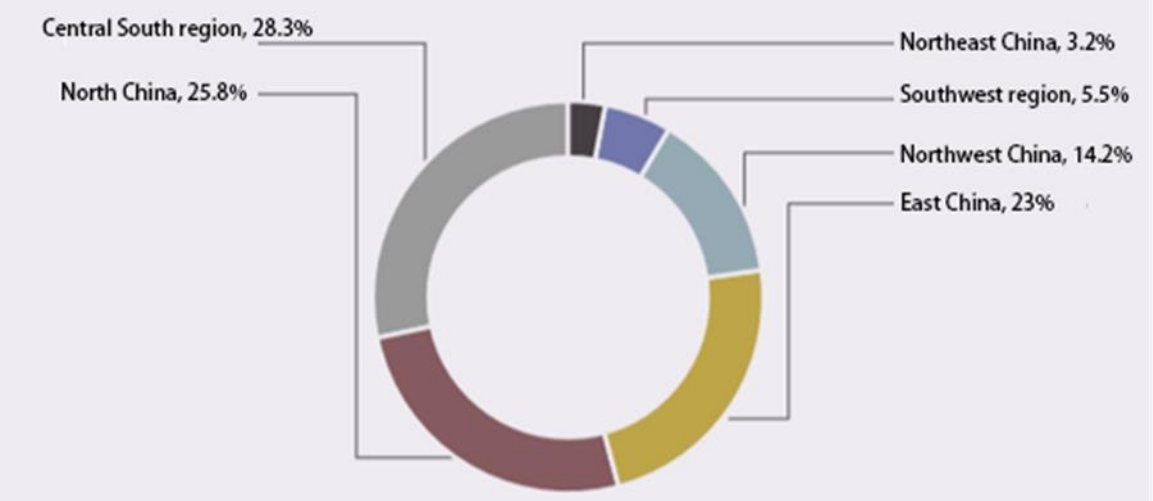

Figure 9. Proportion of installed wind turbine installed capacity in all regions of China in 2018

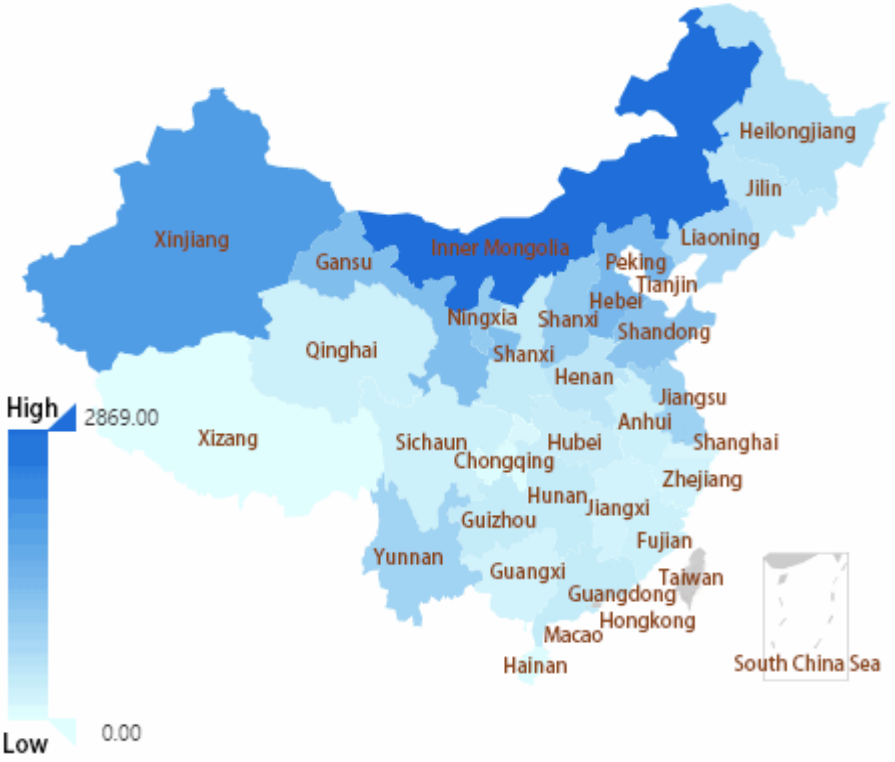

Figure 10 Cumulative wind power installed capacity of each province (region and city) in China as of the end of 2018

3.6 Market share of Chinese manufacturers [19]

The newly increased hoisting capacity in China in 2019 is 29.58GW, compared with 21GW in 2018, an increase of 8.44GW, with a year-on-year growth of 40.85%. In 2019, China's wind power market has the top 10 new installed capacity records, as shown in Table 1. Among them, the newly increased hoisting capacity of Gold wind Technology reaches 8.01GW, and the market share reaches 28%; They were followed by Vision Energy, Mingyang Intelligence, Yunda Wind Power and Shanghai Power & Gas, with a combined market share of 76% for the top five.

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Table 1. New lifting capacity and market share of major wind turbine manufacturers in the Chinese market in 2019

Rank	Company	New lifting capacity (GW) in 2019	China market share in 2019
1	Goldwind Technology	8.01	28%
2	Vision Energy	5.42	19%
3	Mingyang Smart Energy	4.50	16%
4	Yunda Wind Power	2.06	7%
5	Shanghai Electric	1.71	6%
6	CNOOC	1.46	5%
7	Dongfang Electric	1.42	5%
8	Guodian United Power	1.08	4%
9	Xiangdian Wind Energy	0.77	3%
10	China Zhuzhou Institute	0.65	2%
Others (including foreign manufacturers)		2.50	6%

a. Goldwind Technology

With obvious advantages, Goldwind technology has been ranked the first for a consecutive year. In 2019, the newly increased hoisting capacity reached 8.01GW, and onshore wind power is still its main wind power market, with the installed capacity of onshore wind power exceeding 90% of its total installed capacity. But its market share fell slightly, from 32 per cent to 28 per cent, to 4 per cent.

b. Yuanjing Energy Co., Ltd.

Yuanjing Energy's new lifting capacity in 2019 reached 5.42GW, and its market share increased from 17% to 19%, a year-on-year increase of 47%, and it was firmly in the runner-up. 97% of its 675MW offshore wind power's new hoisting capacity comes from Jiangsu Province.

c. Mingyang Smart Energy

Mingyang Smart Energy's newly added hoisting capacity is 4.5GW in 2019, ranking third, with a 78% increase compared to 2018. The market share rose from 12% to 16%, an increase of 4%. The effect of offshore wind power generation is remarkable, and its new hoisting capacity has increased sixfold since 2018 to 559MW.

3.7 Market share of Operating companies in China

The top ten of the cumulative installed capacity of wind power operating companies in 2018 were Guoneng Investment, Huaneng Group, Datang Group, Guodian Investment, Huadian Group, China Guangdong Nuclear Power Corporation, China Resources Group, Tianrun, China Power Construction and Three Gorges Group. More than 140 GW, accounting for 70% of the national installed capacity. As of the end of 2018, the cumulative installed capacity of Chinese wind power development companies is shown in Figure 11. They are the main force in the wind power industry and play an important role in the development of China's wind power industry. In view of the

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background of state-owned enterprises, they tend to be stable in their business style, and there will be no chaos in the development of photovoltaics under the background of rush installation [19].

