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Overview of Key Technologies for Wind Energy Applications

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Abstract

Due to the pursuit of economic benefits and the development and damage to the environment, the need to develop new energy sources is increasing day by day. as one of the earliest and most mature new energy generation methods, wind power has received much attention. However, wind power generation system is constrained seriously by the environment because of the random fluctuation of wind power itself. It is easy to cause problems such as low power generation efficiency and fast device loss due to the influence of wind instability. At the same time, it is difficult to store and connect electric energy to the electricity grid.

Keywords

Wind power generation system; Randomness of wind energy; The volatility of wind; storage and grid connection.

1. Introduction

With the continuous improvement of environmental protection awareness and the rapid development of science and technology, the importance of new energy technology increased rapidly. As the main way to relieve environmental pressure under the current social background, the development of new energy technology and its various impacts have received extensive attention all over the world. Wind power generation is a vital part of new energy generation and plays a significant role in energy conservation and emission reduction. However, in practice, it yields lower-than-expected returns due to high costs, regional wind randomness and fluctuation, and difficulties in integrating into the existing grid. Intelligent optimization can reduce operating costs to increase profits in the wind power field and ultimately protect the environment. Nowadays, the progress and challenges in wind power research at home and abroad are similar: in terms of achievements, the manufacturing and installation costs of wind power facilities have been greatly reduced, and the maintenance costs of the power generation units during operation have also been effectively controlled. However, the impact of wind instability and fluctuations on wind power generation and the subsequent storage and grid connection problems are still being explored, with great development prospects and opportunities. This paper summarizes the main problems facing the current wind power field, analyzes them one by one, and focuses on the volatility problem caused by the characteristics of wind power itself.

2. The Influence of Wind Fluctuation on Wind Power Installations

Unlike conventional power plants such as coal-fired power plants, the stability of wind power facilities during the generation process is highly uncontrollable. The force required to maintain a stable magnetic field around the generator core, which is almost never considered in traditional power generation, is almost impossible to maintain in a wind power plant. Subject to the uncertainty of wind speed, as well as differences in terrain and climate environment, the wind volatility problem faced by wind power installations cannot be fundamentally solved. The

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influence of wind fluctuation on wind power installation mainly focuses on two aspects: the influence on the life of components such as fan blades and the influence on the installation and maintenance of the whole installation. First of all, because the wind speed is always not constant, the force generated by it on the fan blade is also not constant, so the speed of the fan blade and the internal magnetic induction coil driven by it is also unstable, and the centrifugal force in the inertial force system will also be unstable or even in a disorder. Secondly, the small dust and water vapor in the air carried by the wind will also cause different degrees of damage and corrosion to the wind power equipment, especially the fan group, under different temperature conditions, making the life of the fan is often shorter than the design expectation, increasing the maintenance and debugging difficulty of the overall device. In addition, due to the different wind direction and area of wind turbines in different environments, the impact of different wind turbines is also unique, and the inconsistent power generation and loss degree between different wind turbines greatly increase the difficulty and cost of the construction of wind power grids，which also brings new difficulties to the interconnection between different wind power installations.

3. The Volatility of Wind Technology Solutions

3.1. Unstable climate environment response program

Because the climate conditions themselves can only remain roughly regular, their unstable nature also brings great challenges to wind power systems. Currently, the main common countermeasures include three aspects: Firstly, enhance the detection sensitivity of fan blade orientation control facilities. Unlike traditional wind power devices, most current ones are equipped with unified steering control equipment for adjustment based on different wind directions to maximize economic benefits. However, sometimes, operations like steering are not carried out promptly due to minor wind force changes. Secondly, Strengthen the corrosion resistance of exposed facilities such as fan blades. By using special materials or special surface coatings, the corrosion resistance of the exposed equipment can be effectively strengthened, so that its resistance in adverse environments such as sand or rain can be increased, and the service life can be increased. Third: Adjust dynamically according to weather conditions. By forecasting and observing the weather conditions of the region where the wind power installation is located, the wind power system can be suspended and adjusted in time when encountering extreme weather and other conditions, and can effectively avoid the phenomenon of equipment aging and damage caused by overwork in bad weather.

3.2. Intelligent optimization scheme to deal with the randomness of wind speed

For wind power systems, the randomness of wind speed has a significant effect on the device. For example, When the wind is too small, in order to avoid fans blades frequently in the state of starting and stopping, sometimes artificial regulation is adopted to make the fan rotate at a low speed, but it will lead to increased costs. While in the case of excessive changes in wind speed, if the wind power device is forced to work, there is a great chance that the wind power device will have unnecessary losses or even damage, at this time, in order to avoid risks, wind power often has to be abandoned and limited, so that wind power projects often have a high installed capacity but low utilization rate, which affecting economic benefits. For the above situations, the common solution is to build a mathematical model to predict. By considering different variables to establish the function, the influence of different wind speeds on wind power installations can be fitted to a large extent, and then the corresponding control scheme can be selected according to the advantages and disadvantages of the influence. Through the mathematical model, a rough wind speed prediction diagram can be obtained to predict the

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wind speed distribution of some regions in the future for several times, and on this basis, intelligent optimization can be carried out, so that the corresponding wind power equipment can choose the best direction and operation mode with greater benefits and lower risks, so as to achieve the goal of maximizing profits. At the same time, due to the different geographical locations of different wind turbines, they are affected by the randomness of wind speed is not the same, if through a comprehensive consideration of wind speed, environment and other comprehensive conditions for intelligent optimization, it can make every wind turbine as much as possible to play its economic benefits and avoid waste.

