Application and Development Trends of Meteorological Services in Energy Industry

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Abstract Ulanqab City is rich in wind and solar energy resources, and the development prospects of wind power and photovoltaic power generation industry are broad. The development of new energy is one of the important measures to address climate change. In this study, the current situation of climate argumentation, meteorological observation, weather forecast and meteorological services carried out by the meteorological departments of Ulanqab City in the development and utilization of wind and solar resources was analyzed. Refined meteorological services are the guarantee for the development of new energy industry. In the future, it is necessary to further enhance the capacity of energy meteorological services, promote and apply digital information technology, and strengthen the level of meteorological services.

Key words Wind and solar resources; New energy industry; Meteorological services

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Under the trend of global warming, extreme weather events occur more and more frequently, and the ecological environment have suffered severe damage, so mitigating climate change is an urgent task at present. Exploring new energy sources is one of the important measures to actively respond to climate change. The report of the 20th National Congress of the Communist Party of China proposed that it is needed to accelerate the planning and construction of a new energy system. Converting wind and solar energy into electricity to ultimately serve various industries in society and the production and life of the people is an important way to promote the transformation of China's energy structure and achieve the goals of carbon peaking and carbon neutrality. Meanwhile, natural resources such as wind and light are highly susceptible to the uncertainties brought about by changes in climate conditions, so that wind power generation and photovoltaic power generation have the characteristics of volatility, intermittency and randomness. Therefore, it is necessary to enhance meteorological services such as weather forecast and climate assessment, and build a complete meteorological service system for clean energy power generation to facilitate the development of new energy industry[1].

1 Current situation of development and utilization of power generation based on wind and solar energy in Ulanqab City

Ulanqab City is located in the central part of Inner Mongolia Autonomous Region, with an altitude of 1 595 - 2 150 m. It serves as the main channel for the flow of Siberian cold high-pressure air and Mongolian cyclones into the interior, and has a semi-arid continental monsoon climate of the middle temperate zone. This area features low temperatures, little precipitation and long sunshine duration. Annual average sunshine duration is as high as 2 775 - 3 080 h, and annual average total solar radiation is 5 500 - 6 200 MJ/m^2. There are many windy days here, and the number of windy days in spring reaches 60 d. The number of starting wind with a speed of ≥3 m/s is more than 280 d/a, and the annual average wind speed at 70 m above the surface is 7.2 - 8.8 m/s. Within a year, the effective wind hours reach 7 300 - 8 100 h, and the effective wind field area is 6 828 km^2. The technically exploitable capacity of wind energy resources is approximately 68 million kW. It is characterized by abundant effective wind hours, high wind energy quality, and large site area. In areas where both wind and solar energy resources reach the national first-class resource level, large-scale wind and photovoltaic power stations can be planned and constructed.

Relying on its climatic resource advantages, Ulanqab City has always regarded new energy industry as an important measure to improve the quality of economic development. On the basis of fully developing and utilizing renewable resources, it focuses on equipment manufacturing, continuously promotes the construction of large-scale wind and photovoltaic power bases to transform the advantages of wind and solar resources into industrial advantages, vigorously developed the two landmark industries of wind power and photovoltaic power, and support the green, low-carbon and sustainable development of local economy and society. By the end of 2024, the installed capacity of new energy in Ulanqab City had reached 16.788 million kW, among which the installed capacity of wind power was 12.725 million kW, and that of photovoltaic power was 4.063 million kW, accounting for 61% of the city's total power generation capacity. A new energy base with a capacity of over 10 million kW had been built, and the installed capacity of clean energy exceeded that of thermal power, achieving a historic

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breakthrough.