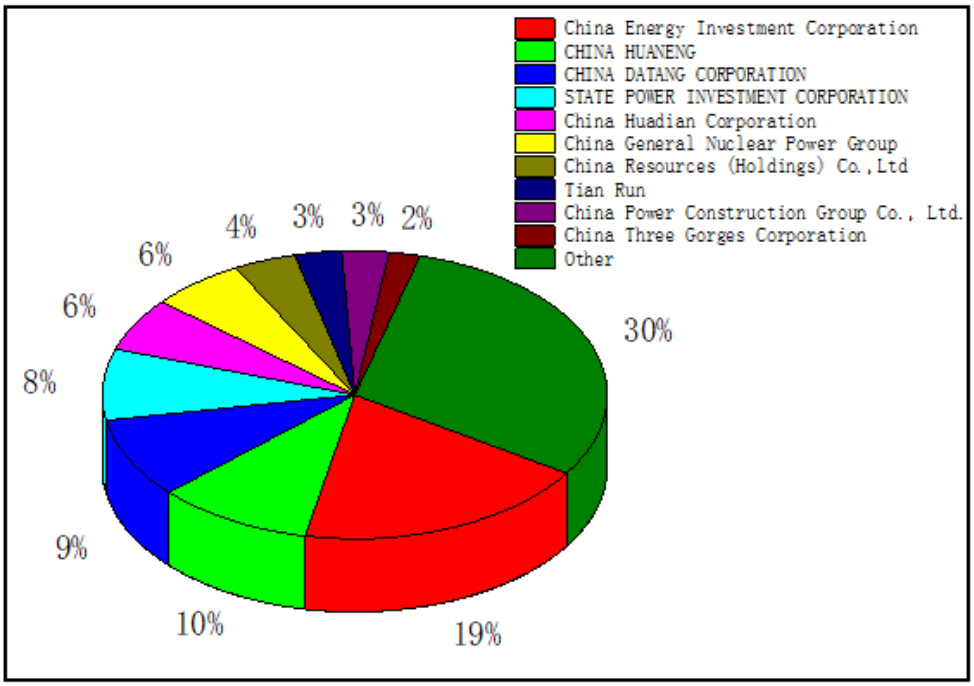

Figure 11. Cumulative installed capacity of Wind power developers in China as of the end of 2018

4. Strength and weaknesses of the studied scenarios

4.1. Strength

a) Cleanliness. The use of wind power to convert wind energy into mechanical energy and then into electrical energy is clean and pollution-free, and will not produce greenhouse gases and pollutants. Compared with the traditional conventional thermal power generation through coal-fired power generation, wind power generation can reduce the emission of greenhouse gases and pollutants, and has good environmental benefits.

b) Renewability. Wind energy resources are renewable energy and a form of conversion of solar energy with inexhaustible characteristics, without worrying about resource exhaustion.

c) The reserves are huge. According to the results of the 3rd census of wind energy resources of the National Meteorological Administration, the total reserves of wind energy resources at a height of 10 meters from the ground on China's land reached 4.35 TW, the technically developable volume was about 297 GW, and the technically developable area was about 200,000 km^2. In 2007, the Meteorological Administration of China used numerical simulation technology to calculate the area of wind power density greater than or equal to 400W/km^2. It is concluded that the theoretical exploitable amount of wind energy resources at a height of 50m from the ground in China is 2.68 TW, and the theoretical developable area is 540,000 km^2. The Energy Research Institute of the National Development and Reform Commission, in accordance with the “National Comprehensive Survey of Coastal Zone and Tidal Flat Resources” and the “National Marine Functional Zoning”, is avoiding sea areas for port shipping, fishery development, tourism and engineering planning, as well as 60 specially allocated waves for development. In the utilization

area of ocean energy such as electricity and tidal current, and considering that 20% of the total sea surface can be used, the installed capacity of offshore wind power is about 150 GW.

d) Wind energy resources are widely distributed. The three north areas of China (northeast, north, northwest) are relatively flat, and the wind energy resources are very rich; the southeast coast is affected by the Taiwan Strait. When the cold air goes south, the narrow tube effect makes the wind speed increase, making this area very rich in wind energy resources. The islands near the Taiwan Strait are also rich in wind resources. In addition, some provinces in the interior of China still exist-some areas with rich wind energy resources, such as river valleys, mountainous areas, and lake areas, are connected into a piece of land and distributed in islands.

e) Wind farm construction has low land requirements. Wind power plants can be constructed on land that is difficult to use in agriculture, such as desert Gobi, sparse grasslands, coastal beaches and waters, and the cost of land use is low.

f) The operation of the device consumes few resources. In addition to the manufacture and installation of wind power equipment, during operation the wind turbine does not require additional equipment to provide power and consume other resources.

g) The wind power industry can promote local economic development. The development of wind energy can form a clean energy industry and promote economic development in less developed regions. Large-scale wind farms will also form unique cultural landscapes and develop tourism for tourists to visit.

4.2. Weaknesses

From the perspective of industrial layout, there are three main problems [21]:

a) Heavy wind farm construction, supporting light industry. Taking Jiangsu as an example, Jiangsu has made great efforts in developing downstream wind farms. According to the Jiangsu Province onshore wind-farm-project plan, by the end of 2015, the onshore wind power installed capacity is planned to be 3 GW. This plan has been completed, and the only areas that have not yet been opened are low wind speeds. This is inseparable from the strategy of developing wind farms as the focus of development in all coastal areas of Jiangsu. All regions generally adopt the strategy of "replace equipment with resources", and pay less attention to attracting wind power manufacturing enterprises and building wind power supporting industry chains, and insufficient advancement has caused that there are few wind power resources available at present, making it difficult to form a wind power equipment manufacturing enterprise. A large-scale settlement and large-scale development.

b) Heavy parts production, light machine manufacturing. Based on Jiangsu's good manufacturing foundation, there are currently many wind power accessory companies that manufacture high-speed gearboxes, fan blades and other components, but in the field of machine manufacturing, the foundation is still relatively weak, only a few companies such as Huarui Enterprises can produce wind turbines.

c) Reintroduce assembly and lighten independent research and development. At present, most of the wind turbine manufacturing enterprises in Jiangsu mostly import parts and components from overseas and assemble them locally. They only play the role of a "processing plant", especially lack of core technology and lack of scientific and technological content. A complete set of industrial chains from independent R&D and testing to complete machine production,

assembly and commissioning, lacking the core competitiveness of complete machine development and manufacturing.

From the perspective of industry development status, there are three main problems [21]:

a) Market competition is fierce, and mutual price reduction is obvious. Due to the good wind resources and strong power grids in Jiangsu, the local government has given greater support to the wind power industry in the past few years. Under the leadership of the group, various wind power developers have invested heavily in robbing resources. The direct consequence is that today's market competition has formed. With the intensification of the wind, there is a phenomenon of mutual price reduction among wind-power-equipment manufacturers, and no enterprises can obtain the maximum benefit. Taking small wind turbines as an example, due to intensified competition, the price of 1.5MW wind turbines of a company in Nanjing has dropped significantly, from 400,000 yuan per unit in February 2013 to less than 300,000 yuan.

b) Some wind power development projects have low profitability. The early development projects of wind power in Jiangsu and other provinces in China adopted the concession project method of tendering and bidding. The developer who can provide the lowest on-grid electricity price won the bid. The winning developer is responsible for the investment, construction, operation and maintenance of the wind power project. The government and the bid development The power supplier signs a power purchase agreement to ensure that all power is purchased at the bidding price within the prescribed period. According to the current electricity pricing policy of the National Development and Reform Commission, the price of land-based wind power projects is 0.6 yuan/kWh, the land-based electricity price of concession projects that were tendered early still continues to the standard of 0.49 yuan per kWh, and the profit pressure is very great. At present, most of these concession projects are located at the critical point of profit and loss, and some even lose money.

c) It is difficult for some enterprises to withdraw funds, and liquidity pressure is greater. Due to the difficulty of financing for some wind power companies and the tight funds, it directly affects the return of funds from upstream wind power equipment manufacturing companies. According to the surveyed company, there are almost no direct payment methods by cash or bank deposits for downstream companies. Generally, they are paid by acceptance. Due to time constraints, the company’s capital return is affected. Generally, this increases the operational risk and capital pressure of wind-power-equipment companies.

