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Analysis of wind power generation technology and its application in energy saving

Maojiu Wu

School of Physics and Materials Science, Tianjin Normal University, Tianjin, 300387, China

2130300162@stu.tjnu.edu.cn

Abstract. Demand for electricity is on the rise as the economy is constantly on the move. Traditional thermal power generation is inefficient and harmful to environment. Wind power generation has gradually become one of the most important energy sources developed by various countries because it is a clean energy source. Wind power is widely distributed in China and the geographic advantages accelerate the construction of large wind farms. In order to develop wind power generation more efficiently, it is necessary to analyse the technology and environmental conditions in detail. This article has been a review of the current state of wind power generation in China. The principles of wind power generation and the types of wind turbines are introduced. The impact of wind farms on the climate is also discussed. It also examines the role of wind energy as a means of saving energy and reducing pollution. This paper may offer a reference for the development of wind power generation.

Keywords: wind power generation, wind turbines, wind farm construction, energy conservation and emission reduction.

1. Introduction

The demand for electricity is increasing day by day with the continuous development of the economy. Traditional thermal power generation is not only inefficient but also harmful to environment. In order to develop economy with consideration of environmental issues, as wind power is a kind of clean and renewable energy, wind power has slowly become one of the most important sources of energy that various countries are developing. Wind turbine production has gradually become a new manufacturing industry. In China, a variety of wind turbines are used, and the most common type is the horizontal-axis wind turbine. The construction of wind farms has been accelerated due to China's geographical advantages and a series of energy conservation and emission reduction policies, although wind farms have a certain impact on the climate. To ensure the orderly development, standardized construction and sustainable development should be conducted. This paper is a review of the current state of wind power generation in China. Introduces the types of wind turbines and the principle of wind energy production, and the environmental and climatic impact of wind energy production. The role of wind power generation in energy conservation and emission reduction is analysed. This paper can be used as a reference for the development of the technology of wind power generation in China.

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2. Current situation of wind power generation in China

2.1. Wind energy condition in China

Wind energy is a new type of energy source widely distributed in China, because of China's advantageous geographical location from the Pacific Ocean in the east to the Indian Ocean Sea in the south. Therefore, the southeast and south monsoon brought by the southwest monsoon of the Indian Ocean, the southeast monsoon of Australia and the high pressure of the North Pacific Ocean have greatly enriched China's wind energy resources. China is rich in wind energy resources, has good development prospects, and has great development potential.

2.2. Offshore and onshore wind power

From the perspective of the distribution of wind power in China, the coastal tidal areas, offshore areas and island areas have very rich wind resources, while the coastal areas have advanced economic development and large energy demand, providing the required basis for the development of offshore wind power.

2.2.1. Comparison of offshore and land power generation. For wind power generation, under the condition of sea height change, the offshore wind speed will decrease, providing a reliable guarantee for the tower construction of offshore wind power generation and reducing the intensity of offshore wind turbulence. And the stability of the dominant wind direction is ensured, and the improvement of the life of the wind turbine is realized. In general, the service life of offshore wind turbines is about 2.5 times higher than that of land. On the basis of the same power generation equipment, with the help of offshore wind power generation, more power generation can be created and the power generation efficiency can be improved[1].

2.2.2. Difficulties in offshore power generation. Power generation equipment at sea level needs to withstand severe waves and strong winds, which will increase the difficulty of its installation. There will be the influence of offshore climate and seawater corrosion, and it must ensure that it has a strong anti-corrosion effect. In the construction process of the generator set, it is necessary to fix it on the seabed with the help of pile piercing structure, resulting in high cost and large resource consumption.