2 Application of meteorological services in energy industry

2.1 Precise climate argumentation The census of climate resources is a fundamental task for the development of new energy[2]. When large-scale development and precise site selection for new energy is conducted, it is necessary to utilize a large amount of climate data for argumentation, conduct a census of climate resources, and determine the feasibility report for resource development. Ulanqab City is rich in solar and wind energy resources. The distribution and potential for development of these resources need to be confirmed through detailed climate data from meteorological departments. The meteorological departments of Ulanqab City have basically established a modern meteorological system that meets the demands and has a complete structure and strong support. The quality and efficiency of ecological meteorological services have significantly improved. It is needed to continuously strengthen the technological support for responding to climate change, give full play to the advantages of meteorological science and technology, conduct climate feasibility studies for the development and utilization of wind and solar resources, and promote the development of green production models.

2.2 Detailed meteorological monitoring To generate electricity using wind and solar energy, a large amount of meteorological element data such as wind speed, wind direction, temperature, humidity and solar radiation through observation should be first obtained to conduct meteorological forecasts for wind power and photovoltaic power generation before the electricity generated can be predicted. These meteorological elements are constantly changing, and their variations directly affect power production and dispatching. Therefore, unlike traditional coal-fired power generation which is "generated as needed", the development and utilization efficiency of new energy sources should be improved to deal with the huge challenges brought by the randomness and volatility of weather. For instance, when wind speed is predicted, if the forecast result deviates by 1 m/s from the actual situation, the maximum error in wind power generation prediction may reach 30%, and solar power generation may drop sharply by 50% due to cloud cover. Hence, strengthening precise monitoring of meteorological elements is an important basis for accurately predicting the development and utilization efficiency of new energy. The meteorological departments of Ulanqab City have built multiple automatic meteorological observation stations throughout the city. At the same time, they use weather radar and Fengyun meteorological satellites to precisely capture the changes in the data of meteorological elements of wind and solar energy in Ulanqab City, and combine with the data of elements monitored by a large number of meteorological equipment around the power plants, so as to provide reliable and accurate data support for the precise forecast of the weather at each pole tower location.

2.3 Accurate weather forecast The conversion of wind and solar resources into electricity is greatly affected by the weather. When wind speed is small, the wind turbine cannot rotate; as wind speed is too high, it will cause the wind turbine to shut down. In case of snowfall, sandstorms and other weather, photovoltaic panels are covered and blocked, which directly affects power generation[3]. Therefore, accurately predicting power generation capacity by meteorology is extremely crucial. It is necessary to rely on meteorological elements such as wind and solar energy on the day to make weather forecast. The meteorological department of Chahar Right Middle Banner, Ulanqab City prepares 24-hour and 48-hour wind energy forecasts every day and provides them to the wind power base of Chahar Right Middle Banner. The staff of the wind farm determine the number of wind turbines to be started and the power generation volume based on weather forecast every day. Meteorological forecasts of wind energy have become the "schedule" for wind farms to arrange their work, and scientifically guide the starting and rotation speed of each generator, thus overcoming the instability and overcapacity of wind energy.

2.4 Fine meteorological services Wind and photovoltaic power generation projects in Ulanqab City are built in remote mountainous areas and open fields. These regions usually have harsh environments and complex and changeable weather, which has a significant impact on the safety of power equipment and the efficiency of power generation. In case of strong convective weather such as thunderstorms, power facilities will be damaged. High temperatures can cause conductors to overheat, leading to tripping accidents. Extensive ice accumulation in winter can overwhelm pole towers, while heavy precipitation in summer can damage power transmission and transformation equipment, *etc.* All these require meteorological departments to strengthen forecasting and early warning work of meteorological disasters and carry out refined meteorological services for disaster prevention and mitigation.