From the perspective of wind-power-generation technology, there are four main problems:

a) There is a problem with the quality of wind power. On the one hand, although natural wind resources have greater energy, their properties are more variable, mainly represented by unstable wind direction and speed. In the traditional way, people use the inertia of the wind wheel to analyze the stability of the output power of the wind turbine. However, this method will form harmonics and reduce the power output to the grid. On the other hand, when the integrated capacity in the power grid meets the rated capacity, the voltage stability will be reduced. If there is a problem in the power grid, the unstable voltage will prevent the unit from effectively delivering energy to the power grid and make the protection action cut out. The power grid directly causes the instability of the power grid.

b) The wind turbine cannot be deployed in the whole machine design. Compared with western developed countries, there is still a large gap between the components of wind turbines in

China. For example, parts such as slip rings need to be imported from foreign countries, which makes it difficult for China's wind turbines to be installed and designed locally. At the same time, in the management and consultation of wind turbines, it has not formed an industrial chain, and the system is not perfect, which has a greater impact on the development of wind power generation [22].

c) Fan safety is not high. At present, due to the poor management of wind power enterprises, the lack of understanding of employees' ideas and the lack of professional level, etc., no attention has been paid to the safety of wind power operations. In the maintenance and inspection of wind turbines, over speed tests, emergency shutdown tests, and vibration tests have been ignored. Such contents make the unit lack of maintenance and inspection, and its reliability is reduced.

d) There are defects in fan control technology. In mechanical control, the blades of China generally use the NANC series of the United States. Although it has good power performance, due to the effect of the wind speed and working conditions of the wind wheel, the force of the wind wheel is uneven. Instability and repeated changes will occur during the process, causing the wind turbine to vibrate and form a large noise.

The most important challenges facing the wind power industry are reflected in the following two aspects [21]:

a) The quality bottleneck of domestic fans is obvious, which restricts the further development of enterprises. The investment in domestic wind turbines is relatively small in the early stage, but there are certain problems in the technical quality of the wind turbine. The investment and maintenance costs in the later stage are relatively large. The comprehensive cost is much larger than that of imported wind turbines, and the profitability is not strong. For example, according to the author's research in a wind power company in Qidong, the surrounding villagers dug ponds within the land occupied by wind turbines. If repairs or maintenance is required, the fishponds need to be backfilled. The negotiation backfill for a fishpond ranges from a few hundred thousand to as many as hundreds of thousands. The maintenance of the gearbox requires 700,000 to 800,000 yuan, and the use of special lifting equipment such as a 500-ton large crane requires 200,000 to 300,000 yuan at a time. According to a wind power company in Yancheng, according to the experience of foreign wind power development, the cost of overhaul and operation and maintenance of a wind farm accounts for about 27% of the total life cycle of a wind farm. However, taking into account factors such as poor quality of domestic wind power equipment and high wind-power-grid-connection requirements, this cost may be doubled. The disadvantage of the comprehensive use cost of domestic wind turbines has seriously restricted the further development of wind-power-equipment companies.

b) The reduction in electricity prices has prompted the industry to reshuffle. On December 24, 2015, the National Development and Reform Commission issued the "Notice on Improving the Benchmark Electricity Price Policy for Onshore Wind Power Photovoltaic Power Generation". Hours, the adjustment is 0.47, 0.50, 0.54, 0.6 yuan/kWh, and will be further adjusted to 0.44, 0.47, 0.51, 0.58 yuan/kWh by 2018. Jiangsu belongs to the four categories of wind-power-resource areas. From 2009 to 2015, onshore wind power projects have always adopted the electricity price plan of 0.61 yuan/kWh. If the electricity price is reduced to 0.58 yuan/kWh by 2018, the price reduction will be close to 5%, which may cause the internal rate of return of

the equity of wind farms in Jiangsu to fall by 2 to 2.5 percentage points. It is foreseeable that those wind power manufacturers that were originally hovering around the profit and loss point will likely turn into losses or even withdraw from the market.

5. A description of the solution proposed

Solutions to the existing problems are as follow [21]:

5.1 Integrate the resources in the existing area, and re-reasonably plan and adjust the industrial layout.

Although Jiangsu and some other provinces have basically formed a wind power industry chain, in order to avoid the market from falling into vicious competition, government departments should combine local wind energy resources and industrial development foundations in a timely manner to reintegrate existing resources in the region, rationally allocate and layout. At the same time, the construction of the base will be promoted, and the wind power leading enterprises that have been developed into large scales will become larger and stronger, forming an industrial pattern based on the leading enterprises and dominated by the wind power industrial base.

5.2 Formulate supportive policies to mobilize the enthusiasm of local governments and investors.

For qualified wind power equipment companies, support the application of various financial support such as major scientific and technological projects and high-tech industrialization projects set up by the state. At the same time, we should increase assistance to wind power enterprises in taxation policies. Raise funds for qualified enterprises by means of listing financing and issuing corporate bonds. Accelerate the establishment of venture capital and guide entrepreneurial venture capital to support the development of the wind power industry.

5.3 Build a certification platform to promote technological innovation in the wind power industry.

Around key areas such as wind turbines, key components and control systems, national and provincial enterprise technology centers, engineering technology research centers and other wind-power-technology innovation support platforms should be built. Build a public service platform for wind power product and equipment testing, promote the construction of onshore and offshore wind power test sites, formulate local standards for wind power technology, and provide technical support for building a wind power industry cluster.

5.4 Actively launch related supporting policies to fully guarantee the development of wind power industry.

The healthy and fast wind power requires not only the incentive policy directly aimed at the wind power itself, but also other related supporting policies to provide support for the smooth integration of wind power. Compared with foreign countries, China still has many gaps in supporting policies and urgently needs to be improved. Although the wind power technology standard system has been basically perfected and the relevant testing and certification mechanisms have been basically established, due to various reasons, the implementation of these policies is not ideal, and the level of policy implementation needs to be strengthened as soon as possible.

5.5 At the same time as policy incentives, we should pay attention to the standardized requirements of the wind power industry.

For a long time, the distinguishing feature of China's wind power development policy is "re-incentive incentives, light constraints", which is also an important reason for the disorderly development of Jiangsu and the national wind power industry and excess capacity.

5.6 Improve the quality of wind power and develop new technologies.

Use superconducting energy storage technology to keep the frequency and output voltage of wind turbines stable. Improve the mechanical structure, prevent the load of the mechanical structure from being affected by the change of wind force, and reduce the stress on the parts, reduce the weight of the entire unit and components, and greatly reduce the cost. Enhance the safety of wind turbines, conduct over speed testing on wind turbines, and detect the action of over speed protection actions, over speed channels, over speed modules, and over speed sensors and the brake circuit. The use of an adaptive controller allows the wind turbine to be optimized for its power factor within the maximum range.

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Master Program on Bio-Based Circular Economy

Course of Renewable Energy Technologies

Wind Energy in China

Students: *Haihua Xu; Kun Sun; Songyang Li; Hui Li*

Co-funded by the Erasmus+ Programme of the European Union

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Contents

- Background
- A short description of the technologies
- The present status
- Strength and weaknesses of the studied scenarios
- A description of the solution proposed

1. Background

- Wind energy is a rich and clean new energy source

- Feature:
- Renewable;
- Pollution-free;
- Large reserves ;
- Wide distribution.

