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Offshore Wind Turbines Operation and Maintenance in China: A Case Study of Donghai Bridge Offshore Wind Farm

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Abstract. China has great potential in offshore wind energy and makes an ambitious target for offshore wind power development. Operation and Maintenance (O&M) of offshore wind turbines become more and more important for China wind industry. This study introduces the current offshore wind power projects in China. Donghai Bridge Offshore Demonstration Wind Farm (Donghai Bridge Project) is the first commercial offshore wind power project in China, which was connected to grid in June 2010. O&M of Donghai Bridge Project represent the state-of-the-art of China offshore O&M. During the past two and half years, O&M of Donghai Bridge Project has gone through three phases and stepped into a steady stage. It's believed that analysis of O&M of Donghai Bridge Project is very helpful for China's offshore wind power in the future.

Introduction

Although China's installed offshore wind capacity is ranked number three globally, China's offshore wind has only a minor share in China with 389.6 MW total offshore capacity by the end of 2012 [1]. As estimated, the total available offshore wind energy potential of China reaches approximately 400~500GW [2], and Chinese government encourages accelerating the offshore wind power development. China National Energy Administration, the competent authority of energy in China, officially issued wind power development plan of the 12th Five-Year Plan and the 13th Five-year Plan on July 2012 in order to promote China's wind energy development from 2011 to 2020. The plan announced that the total installed capacity of wind power in operation will reach 100GW with 5GW offshore wind accounting for about 7% of 70GW new installation of the 12th Five-Year Plan. During the 13th Five-Year Plan, the new added capacity of offshore wind energy will reach to 25GW, and account for 25% of new installed wind power from 2016 to 2020 [3].

Current offshore wind power projects in China

The first large commercial offshore wind farm project in China is alongside east of the Shanghai Donghai Bridge. The project consists of 34 wind turbines manufactured by Chinese supplier Sinovel and comes to 102MW capacity with each rated at 3 MW [4]. The project began its construction in April 2008 and was completed in June 2010 with all wind turbines connecting to the grid [5]. Donghai Bridge Offshore Demonstration Wind Farm (Donghai Bridge Project) has generated more than 495GWh by the beginning of August 2012 [6].

Rudong Intertidal Trial Wind Farm Project (Rudong Trail Project) is the world first inter-tidal wind farm accomplished in September 2010. The project has successfully installed 16 turbines from 8 domestic manufacturers with total capacity of 32MW [7]. On the basis of success of Rudong Trail Project, Rudong Offshore Demonstration Wind Farm project (Rudong Demo Project) started in June 2011 in Rudong County, East China's Jiangsu Province. Currently, this Farm is China's largest offshore (inter-tidal) project with the installed capacity of 200MW.

Operation and Maintenance of Offshore Wind Farms in China

From one 1.5MW wind turbine was installed and connected to grid in Bohai Bay in November 2007 as the first offshore project, five years have passed. There are only three commercial offshore wind farms by far in China. Besides three commercial offshore wind farms, several experiment offshore wind turbines as prototypes were installed, operated and maintained by their own manufacturers. Rudong Trail Project is operated by China Longyuan Power Group Corporation Limited (CLYPG) and maintained by turbine suppliers because the farm is an experiment project. Rudong Offshore Demonstration Wind Farm project is adjacent to 32MW Rudong Trail Project and composed of the first phase of 100MW, the second phase of 50 MW [8] and extension phase of 50MW [1]. The Demonstration Wind Farm is also operated by CLYPG. Because it is still during warranty period, all turbines of the Demonstration Wind Farm are maintained by their manufacturers.

As the first commercial offshore wind project of China, Donghai Bridge Project has been put into operation more than two and half years, and it has become a benchmark of China's offshore wind. By far Donghai Bridge Project is only one which can provide helpful experiences for operation and maintenance of offshore wind farm in China.

Operation and Maintenance of Donghai Bridge Project

The Profile of Donghai Bridge Project. Donghai Bridge Project is specially designed for Shanghai World Expo 2010 with strong political purpose. It was built, managed by a consortium of four companies. The wind farm is composed of thirty-four 3 MW wind turbines in four rows along 1,000m east of Donghai Bridge. It connects to grid of the Yangshan deep-water ports and Nanhui Xincheng Town, Pudong District, Shanghai. The wind farm has generated 495GWh electricity by August 2012 since June 2010. The average utilization rate of wind turbines has reached above 95%.

The Three Stages of Operation and Maintenance. In the past three years, the operation and maintenance service has experienced 3 periods for Donghai Bridge Project, and each period has different characteristic. The first six months are phase 1, the second six months are phase 2, and the following two years are phase 3.

Operation and Maintenance during Phase 1. The first six months were most important period. During the first phase, the O&M service team was busy dealing with all kinds of issues of O&M even there were more than 40 on-site engineers in the service team. As nobody of service team had any experiences of offshore O&M with their previous work, the service team had to spend several months to learn how to understand the working characteristics of offshore wind turbines of Donghai Bridge Project. Usually, the unreliability of wind turbines can be modeled in terms of failure intensity by the bathtub curve, which indicated there were more failures at the beginning of lifetime [9]. The main problems of O&M during this phase could be classified as the following. (1) Wind turbines broke down with unknown reasons. (2) There were no reasonable maintenance programs for some specific faults. (3) Wrong faults/alarm information because of improper design. (4) Frequent malfunction of same components for unreasonable design. (5) Backup components scheduling strategy was not feasible for O&M. (6) The O&M service team was lack of experience of offshore Operation and Maintenance. (7) Bad weather affected service team to solve faults in time. (8) Too much time for one return trip between wind farm and backup store.