2.2.3. Current situation and development trend of offshore power generation.

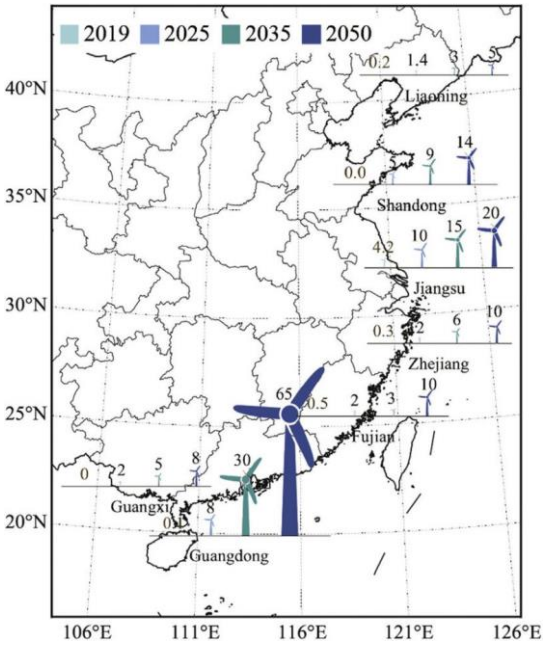

Figure 1. Installed and planned offshore wind power capacity of China(unit: GW)[3].

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Over the past few years, the global wind energy industry has been entering a period of rapid development and expansion. It gives a significant picture of the current situation and the prospects for development of the wind energy industry [2]. The wind power industry has developed rapidly in various countries around the world with the continuous development and utilization of wind power. The production and manufacturing technology and control technology have been continuously improved. The trend of wind power development to offshore has further indicated that wind power generation is developing steadily. The installed and planned offshore wind power capacity of China is shown in Figure 1[3].

3. Wind power generation technology

3.1. Wind power generation theory

The wind power generation mainly uses the wind to drive the blade to rotate and convert mechanical energy into electrical energy. The current wind power generation system mainly includes: gearbox, deflection system, hydraulic system, brake system and control system. In the course of the operation of the wind power generation system, and the gearbox can effectively increase the speed of the generator through the combination of gears, which can ensure the stability of power generation while increasing the power generation. The yaw system can flexibly adjust the sweep area of the wind turbine in response to changes in wind direction, and the sweeping surface can be perpendicular to the wind direction, maximizing the use of wind resources. In a wind power system, pitch fans as well as wind turbine blades need to be able to rotate around the center of the root, so that the wind power generation system can adapt to different wind conditions. When the wind power system is shut down, the tip of the blade will be thrown out to increase the damping, which is convenient for the wind turbine to stop and the hydraulic system and brake system often operate in conjunction during the shutdown process[4].

3.2. Classification and basic structure of wind turbines

3.2.1. Classification of wind turbines. According to the direction of the main axis, wind turbines can be divided into horizontal axis turbines and vertical axis turbines. Depending on their power output, wind turbines can be divided into small, medium, large and megawatt series. Wind turbines can be divided into fixed pitch, variable pitch active stall and independent variable blade types according to the power control mode. On the basis of their mechanical design, wind turbines can be divided into those with a gear drive, those without a gear drive and those which are a combination of the two. Wind turbines can be divided into two categories according to the type of generator used: asynchronous and synchronous[5].

3.2.2. Basic structure of wind turbine. Modern horizontal shaft wind turbines mainly include impellers, engine rooms, transmission devices, control systems, braking systems, yaw systems, hydraulic devices, towers and foundations. The design of vertical axis wind turbines is simpler than that of horizontal axis wind turbines because the axis of rotation of the rotor is perpendicular to the ground or the direction of the airflow, and it is not necessary to reverse the wind when the wind direction is changing, thus the gyroscopic force is reduced when the wind wheel is in the direction of the wind.

4. Impacts of wind farm on climate

Climate is a complex factor composed of multiple factors and the energy structure will change the surface characteristics to a certain extent, because the construction of wind farms changes the original mechanism of natural climate cycle and affects its process .It may cause some changes in the natural climate. The construction of wind farms will affect the roughness of the surface, due to the rotation of the blades, agitating the air, causing it to form turbulence, affecting the height of the atmospheric boundary layer, which in turn may change meteorological parameters such as temperature, humidity, and wind speed, finally cause an impact on the climate[6].