- **In China, it has become one of the important components of China's sustainable development strategy.**

2.A short description of the technologies

Principles of wind power

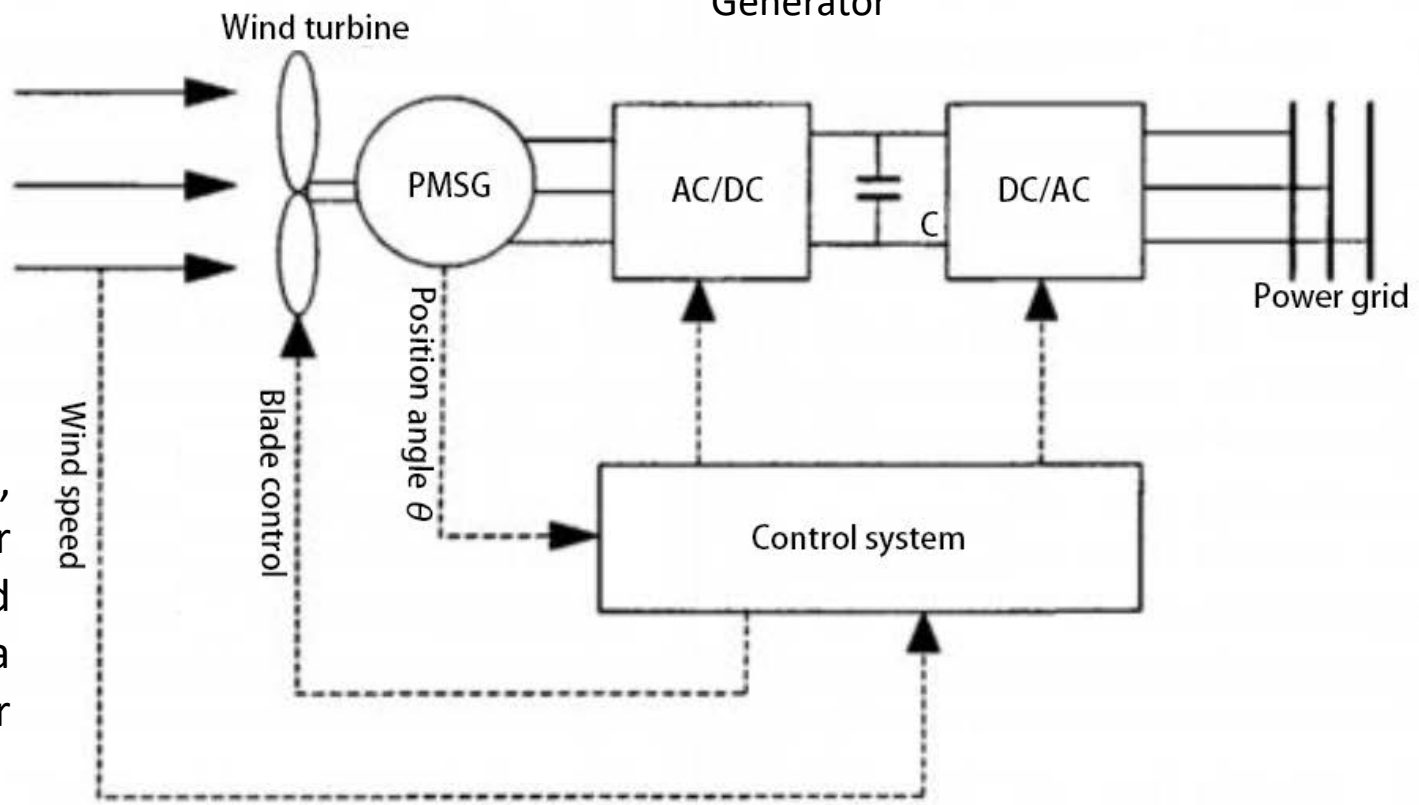
PMSG:Permanent Magnet Synchronous Generator

Generators play a vital role in the process of wind power generation.

Influences:

1.Energy conversion efficiency.
2.Operating efficiency
3.Mechanical structure.

Improving the level of wind power generation, making the conversion efficiency of wind power generation higher, operating more reliable, and providing higher quality of electrical energy are a major direction of development of wind power generation technology



2.A short description of the technologies

Wind power technology

1.Constant speed constant frequency power generation technology

Component:
1.Generator
2.Variable speed gear box
3.Transformer

Adjust the speed ratio of the gearbox

↓

Wind turbine speed remains unchanged

↓

Constant power frequency

2. Variable speed constant frequency power generation technology

As the wind speed changes, adjust the generator speed to maximize power.

↓

Vector control and other means to control the speed of the motor

↓

Regulation of power electronic equipment

↓

Constant frequency current

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3.1. Overview of wind resource distribution in China

China has a vast territory and a long coastline, with a land area of approximately 9.6 million square kilometers and a coastline (including islands) of 32,000 kilometers. It has abundant wind energy resources and huge potential for wind energy development.

The distribution map of China's wind energy resources is shown in Figure 1. The regions with abundant wind energy resources are mainly concentrated in the southeast coast and nearby islands and in the north (northeast, north, northwest) regions. There are also some relatively abundant inland wind energy resources. In addition, offshore wind energy resources are also very rich.

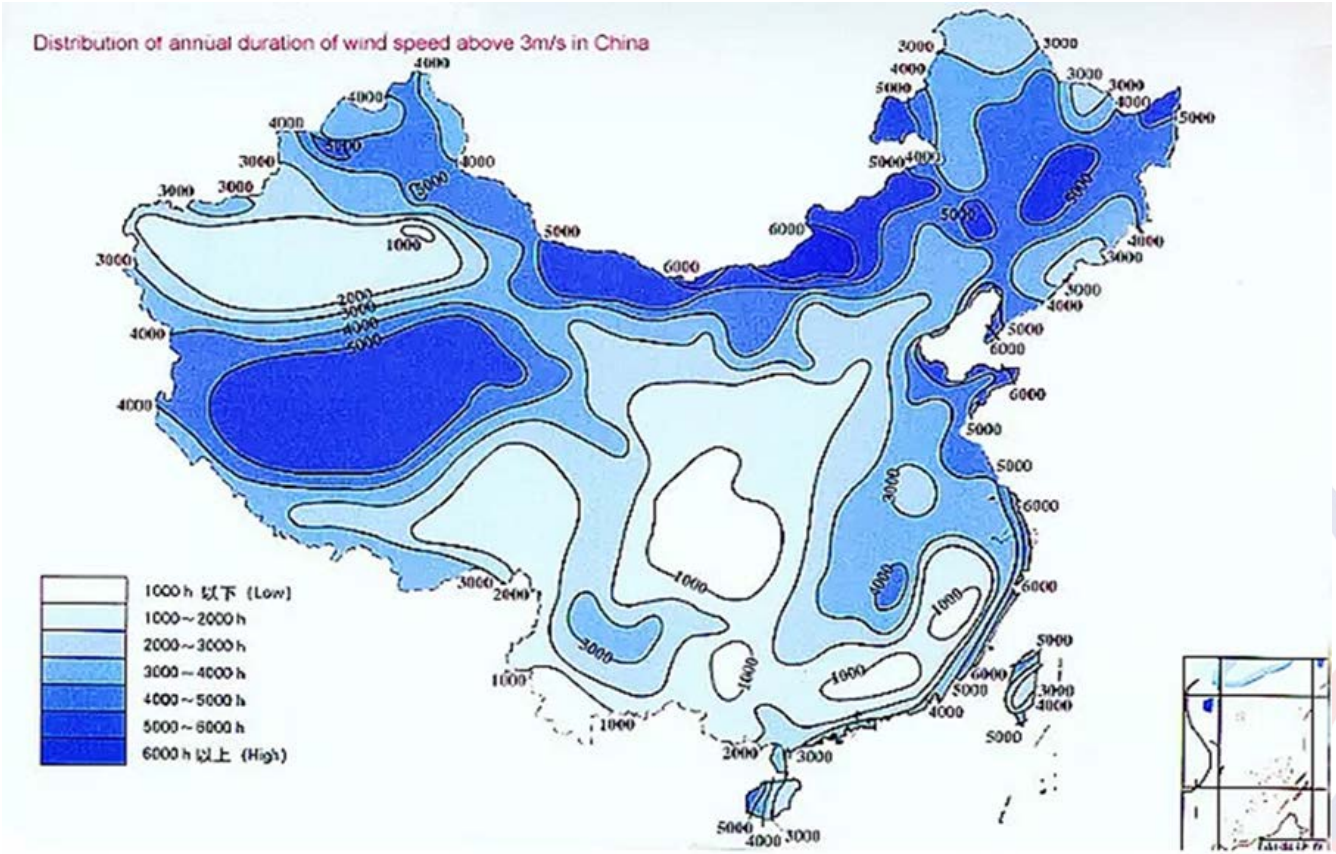

Figure 1. Distribution of wind energy resources in China

3.2. Development status of wind power industry

China's installed wind power capacity has ranked first in the world for 10 consecutive years, and wind power has become the third largest source of electricity after thermal power and hydropower in China.