For centralized photovoltaic power stations and distributed wind and photovoltaic power plants, the Meteorological Bureau of Ulanqab City provides refined meteorological services and strengthens the release of special reports, quick reports and early warnings for major weather processes. For the issue of lightning protection in wind farms, the Meteorological Bureau of Chahar Right Middle Banner has set up six inspection points of lightning protection for each wind turbine, opened up the lightning protection market, reduced the inspection cost of lightning protection to 500 yuan per turbine, and provided professional lightning protection inspection services for wind farms. At the same time, by leveraging the advantages of meteorological technology, meteorological insurance compensation certificates are provided to wind farms to ensure that in the event of a wind turbine being damaged by lightning strikes, a real-time forecast at the time of the incident is issued, enabling timely acquisition of insurance claims and reducing the disaster risk losses of wind farms. The meteorological department of Chahar Right Middle Banner issues about 20 meteorological insurance certificates for wind farms every year, helping them recover losses of tens of millions of yuan. On June 5, 2016, three wind turbines at China General Nuclear Power Corporation's wind farm were damaged by lightning strikes, resulting in a loss of approximately 4 million yuan. The Meteorological Bureau of Chahar Right Middle Banner promptly provided the actual weather conditions of that day, proving that the incident was a lightning

strike disaster. The China General Nuclear Power Corporation's wind farm received full compensation from the insurance company.

3 Development trends of meteorological services

3.1 Enhancing the capacity of energy meteorological services It is needed to carefully study the *Implementation Plan for Energy Meteorological Services in Inner Mongolia* issued by the Meteorological Bureau of Inner Mongolia Autonomous Region, clarify important tasks, and accelerate the improvement of energy meteorological service capabilities. Firstly, efforts should be made to enhance the capacity for resource assessment, meteorological conditions and climate change should be studied and analyzed for the further development of wind and solar energy resources and site selection. Secondly, it is needed to give full play to professional advantages, strengthen meteorological guarantee services for the normal operation and maintenance of wind and solar power stations, and provide services for disaster prevention and mitigation during the operation of stations under extreme weather conditions. Finally, to meet the diversified demands for energy meteorological services, it is necessary to explore precise forecasting technologies for wind and solar power generation, establish an integrated meteorological service platform, enhance the capacity for diversified service support, achieve full coverage of meteorological disaster early warning services for energy supply security, and promote the sustainable development of energy industry.

3.2 Promoting and applying digital information technology Based on the big data sample library of historical weather in Ulanqab City, superalgorithms are used to refine longitude and latitude coordinates as much as possible in space and narrow the grid of prediction data. Meanwhile, it can continuously increase the prediction frequency of meteorological elements in time, and update the data every hour in case of various extreme weather. When sand and dust weather occurs, for the prediction of photovoltaic power generation output, the influence of sand cover thickness on power generation can be obtained by using the supercomputer operation model. Algorithms can be used to establish precise prediction models for wind power output under various extreme weather conditions such as high temperatures, and cold waves, thereby achieving detailed classification and accurate forecasting. Information technologies such as big data and artificial intelligence are promoted and applied to enhance the ability to predict weather changes, making the development of wind and solar power generation energy industry more stable and more efficient[4].

4 Conclusion

The installed capacity of new energy sources such as wind power and photovoltaic power in Ulanqab City is getting larger and larger, and it has become an important energy base in China. Meanwhile, the development of wind and solar power industry must rely on accurate weather forecasts and meticulous services. In the face of the accelerated transformation of energy industry, meteorological departments should fully grasp the ability of weather and climate change, give full play to the role of "meteorology + energy", strengthen the research and development of numerical model forecast products for wind and solar energy, carry out short-term revised forecasts, continuously optimize algorithm models, produce multi-element prediction products at different time and space scales, continuously improve the level of energy meteorological services, and establish an energy meteorological service system that meets market demands to ensure the sustainable development of wind and solar power generation.

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(especially July and August). They were relatively rare in winter (December, January and February).

(4) The temporal distribution of regional and local rainstorms in Jining City also had certain regularity. The frequency of regional rainstorms was relatively stable, while the frequency of local rainstorms generally showed an upward trend.

(5) There were significant differences in the spatial distribution of the number of rainstorm days and the total amount of rainstorms in Jining City. The frequency and intensity of rainstorms in the southeast were significantly higher than those in the northwest.

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