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4.1. Influence on surface roughness

The value of surface roughness reflects the interaction force between the underlying surface and the air flow near the ground, and also reflects the material and energy exchange and transmission intensity of them, which is affected by vegetation characteristics, wind speed, wind direction and other factors[7]. Numerous climate change studies have shown that regional climate change caused by the change of the underlying surface may be more serious than the impact of greenhouse gases. So in the study of the impact of climate change, as the first-order climate forcing factor, the role of the underlying surface cannot be ignored[8].The sudden establishment of many wind turbines on the flat ground has fundamentally changed the natural environment of the original underlying surface such as farmland and pasture, and the wind turbines are highly concentrated, replacing the original loose plant-covered soil with hard, dense, dry and impervious fan bases such as cement, asphalt, masonry, terracotta tiles and metal plates. The huge wind turbine changes the temperature, humidity, wind speed and direction of the air and changes the transmission of water and heat in the soil, thereby causing climate change[6].

4.2. Influence on turbulence

The wind turbine is operating in the wind farm, and the wake effect generated by the upstream wind turbine will affect the air flow field in the wind farm to a certain extent and the power output of the downstream wind turbine will be changed accordingly. In addition, the turbulence of the air is also increased due to the wake effect of the wind turbine, which strengthens the exchange of various physical quantities in the vertical direction, and the wake effect causes non-negligible energy losses to the operating wind farm. Although the energy generated by wind farms and the energy dissipated by kinetic energy are only a small part of global wind energy, wind energy can drive more energy flow by transferring heat and moisture. So under equal conditions, changing the kinetic energy of air will have more obvious climatic effects than changing radiation[9]. At the boundary layer of the atmosphere, considering the energy conversion effect of the overall wind farm, the rotation of the wind turbine will produce a large turbulent energy, and the turbulent energy in the land wind farm area will increase by about 0.9 m^2/s^2 on average, and the offshore wind farm may reach 1.3~3.1 m^2/s^2 [10]. And the turbulent scale is getting bigger and bigger in the process of energy diffusion downstream, which directly increases the turbulent exchange coefficient of the wind farm near the ground layer, and the mixed transport of turbulence transmits the momentum to the downstream. And converts kinetic energy into heat energy through viscosity(friction) dissipation, and the thermal energy gradually dissipates and heats the atmosphere, resulting in an increase in temperature. The heat exchange of turbulent flows is gradually reduced from the surface to the sky, and the rise in temperature is due to the influence of wind turbines on two processes, namely longitudinal and lateral movement turbulent heat transfer. These two processes play a key role in surface temperature and atmospheric circulation. Heat and moisture transfer from terrestrial and oceanic surfaces into lower atmospheric layers are called turbulence. Lateral heat transfer is the process by which a steady and large-scale wind carries large amounts of heat away from hotter areas (usually horizontal) and then transfers it to cooler regions[11]. This process is a crucial step in large-scale heat redistribution, and the effects of turbulent motion are limited.

4.3. Influence on atmospheric boundary layers

The atmospheric boundary layer is located at the bottom of the troposphere and is directly attached to the ground, so it is strongly affected by various interactions and topography, such as turbulent friction, water vapor exchange and material diffusion. Whether it is climate change or atmospheric circulation anomalies are inseparable from land surface processes and atmospheric boundary layers[12]. A single wind turbine affects momentum transport through the pressure gradient and wake flow of the blades, while a series of wind turbines affect momentum transport by changing the length of the boundary layer.