2003-2010 is a period of rapid development, with a compound growth rate of 115%; The first construction peak

From 2011 to 2012, after a long period of development, China‘s newly installed wind power capacity declined for two consecutive years；

From 2013 to 2015, China's wind power industry resumed growth, with a three-year compound growth rate of 33%; The second construction peak

From 2016 to 2017, new domestic installed capacity further declined；

From 2018 to now, the newly installed wind power capacity has been improved, and it has resumed its upward trend. It is currently the third construction peak.

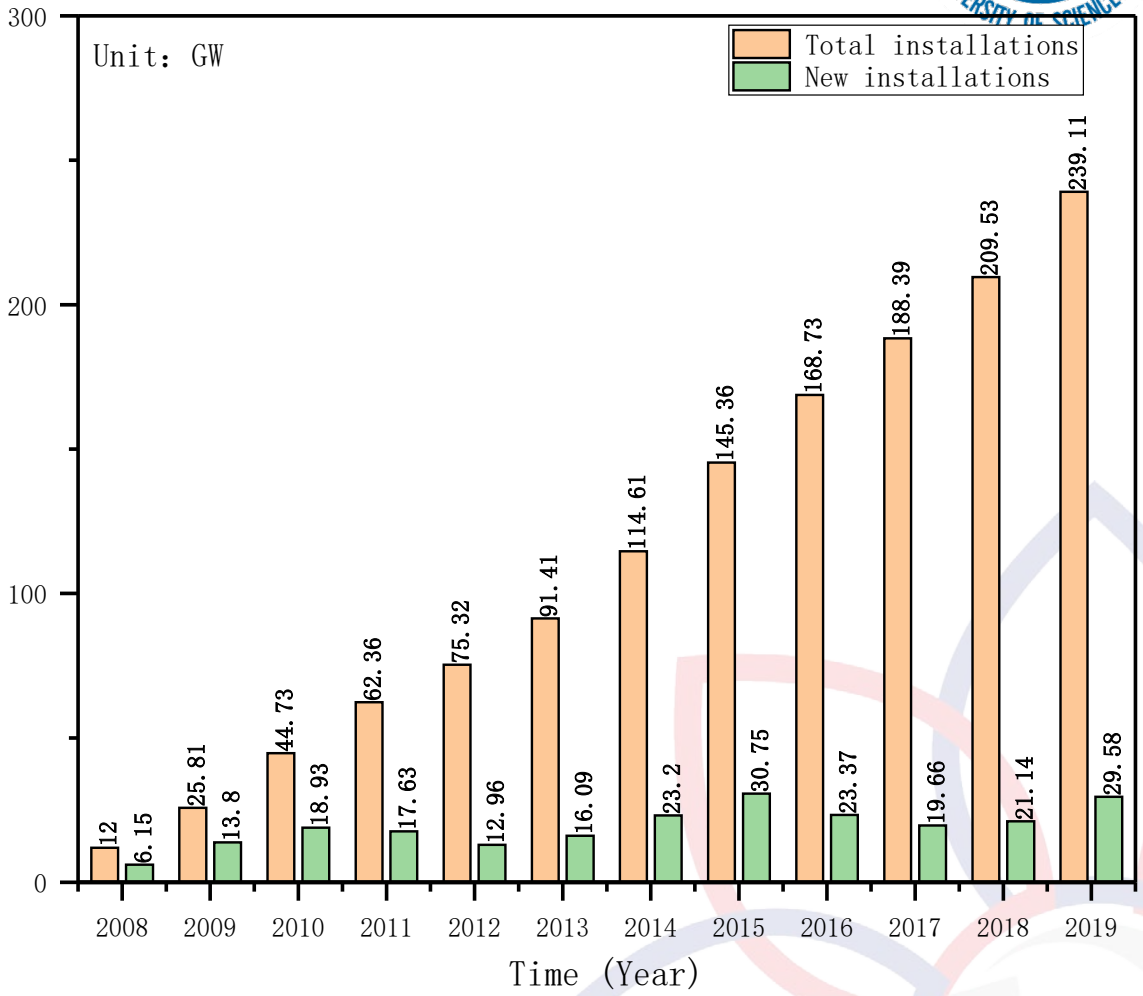

Figure 2. China's new and cumulative wind power installed capacity from 2008 to 2019

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3.2. Development status of wind power industry

In 2016, China added 154 offshore wind power installations, with an additional installed capacity of 590,000 kw, and a total installed capacity of 1.63 GW, with an increase of 56.73%.

In 2017, China added 319 new offshore wind power installations, with an additional installed capacity of 1.16 GW, and a total installed capacity of 2.79 GW, with an increase of 71.17%.

In 2018, China added 1.65 GW of offshore wind power, with a total installed capacity of 4.44 GW, an increase of 59.14%.

From the perspective of wind power structure, by the end of 2019, among the 240 GW of cumulative wind power installed in China, the main proportion of onshore wind power installed capacity is 233 GW, accounting for 97.5%. The cumulative installed capacity of offshore wind power is 5.93 GW, accounting for 2.5%.