3.3. The intelligent optimization scheme for wind speed volatility

Considering the uneven level of infrastructure in different regions and the fact that wind turbines are mostly built in remote locations such as suburbs and wilderness to maximize the use of wind power, real-time model prediction is difficult to implement in some cases. With the continuous increase of grid-connected installed capacity of wind power, the inevitable gap and fluctuation of wind power pose a challenge to the stability of real-time operation of power system. In view of this difficulty, since the volatility of wind energy shows a certain periodicity in the unit of year, the volatility of wind speed is currently mainly predicted and optimized by the two sets of intelligent control schemes of long-term prediction system and short-term prediction system. The long-term wind prediction is mainly related to the climate of the location of the unit. By roughly sorting out the occurrence frequency of adverse weather factors such as local climate, annual air humidity, sand and dust, and seasonal wind direction, a rough mathematical model of wind power can be obtained and based on this, corresponding regulation can be carried out to reduce the influence and damage of wind power system caused by wind volatility to a certain extent. The short-term forecast is mainly based on numerical weather prediction (NWP). Through the traditional weather analysis methods such as bellows and hot air balloons, the actual situation of the atmosphere is understood. Under certain initial value and boundary value conditions, the atmospheric motion state and weather phenomena in a certain period of time are predicted by numerical calculation by large computer. This method can accurately estimate short-time weather and changes in wind speed and direction, which is conducive to self-adjustment of wind power systems. However, the NWP system is still unable to give timely feedback in the face of extremely short and sudden weather changes. At present, many new very short time forecasting models have been put forward and tested, showing strong competitiveness.

4. The Storage of Wind Power

The volatility of wind makes the electricity generated the same storage problems as other new energy generation methods. Different from traditional energy and some new energy power generation methods such as nuclear energy, which can generate continuous and regular power, wind power cannot generate regular current due to the root cause of wind randomness, so special storage methods are needed for subsequent grid-connected application. So far, In addition to the common electrochemical energy storage methods such as the establishment of special energy storage power stations and large batteries for wind power facilities, more and more mechanical and electromagnetic energy storage methods have been applied due to the gradual maturity of their technologies. For example, mechanical energy storage has a high degree of reliability and stability compared to traditional electrochemical storage methods, making it less prone to failure when faced with large and frequent unstable electricity inputs from wind power. At the same time, the energy storage time is longer and less likely to be lost, making it a good way to store wind energy. However, it also faces unfavorable factors such as higher energy loss during the conversion process and greater constraints from the terrain in the construction of storage facilities, which makes it difficult to promote. In general, what kind

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of energy storage method is suitable for a wind farm needs to comprehensively evaluate many factors such as economic cost, geographical location, material acquisition difficulty, etc., and select the appropriate plan for implementation according to local conditions.

5. The Grid Connection of Wind Power

Like other new energy generation methods, wind power generation system also has the problem of grid connection caused by unstable and balanced power generation. At different times, the amount and periodicity of electricity generated by wind turbines fluctuate greatly, and the construction sites of wind power systems are generally located at a considerable distance from large-scale electricity consumption areas such as cities and industrial zones. Directly connecting to the existing power grid can cause voltage surges or even power outages and equipment damage due to sudden large currents. Since the grid-connected problem appeared at the early stage of the development of wind power and was similar to the obstacles encountered by other new energy power generation technologies, the solution of wind power grid-connected has always received more attention. At present, simulation technology, power dispatching technology, wind power forecasting technology, test detection technology and so on are widely used. In general, by combining with computers to conduct intelligent regulation, it can greatly improve the waste of electric energy resources and unnecessary losses caused by fluctuations in current intensity in the grid connection process. In terms of grid connection types, it can mainly be divided into grid-side grid connection and power grid-side grid connection. The two forms have their own characteristics. Among them, the grid-side grid connection utilizes a transformer to directly connect with the distribution grid. This makes the energy storage method more flexible, enabling it to bypass the restrictions of the size and site factors of the storage facilities. Moreover, through the form of direct connection to the grid, it can further save facility costs and corresponding construction and maintenance expenses, achieving the goal of cost reduction and efficiency improvement, and is more suitable for new energy power generation methods. Among them, multi-terminal direct current transmission based on voltage source converter stations has become the first choice for long-distance transmission and grid connection of large-capacity wind power due to its mature and reliable technology.

6. Conclusion

The paper summarizes the challenges and difficulties encountered in the application of wind energy technology under the current development background. By comprehensively discussing the randomness of wind energy fluctuations, the storage of wind power and the difficulties existing in the parallel network, the development status of wind power field, the obstacles still to be solved, and the current exploration and related achievements in these fields are presented in a macro and comprehensive way. For the random and fluctuating problems of wind itself, large-scale regulation is carried out through intelligent control system to maximize the protection of equipment and improve the energy utilization rate. In the transportation link of generating electric energy, special battery storage and grid side connection are used to avoid the problems existing in the electric energy and network. Although most of the research in relevant fields at home and abroad is still based on traditional fields such as installation and maintenance costs of wind power systems, with the continuous development and maturity of new technologies and the continuous improvement of the scale and demand of wind power systems, more and more people have turned their attention to the field of intelligent optimization of wind power. But it is believed that in the near future, the impact of the volatility of wind itself on the power generation, the storage of electric energy and other problems will be paid more attention and eventually be effectively solved, and wind energy will continue to

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reflect its environmental and economic value as an important part of clean energy in the field of new energy.

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