After the construction of large-scale wind farms, wind turbine activities and wind turbine wake effects first affect the atmospheric movement and water vapor transmission in the location and surrounding area of the wind farm. The operation of the wind turbine and its resulting wake effect first affect the turbulent energy transmission and water vapor diffusion in the boundary layer, and then affect

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the boundary layer height around the wind farm. Inside the wind farm, the boundary layer is relatively high, and the downstream is restored to its original state. The influence of wind farms on the boundary layer height in the surrounding area depends on the near-ground atmospheric nodule stability, which depends on the vertical distribution of atmospheric temperature and humidity. At night or at low wind speed, turbulence is mainly subject to surface friction, stable layering, and small change in boundary layer height. During the day, the ground heating causes the air flow to rise, the surrounding air is cooler, and strong convection occurs, which will lead to the appearance of large-scale turbulent vortices and thickening of the interface, and the operation of the wind farm will also increase the boundary layer more obviously[10].

5. Role of wind power generation in the process of energy conservation and emission reduction

5.1. Advantages of building large-scale wind farms in China

Looking at the geographical distribution, China has made remarkable progress in developing onshore wind, mainly concentrated in Inner Mongolia, Ningxia, Gansu and other northwestern regions of China. However, the economic development level of these areas is relatively low, the demand for electricity is much lower than that of the developed areas on the southeast coast, which makes it necessary to carry out large-scale, long-distance high-voltage transmission, increasing the transportation Cost of wind energy. For the generation of offshore wind power, it can meet the economic development needs of the southeast coastal area, reduce transportation costs, and maximize its own benefits. Offshore wind power generation process, it does not occupy a lot of land resources, which greatly promotes the construction of large-scale wind farms.

5.2. Outlook in the future

It is necessary to increase the scale of wind power development in the current development of offshore wind power, so as to make up for the shortcomings in traditional development and enhance its market competitiveness. By actively supporting the development of offshore wind energy production, it can effectively make up for the problems in the energy structure, thereby promoting sustainable economic development. In developing offshore wind power, it is necessary to consider both policy and technology aspects. The development of offshore wind power should be vigorously promoted by introducing appropriate support policies.

6. Conclusion

As a form of power generation, wind power has the characteristics of clean, efficient and renewable, especially in the process of offshore power generation. With the abundant wind resources at sea, it is possible to obtain more massive resources in the process of wind power generation, taking advantage of the length of the coastline. In order to maximize benefits and minimize environmental impact, atmospheric stability, surface parameters, boundary layer atmospheric meteorology and other aspects should be considered for the selection of wind farm location. As China has advantages in this field, wind power generation will be significantly developed, coupling with the reduction of costs and the improvement of environmental problems. In the future, targets for low pollution and high energy efficiency should be achieved, and the study of power storage and development needs more attention.

References

[1] Duan R 2022 Power System Equipment 8 43-45
[2] Liu B, He Z and Jin Hao 2016 Journal of Northeast Dianli University 36(2) 7-13
[3] Deng, X, Xu W, Xu Y, Shao Y, Wu X, Yuan W, and Qin Z 2022 Fundamental Research 1 0.1016/j.fmre.2022.11.008.
[4] Liang L 2021 Rural economy and science and technology 32(20) 5-7
[5] Jiang H, Wang Y and Yang M 2017 Jiangsu Science and Technology Information 17 44-48
[6] Wu Z, Liu W, and Wang S 2014 Electric Power 6 101-105

DOI: 10.54254/2755-2721/10/20230187

[7] Gao Y, Lv S 2001 Plateau Meteorology 4 354-361
[8] Li Y, Gao Y, and Chen X 2011 Journal of Nanjing University:Natural Science Edition 47 (3) 330-338
[9] Hu D, Zhang J 2010 Journal of Solar Energy 31(11) 1485-1490
[10] Hu J 2012 Numerical simulation study on the impact of large-scale wind farm construction on regional climate, Lanzhou University
[11] Wang C, PRINN R G 2010 Atmospheric Chemistry Physics 10 2053-2061
[12] Hu F, Hong Z and Lei X 2003 Chinese Journal of Atmospheric Sciences 27(4) 712-728