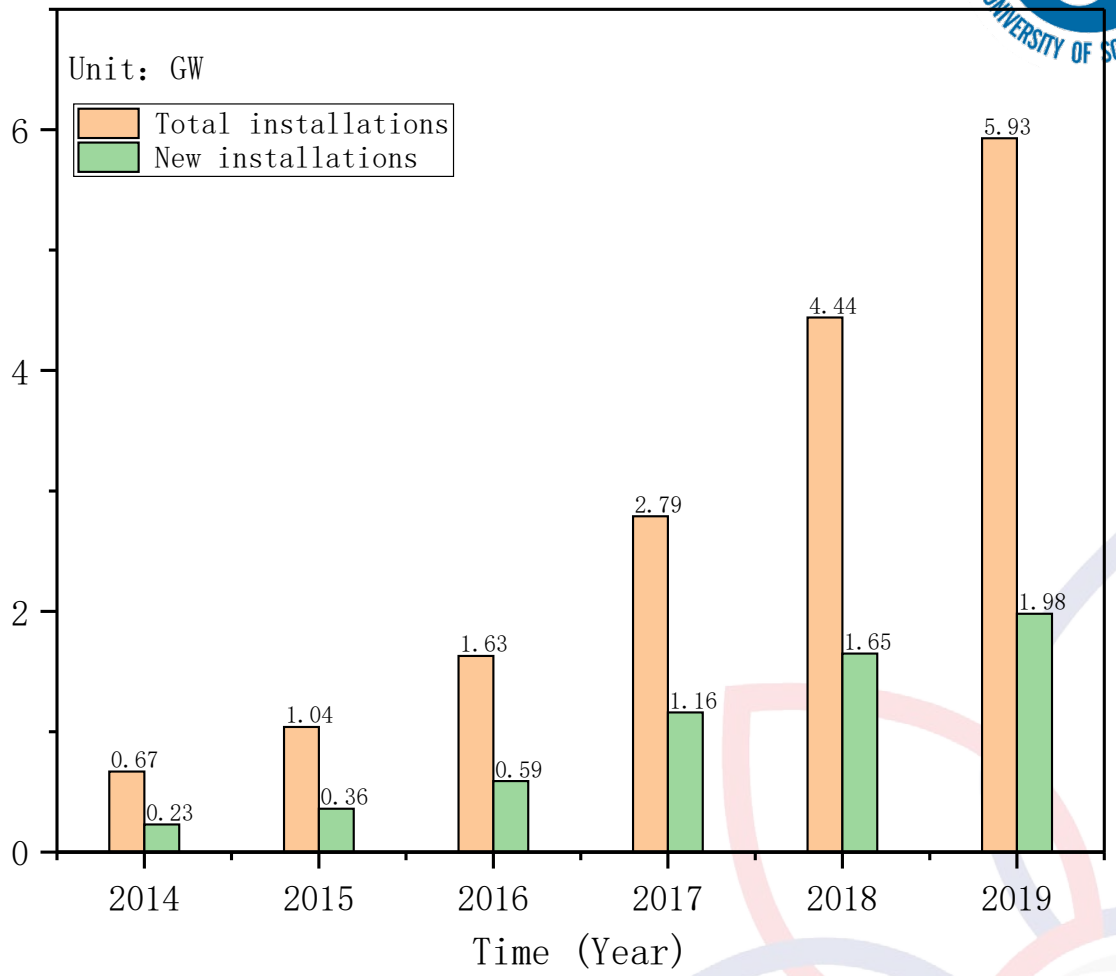

Figure 3. China's cumulative and newly installed offshore wind power capacity 2014-2019

3.3. Current status of the global wind power industry in 2019

In 2019, the newly installed wind power capacity in the world reached 60.4GW, an increase of 19% compared with 2018;

the five markets with the largest installed capacity in the world in 2019 were China, the United States, the United Kingdom, India, and Spain. The market together accounted for 70% of global sales last year.

China accounted for 43.3%. Ranked first in the world in power generation.

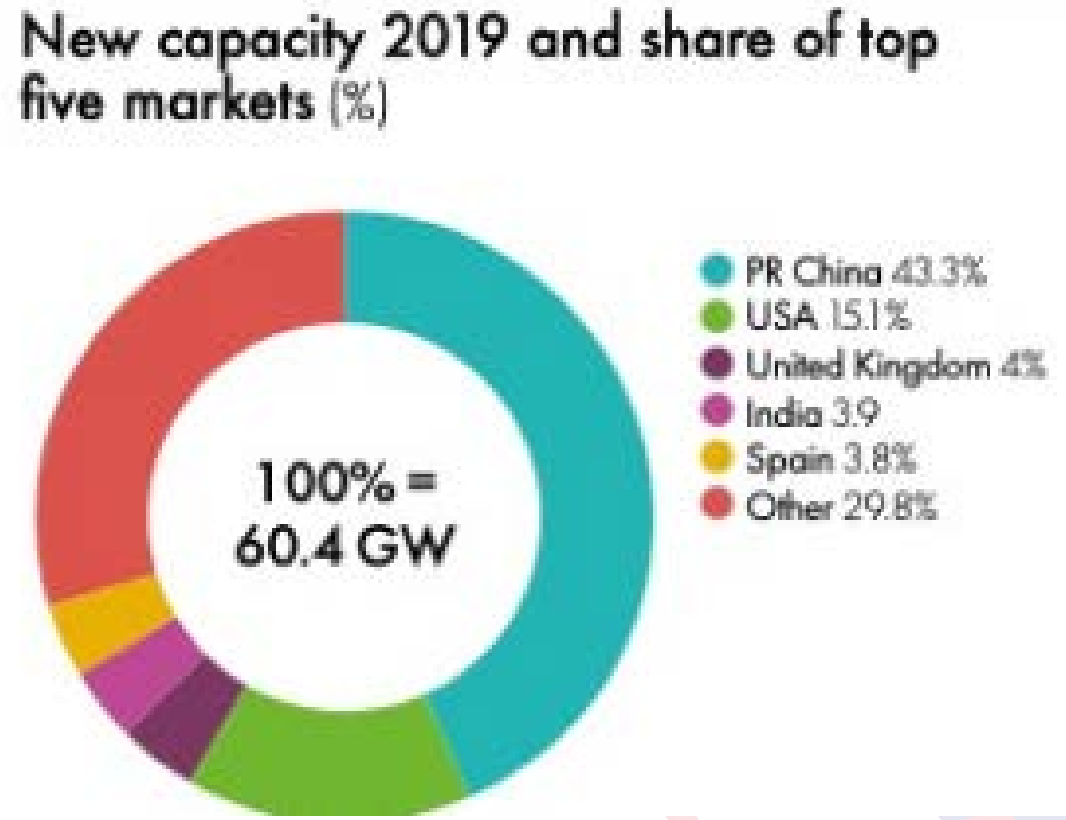

Figure 4. Top five market and proportion

3.3. Current status of the global wind power industry in 2019

The cumulative installed capacity of the global onshore wind power market reached 621GW, and the newly installed capacity reached 54.2 GW;

the cumulative installed capacity of the global offshore wind power market reached 29.1GW, and the newly installed capacity exceeded the milestone of 6 GW, accounting for 2019 global new installed capacity 10% of capacity is the highest level to date.

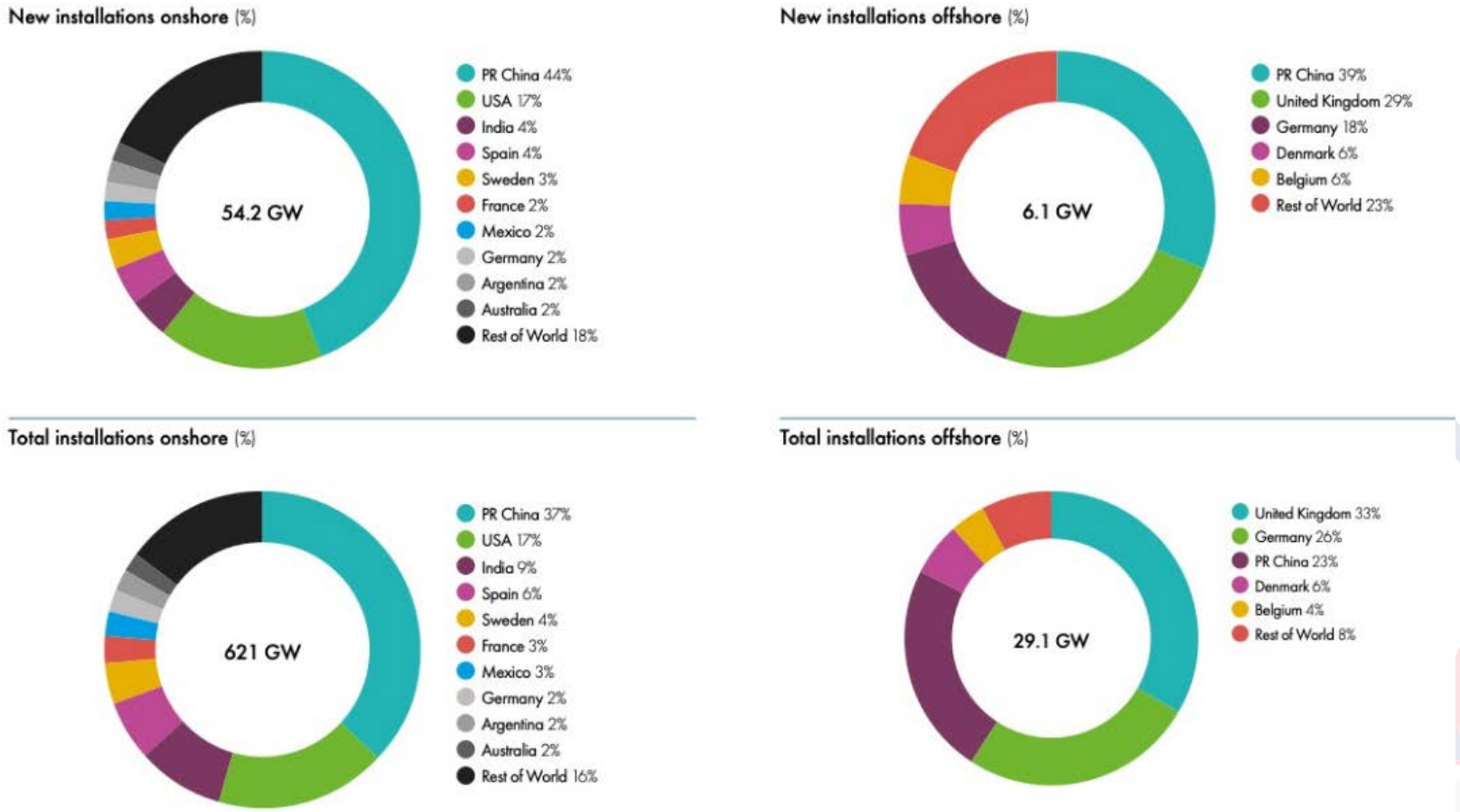

Figure 5. New installation onshore and offshore, total installation onshore and offshore

