Development and Application of Wind Energy in China

Ji Zhong Zhu, Xiao Fu Xiong, and Kwok Cheung

Abstract—**The development of wind energy is one of the most potential among various renewable energy resources. Due to maturing technology, wind energy has become the most promising renewable energy which can be developed and utilized for large scale. China is located in the eastern Eurasian continent and the brink of the world's largest ocean - the Pacific Ocean. It has more than 20,000 kilometers border, 18,000 kilometers coastline and 5,000 offshore islands. The strong climatic differences between land and sea, as well as vast land area and the complex terrain form abundant wind energy resources in China. This paper reports the development and application of wind energy in China. It also analyzes the existing issue on wind energy application in power systems as well as the latest research in this area.**

Index Terms—**Renewable energy, energy development, wind energy, power systems**

I. Introduction

Energy sources used by human beings are divided into primary energy and secondary energy. Primary energy refers to the direct provision by the nature, such as the chemical energy contained in coal, oil, natural gas and other fossil fuels, nuclear contained in nuclear dye, wind kinetic energy and potential energy of water, etc. The secondary energy refers to energy converted from primary energy. For example, power energy that is commonly used is converted from primary energy in the power plants. According to different primary energy, power plants can be divided into four categories: 1) thermal power plants using fossil fuels; 2) nuclear power plants using nuclear fuel; 3) hydroelectric power plants using potential energy of water; 4) other forms of power plants, such as the wind power fields, solar power stations, geothermal power plants, tidal power stations, et al. The energy resources for third and fourth ones are called as renewable energy.

The development of wind energy is one of the most potential among various renewable energy resources. Due to maturing technology, wind energy has become the most promising renewable energy which can be developed and utilized for large scale. With the increasing attention to environmental protection and the worsening of energy shortage, wind energy, as a clean and renewable energy sources, gets a wide range attention. Both developing countries and developed countries have developed wind energy widely to promote sustainable development and reduce emissions of harmful gas. Wind power not only uses the natural resources efficiently and protects the natural environment, but also solves the demand of power energy in remote areas.

Two main reasons causing the rapid development of wind power generation are as follows: firstly, all governments encourage development of wind power in policies; secondly, technology of wind power machines has been advanced and price has been lowed.

The United States has the world's largest greenhouse gas emission. Due to the pressure from world environmental protection, it attaches great importance to develop renewable energy. In the early 1980s, the U.S. government, to encourage the development of renewable energy, issued a series of preferential policies. These policies have attracted a lot of funds for the purchase of wind power machines, which offered a good opportunity for the mass production and quality improvement. In Almonte Yamaguchi, located in the eastern bay area of San Francisco, California, the largest wind power plant in the world was built [1]- [3].

Driving force for the development of wind power in Europe also comes from the pressure to improve the environment. Germany, Britain, Denmark, Spain and other countries made preferential policies in power system laws and regulations, which maintains a stable and rapid growth in wind power. After 1996, the annual growth rate of wind power get more than 30%, which makes it become the fastest growing clean power.

At present, China's wind energy is growing very fast. China is located in the eastern Eurasian continent and the brink of the world's largest ocean - the Pacific Ocean. It has more than 20,000 kilometers border, 18,000 kilometers coastline and 5,000 offshore islands. The strong climatic differences between land and sea, as well as vast land area and the complex terrain form abundant wind energy resources in China.

Due to the different geographical location, monsoon, landform and other factors, wind energy resources in China have the following characteristics [1]-[3]:

- The wind in the north region is stronger than that in the southern region;
- The wind in the plains is stronger than that in the hills and mountains;
- The wind in winter and spring is stronger than wind in summer and fall due to the impact of the Siberian high pressure.

This paper introduces the development of wind energy in China as well as wind energy applications in power systems.

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II. Development of Wind Energy in China [1], [2]

In the late 1950s, some small-scale wind farms with 10kW single-capacity were built in Jilin, Liaoning, Xinjiang and other provinces/districts in China. China began to use grid-connected wind power generation in 1970s. Three wind turbines, whose single-capacity is 55kW made by Vestas in Denmark, were introduced to Shandong Rongcheng in 1983. This started the testing and demonstration of the grid-connected wind power generation technology. The first grid-connected wind farm in China was built in 1986. Five wind farms had been set up, and over 30 units had been installed during 1985-1990. These wind farms have a common characteristic, that is, small-scale project and small single-capacity. The largest capacity of the wind farm was 200 kW and the cumulative installed capacity was 4200 kW in that time.