In order to solve aforementioned problem, the service team took as much as possible methods to make sure every turbine in good condition. The service team had many engineers from Original Equipment Manufacturer (OEM), who were fully understands the technical specifications of wind turbines. If SCADA system in control center indicated some alarm or failures, the service team could identify the right component explicitly from information of SCADA system. Spare parts of wind turbines are enough to replacing any subsystems of turbine or even the entire turbine. Maintenance inspections were carried out frequently with very short time intervals during the first phase. In order to reach wind turbines more quickly, the service team employed a fishery patrol ship and a maritime patrol ship as transportation tools. Then O&M engineers could get to the wind turbine with failures as soon as possible if the weather condition permitted. The service team collected the daily operation data and repair information of every wind turbines to make its own file which recorded O&M information. These files were very valuable for O&M of the offshore wind turbines.

Operation and Maintenance during phase 2. The second period is from the seventh month to the twelfth months. During second six months, although the wind turbines still suffered a lot of faults and failures, the maintenance team already had proper methods to deal with them and formed reasonable maintenance strategy for wind turbines. The team had set up O&M record files for every single wind turbine of Donghai Bridge Project, which were added new records constantly. According to analysis of previous faults and failures from turbines' record files, the maintenance engineers could diagnose the root cause of particular component faults. With O&M experience of the first half year, the service team became to be familiar with the characteristic of 34 wind turbines. If monitor system in control center gave alarm or fault information of one wind turbine, maintenance engineers could diagnose what kind malfunction it might be from its maintenance record. And according to maintenance record and maintenance experience, engineers could analyze whether it was hardware malfunction or software malfunction. Maintenance staff can solve some software malfunctions of wind turbines through remote control mode without entering into wind turbines. It saved a lot of time cost, human cost and electricity cost because a back and forth to offshore wind turbine took at least one day.

Maintenance team found some false alarms of subsystems of wind turbines happened because of unreasonable design of the subsystems. It was the first time that the domestic wind turbines were installed in offshore farm for Donghai Bridge Project and these turbines were not mature and perfect products for offshore wind. Some parameters of components were designed with very strong restraints without considering practical deviation and exception. Sometime these restraints conducted false alarms and stopped wind turbines. These unreasonable designs were optimized by feedback of maintenance team to design department. For example, at the beginning the lower threshold of generator speed connecting grid was set as 800rpm when the wind turbine was designed. Actually in the farm offshore wind speed changed so quickly that wind speed reduced from 20m/s to 3m/s in very short time and rotor would stop revolution quickly. But invertor of wind turbine was still in working status, therefore it caused malfunction. O&M engineers reported such kind of problems to design department of wind turbine, then design engineers reconsidered experience values and calculated values together and optimized deviation of theoretical values. And false failures mentioned previously could be reduced after optimization.

Operation and Maintenance during phase 3. The recent two years are the third period. From the second year, the offshore wind turbines came into stable stage. With maintenance and optimization in the first year, faults and breakdown of wind turbines' components has reduced dramatically. In the second year, replacement of components reduced to 1 to 2 times and there were no batch recall because of components defects. Hence it resulted that number of maintenance personnel reduced more than 2/3 to about a dozen persons. The maintenance cost of second year reduced 30% comparing the first year. It is estimated that the maintenance cost of third year will be less than the second year. The availability factor of wind turbines had increased 3% in the second year.

There are two maintenance approaches employed in O&M of Donghai Bridge Project. Generally, reactive maintenance and preventive maintenance approaches are used simultaneously for O&M of wind turbines. The combination of reactive maintenance and preventive maintenance is consisted of regular inspections, failure elimination, and regular maintenance. The maintenance team executes total maintenance for every wind turbine in every six month as regular maintenance after the first regular maintenance on fourth month. The execution of regular inspections and failures elimination depends on weather condition. They usually were arranged on days without wind or with breeze. The service team tried their best to avoid days with strong wind in case affecting power generation. On the other hand, regular inspections and failures elimination cannot be done if weather is too bad to reach wind turbines.

The maintenance team is beginning to consider another maintenance approach: predictive maintenance as advanced maintenance method. Because predictive maintenance monitors wind turbines' parts constantly and detects problems well in advance of actual failures, it can reduce non-scheduled maintenance of turbines. The team provides oil analysis report of components to expert to determine whether the amount of oil is within right range. The oil analysis report also can be used to predictive change trend of oil capacity for the long term maintenance. Predictive maintenance lowers inventory costs as it helps to deploy new component backup scheduling plan and optimize spare parts inventory.

Conclusion

Chinese government encourages developing offshore wind energy and intends to be a leader of offshore wind in the world. O&M of offshore wind turbines accounts for important part of the lifetime cost. The share of O&M costs of offshore wind is significantly higher than onshore wind in China, and it is higher than counterpart of countries of EU. Optimizing O&M is a priority for China's offshore wind development. Donghai Bridge Project is the first commercial offshore wind farm in China and analyzing its O&M is the best way to understand O&M of offshore wind turbines in China. The relatively high O&M cost of Donghai Bridge Project indicates that there are a lot work needed to be done in order to make O&M cheaper and more effective.

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