3.3. Comparison of power generation capacity among China's power generation industries in recent ten years

In 2019, the power production and supply capacity continue to improve and the structure is further optimized. In 2013, China's wind power generation capacity was 135.7 TWh. As of 2019, wind power generation capacity was 405.7 TWh, accounting for 5.4%. In just 6 years, it has grown three times as much as in 2013.

In general, the proportion of wind power generation in the total composition of national power generation is increasing year by year.

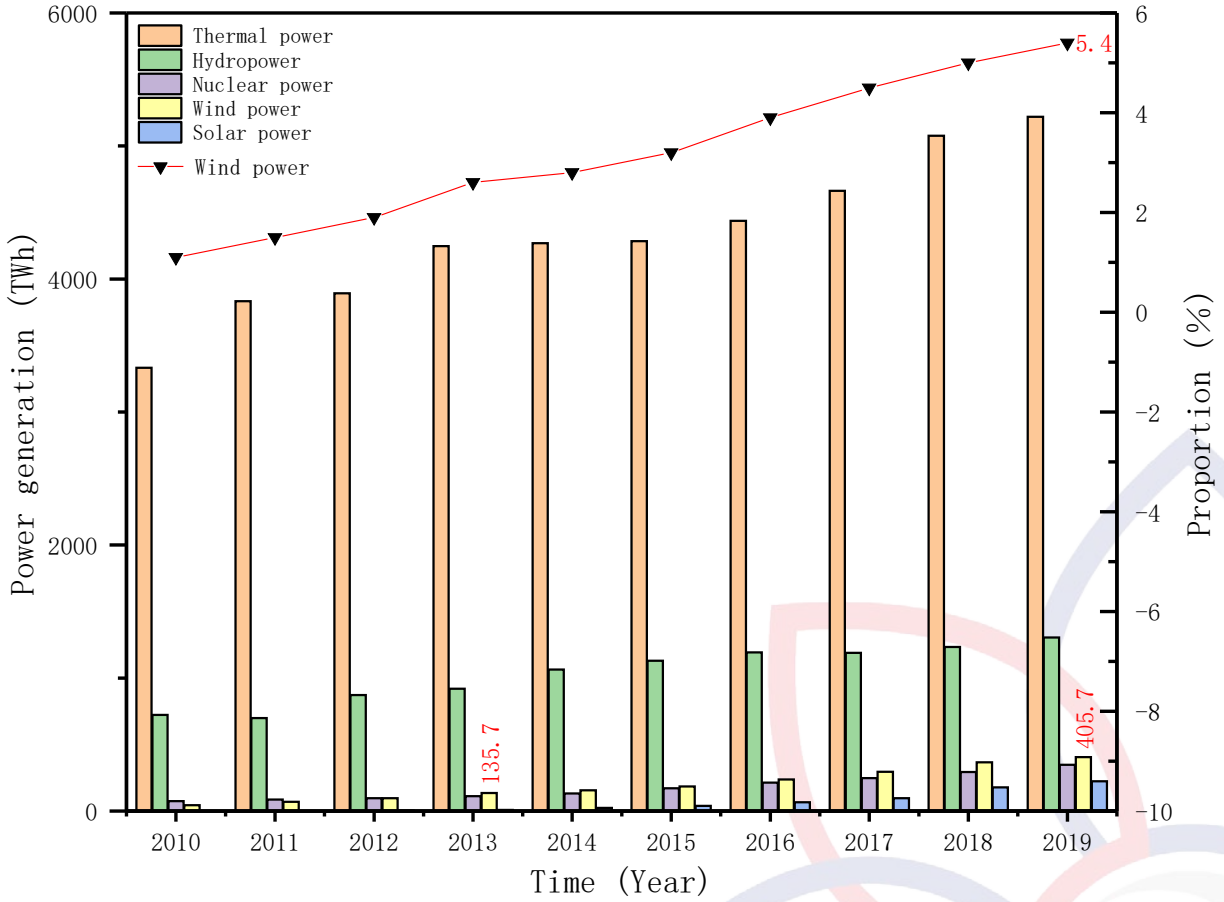

Figure 6. Comparison of power generation capacity among China's power generation industries from 2009 to 2020

3.4. Comparison of installed capacity among different regions in China

In 2018, the proportion of newly installed wind power capacity in the six regions in China is as follows: Central South region (28.3%), North China (25.8%), East China (23%), Northwest China (14.2%), Southwest China (5.5%) and Northeast China (3.2%). The "three northern regions" accounted for 43.2% of new installed capacity, and the Southern Middle East for 56.8%.

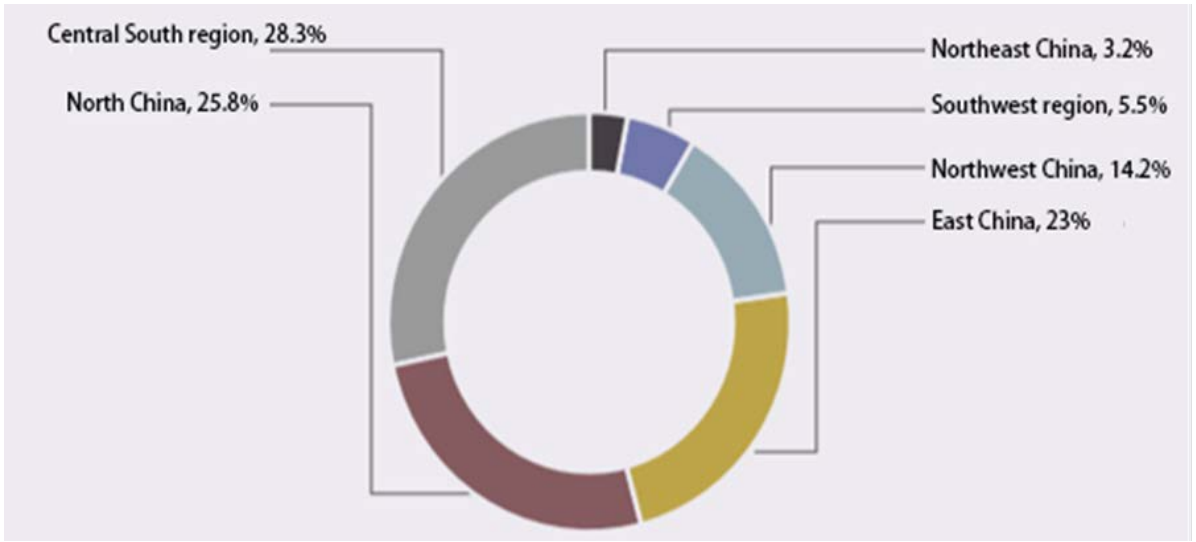

Figure7. Proportion of installed wind turbine installed capacity in all regions of China in 2018

Figure 8. Cumulative wind power installed capacity of each province (region and city) in China as of the end of 2018

3.5. Market share of Chinese manufacturers

In 2019, the new installed capacity in China is 29.58GW, an increase of 8.44GW compared with 2018, with a year-on-year growth of 40.85％.