During 1991-1995, some bigger wind farms had been built in China by use of soft loan from foreign governments, such as Dabancheng wind farm in Xinjiang whose installed capacity was the first one that over ten thousand kilowatts, Nanao wind farm in Guangdong, Shangdu and Sunite wind farms in Inner Mongolia, as well as Wafangdian and Zhejiang Cangnan wind farms in Liaoning etc. By the end of 1995, 14 wind farms had been established and over 180 units had been installed. The cumulative installed capacity was 37MW. The largest single-capacity was 500 kW.

By the end of 1999, total installed capacity of wind power in China reached 267.9 MW; the largest single capacity was 750 kW, the number of wind farms increased to 24. Since 2000, the installed capacity of China wind power has increased year by year.

In addition, China's offshore wind energy reservation is much larger than that on land. Its energy reservation available is more than 700 million kW at the height of 10m, and it is very close to load centers. The Chinese government adheres to the principle of wind power concession to build large wind fields. It tries to promote wind power equipment localized, and gradually establishes China's own wind power industry system. In accordance with the requirements of "integrating into larger power grid and building large bases", China will strive to construct some 10 million kW of wind energy bases in Gansu, Inner Mongolia, Hebei, Jiangsu and other places in more than 10 years. In May 2008, the first national offshore wind energy demonstration project - Shanghai Donghai Bridge offshore wind farm, which has been approved by China National Development and Reform Commission, would install 34 domestic 3MW offshore wind turbine units whose total installed capacity is 102MW. On September 4, 2009, the first three generating units have been successfully put into operation, and others will be put into operation in 2010. On the other hand, China has started to engage in extensive offshore wind resource measurement and specification, which has been made as an important part of wind energy development in China.

III. Problems of Wind Energy Construction in China

Wind energy is the most clean renewable energy. It produces no air or water pollution, involves no toxic or hazardous substances, and poses no threat to public safety. However, people still have some environmental concerns on wind energy. An investigation of the environmental impacts of wind energy production reveals a few hazards. For example, some people have focused on adverse environmental impacts of wind-energy facilities, which include aesthetic and other impacts on humans and effects on ecosystems, including the killing of wildlife, especially birds and bats. Some environmental effects of wind-energy facilities, especially those from transportation (roads to and from the plant site) and transmission (roads or clearings for transmission lines), are common to all electricity-generating plants; other effects, such as their aesthetic impacts, are specific to wind-energy facilities.

In addition to these common environment issues, there are several problems in the planning and construction of wind power in China [1]-[3]:

1) The planning of wind farm that is uncoordinated with the development of grid mainly focuses on the planning of wind resource. Actually, some areas planed to have wind farm even lack specific power transfer and consumptive program for wind power. For instance, there'll have two wind power bases with capacity of 10 million kilowatts-level in Nei Monggol Province of China, but how to transfer and use the wind power has not been confirmed yet.
2) The construction of wind farm is uncoordinated with the construction of power grid, resulting in some wind farm cannot synchronize timely or contribute limitedly. For example, the maximum contribution for Jiuquan wind farm in Gansu Province in which 260 thousand kilowatts wind power has been put into operation can only reach 65% of its rated value.
3) The exploitation of wind energy resource is not coordinated with the hydropower, Fossil-fired power and other powers. So the capacity for peak adjustment is not inadequate in China. In the period of 2009 Spring Festival, all wind farms in Nei Monggol and part of wind farms in Jilin have to be suspended in order to ensure the heating supplies for residents that need to give the priority to the heating unit. Similarly, Gansu Power Company has to limit the normal operation of hydroelectricity in Yumen region in order to ensure a smooth transmission of wind power in Jiajiu power grid.

Due to the rapid development of wind energy in China, it also led to some problems in wind energy equipment manufacturing. For example:

1) The rapid development of the wind power industry led to excess capacity and intense competition. China Wind Energy Association data show that, in a few short years, China's wind power machine manufacturing enterprises dramatic expansion from 6 in 2004 to 70 today. In addition, the total number of wind power equipment parts manufacturing enterprises has more than one hundred, which has exceeded market capacity.
2) The lack of core technology. In recent years, China's wind power equipment, and technical ability have been greatly improved. For example, fan parts and

components, we did rely on imports ten years ago, and now we are able to make them by our own. However, we still have not mastered the core technology in the development and design of the wind machine. Most of the technologies in wind energy equipments are introduced from other countries. The intellectual property rights are still abroad, rather than our own technology.