In 2019, the top ten manufacturers in China's wind power market are shown in Table 1. Among them, the new installed capacity of Goldwind Technology reaches 8.01GW, and the market share reaches 28%; It was followed by Vision Energy, Mingyang Smart Energy, Yunda Wind Power and Shanghai Electric, with a combined market share of 76% for the top five.

Table 1. New lifting capacity and market share of major wind turbine manufacturers in the Chinese market in 2019

Rank	Company	New installed capacity (GW) in 2019	China market share in 2019
1	Goldwind Technology	8.01	28%
2	Vision Energy	5.42	19%
3	Mingyang Smart Energy	4.50	16%
4	Yunda Wind Power	2.06	7%
5	Shanghai Electric	1.71	6%
6	CNOOC	1.46	5%
7	Dongfang Electric	1.42	5%
8	Guodian United Power	1.08	4%
9	Xiangdian Wind Energy	0.77	3%
10	China Zhuzhou Institute	0.65	2%
	Others (including foreign manufacturers)	2.50	6%

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3.6. Market share of Chinese operating companies

By the end of 2018, the cumulative installed capacity of the top 10 wind power operating companies had exceeded 140 GW, accounting for 70% of China's installed capacity. They are the main force in the wind power industry and play a decisive role in the development of China's wind power industry.

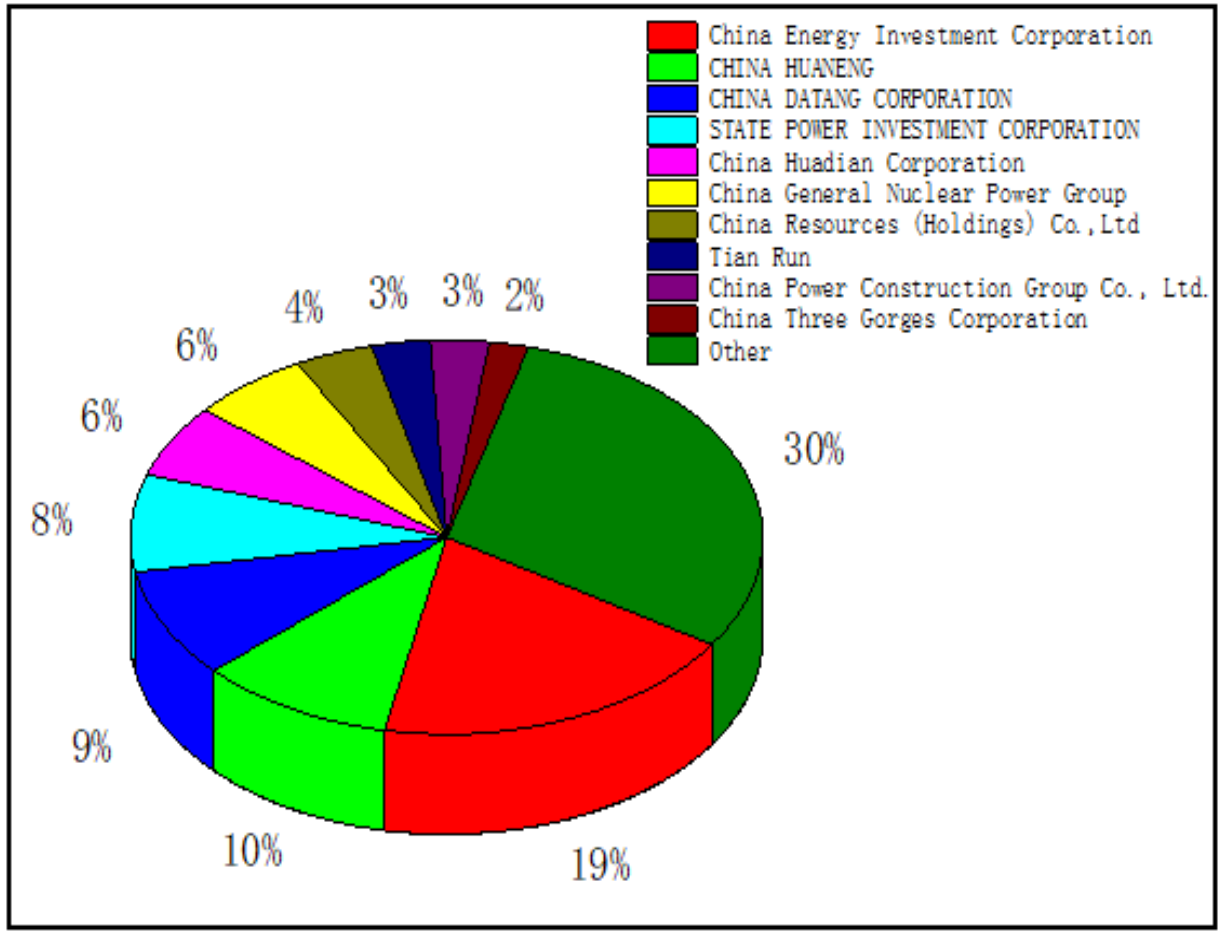

Figure 9. Cumulative installed capacity of Wind power developers in China as of the end of 2018

4.1. Strength of Wind Energy

- Cleanliness.
- Renewability.
- Huge reserves.
- Wide distribution.
- Low land requirement.
- The operation of the device consumes few resources.
- Promotion to local economic development.

4.2. Weaknesses of Wind Energy

From the perspective of industrial layout, there are three main problems :

- Heavy wind farm construction, supporting light industry.
- Heavy parts production, light machine manufacturing.
- Reintroduce assembly and lighten independent research and development.

4.2. Weaknesses of Wind Energy

From the perspective of industry development status, there are three main problems:

- Market competition is fierce, and mutual price reduction is obvious.
- Some wind power development projects have low profitability.
- It is difficult for some enterprises to withdraw funds, and liquidity pressure is greater.

4.2. Weaknesses of Wind Energy

From the perspective of wind-power-generation technology, there are four main problems:

- There is a problem with the quality of wind power.
- The wind turbine cannot be deployed in the whole machine design.
- Fan safety is not high.
- There are defects in fan control technology.

4.2. Weaknesses of Wind Energy

The most important challenges facing the wind power industry are reflected in the following two aspects:

- The quality bottleneck of domestic fans is obvious, which restricts the further development of enterprises. The investment in domestic wind turbines is relatively small in the early stage, but there are certain problems in the technical quality of the wind turbine. The investment and maintenance costs in the later stage are relatively large. The comprehensive cost is much larger than that of imported wind turbines, and the profitability is not strong.
- The reduction in electricity prices has prompted the industry to reshuffle. On December 24, 2015, the National Development and Reform Commission issued the "Notice on Improving the Benchmark Electricity Price Policy for Onshore Wind Power Photovoltaic Power Generation". Hours, the adjustment is 0.47, 0.50, 0.54, 0.6 yuan/kWh, and will be further adjusted to 0.44, 0.47, 0.51, 0.58 yuan/kWh by 2018. It is foreseeable that those wind power manufacturers that were originally hovering around the profit and loss point will likely turn into losses or even withdraw from the market.

5. A description of the solution proposed

Based on the above research, we make the following policy recommendations:

- Integrate the resources in the existing area, and re-reasonably plan and adjust the industrial layout.
- Formulate supportive policies to mobilize the enthusiasm of local governments and investors.
- Build a certification platform to promote technological innovation in the wind power industry.
- Actively launch related supporting policies to fully guarantee the development of wind power industry.
- At the same time as policy incentives, we should pay attention to the standardized requirements of the wind power industry.
- Improve the quality of wind power and develop new technologies.

Thanks for watching!

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