3) The product quality of wind energy equipment is not stable. Since wind energy equipment manufacturing industry is highly competitive, some enterprises, in order to capture the market as soon as possible, focus too much on the development of the capacity, not strictly in accordance with the product development process. There is no enough time to find and solve problems from research prototype to product prototype. The prototype of the current domestic wind power manufacturing enterprises has just come out, running test cycle less than a year, and then entered mass production without enough trial and demonstration.
4) In addition, since the technology of wind energy is relatively backward, it also leads to that new energy does not have a price advantage. This becomes the bottleneck that new energy cannot be market-oriented industrialization.

IV. Application of Wind Energy to Power Systems in China

A. Voltage Fluctuation and Flicker Governance

In general, the balance of reactive power is closely related to the system voltage, while the balance of active power is closely related to the system frequency [4]. The wind turbine and its transmission lines should consume certain amount of reactive power which is associated with the type of wind turbine and the size of wind power. Therefore, the fluctuation of wind speed will generate the fluctuation of output power of wind farm, which will cause the system active power and reactive power changes, consequently, resulting in the voltage change of the adjacent node.

International Electrical Commission established a working group to study the impact on power energy quality after wind fields integrating into power system. It was underlined in their drafting report that the voltage flicker problem may be the main restrictions on the development of wind power.

B. Voltage Stability

Voltage stability can be destroyed and spread in local areas. Currently, to reduce costs and simplify the operation and management, grid-connected wind generator often uses squirrel-cage asynchronous generator. When the wind field capacity is enlarged, the reactive power characteristics of squirrel-cage asynchronous generator will cause the voltage stability to be destroyed, which needs external reactive power compensation to support it.

The voltage stability problem has been recognized as the most obvious issue and also one of the major constraints for the interconnection of wind generation in China. Actually, most current wind farms in China are using the fixed-speed wind turbine that needs to absorb reactive power from the power system while it generates active power, causing a voltage drop at the node of interconnection [5]. In addition, most resource-rich regions of wind energy in China are very far from the load center. Thus, the large-scale wind power needs to be transferred to the load center through the long-distance. Under this circumstances, the voltage drop of transmission line will be very large because of long-distance transmission when the contribution of wind farm is high, which can menace the voltage stability of local power grid and reduce the margin of system stability.

With the increasing of wind power capacity, the problem of voltage stability is increasingly serious in China that has caused the collapse phenomenon of wind farm with the augment of wind speed and rendered the wind turbine closing down because of the voltage fluctuation at bus.

C. Frequency Stability

Frequency stability refers to the ability that the power system can maintain system frequency at a specified operating limit [6]. The frequency adjustment for the traditional power system is usually conducted according to the needs of the random change of load and the power control of interconnection tie. When a large number of wind farms access to the grid, the contribution of wind generators may randomly change due to the fluctuation of wind, which increase the difficulty of frequency adjustment. Ultimately, the stable operation of the system will be deteriorated further.

Since the forecast level of the wind energy cannot meet the requirements of practical engineering, the operation plan of power system integrated with wind energy once became a hot research topic. With large-capacity wind fields integrating into the grid, it requires that dynamic response ability of power system can track high-frequency fluctuation of wind power.

Currently, the study on the frequency influence in China is relatively weak. The existing research focus primarily on the frequency characteristics of the wind turbine, the frequency characteristics of load and the self-regulation strategies after the access of distributed generation, etc. The research about the interaction between wind turbine and grid is relatively less. Fortunately, with the large-scale development of wind power, an increasing number of power companies and research institutes began to pay attention to the frequency problem in China.

D. Controlling Technology

Controlling technology of new style wind energy machine and wind energy generating system is a key technology in China. In the operation of power systems, ideal P_W-V characteristic depends on regulating of conversion efficiency of wind energy. Coefficient of conversion efficiency of wind energy of wind turbine, namely C_P, is the function between tip speed ratio λ and pitch angle β. Therefore, control of pitch angle and rotational speed of generator is important to the wind turbine. To control rotational speed, application of variable speed shifting motors, including double-fed motor and asynchronous motor, has been researched in China.

E. Software Development of Planning and Design of Large-Capacity Wind Fields

Software development of planning and design of large-capacity wind fields is another important aspect. Both the planning and operation of large-capacity wind fields integrating into the power system require considerable technical support [7]. It will need considerable research investment from the dynamic model development of wind fields to the optimized planning and operation of power system.

Thus, China is addressing the following issues:

1) Establish and improve product testing certification system.
2) Enhance the level of domestic wind power equipment technology.
3) Improve the operation and management level after the access of large-scale wind power grid.

V. Conclusion

This paper briefly introduced the current situation of wind energy in the world, especially in China. It reported the problems and developments of wind energy in China. It also analyzes the existing issues on wind energy application in power systems as well as the latest research in this area.

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