Analysis on operation reliability of wind power units in China

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Abstract. As an important direction of renewable energy, wind energy has developed rapidly, but there are also many problems. The reliability of wind turbines has received wide attention. This paper mainly studies and analyzes the development of wind turbines, basic structure, operation and maintenance of the unit, and then puts forward suggestions for improving the reliability of wind turbines in China.

1. Introduction

1.1. Significance
As power source and environmental issues become more prominent, as a clean renewable energy [1], wind power is relatively mature, with short construction period, low environmental requirements, low immigration, flexible scale, low investment cost and the characteristics of environmental and ecological impact are more and more people's attention [2-6]. Last several years, strong supporting from China for power generation [7-9], the present situation and development prospect of wind power industry is quite considerable[10-13].

However, along with the fast growth of the scale and quantity of wind power generation, the operation reliability problem of wind power equipment has become more and more prominent. Thus, it is very imperative to develop research on the wind turbine operation reliability analysis.

1.2. Research status
It can be seen from figure 1 and table 1 that the installed capacity of wind power in China shows a linear growth trend, and the proportion of total installed capacity in the country has increased from 5.36% in 2012 to 9.20% in 2017. Among them, the net increase capacity of wind turbines in 2015 was 34.44 million kilowatts, reaching the maximum in recent years [14]. This is mainly due to the fact that the installed capacity of wind power and solar power has basically reached the national 13th Five-Year Plan. In the next few years, the development of wind power industry will gradually slow down and will form a competitive situation with conventional energy thermal power units.
2. Wind turbine operation reliability

2.1. Wind turbine basic mechanism
Wind turbines are important equipment for converting wind energy into electrical energy. According to the structure of the wind wheel and its position in the airflow, there are two main types of wind turbines: horizontal axis wind turbines and vertical axis wind turbines [15]. According to the function and installation position of each part of the wind turbine in the whole fan system, the wind turbine can be divided into six major systems: rotor system, gearbox system, generator system, tower system, other mechanical systems and other subsystems.

2.2. Wind turbine classification
Generally, according to the blade characteristics of the unit, it is divided into a fixed pitch fan and a variable pitch fan; according to different control modes of the speed, it is divided into constant speed constant frequency and variable speed constant frequency; according to different generator technologies, it can be divided. It is a common induction motor, doubly-fed motor and permanent magnet synchronous motor [16]. At present, the main types of fans are fixed-pitch stall and variable-speed pitch-type fans, among which variable-speed pitch-type fans cause high wind energy utilization and occupy a dominant position in the market.

1.3. Insufficient research
In the early stage of the country, the operational reliability of thermal power units was mainly concerned, while the focus on the reliability of new energy fields, especially wind turbines, was relatively small. Based on this, this paper will elaborate on the reliability of wind turbine operation in China.

| year | total power generation/(10^6MWh) | percentage increase over the previous year/% | wind power generation/(10^6MWh) | Percentage of total power generation/% | utilization hours |
|------|---------------------------------|---------------------------------------------|---------------------------------|----------------------------------------|------------------|
| 2012 | 49865                           | 5.41                                        | 1030                            | 2.07                                   |                  |
| 2013 | 53721                           | 7.73                                        | 1383                            | 2.57                                   |                  |
| 2014 | 55725                           | 3.73                                        | 1599                            | 2.87                                   |                  |
| 2015 | 56938                           | 2.18                                        | 1853                            | 3.25                                   | 1731             |
| 2016 | 59897                           | 5.20                                        | 2410                            | 4.02                                   | 1745             |
| 2017 | 62758                           | 5.90                                        | 3057                            | 4.80                                   | 1948             |

Figure 1. Wind power installed capacity from 2012 to 2017.
2.3. Wind turbine operation in 2017

In 2017, the average utilization hours of wind turbines was 1930.11 hours, the average annual number of unplanned outages was 2.43, and the average annual unplanned outage was 37.64 hours. Among them, the gearbox and pitch adjustment system caused the largest number of cumulative non-stops and accumulated time, accounting for 46.48% and 38.47% respectively. It can be seen that the gearbox, pitch adjustment system and centralized control system are the top three main causes of unplanned outages of wind turbines. See table 2 and figure 2 for details.

Table 2. Wind turbines unplanned to stop the top 10 components in 2017.

| part name                        | number of outages | outage hour | time percentage |
|----------------------------------|-------------------|-------------|-----------------|
|                                  | grand total       | average     | average         | percentage  |
|                                  | number of years per year | per year | every time      |              |
| gearbox                          | 833               | 32132.67    | 3.17            | 38.57       | 46.48       |
| pitch adjustment system          | 859               | 26599.37    | 2.63            | 30.97       | 38.47       |
| centralized control equipment    | 402               | 8229.58     | 0.81            | 20.47       | 11.9        |
| generator cut-in control loop    | 40                | 1615.42     | 0.16            | 40.39       | 2.35        |
| cabin cooling control loop       | 23                | 229.1       | 0.02            | 9.96        | 0.33        |
| overhead line other              | 12                | 153.65      | 0.02            | 12.8        | 0.22        |
| lightning protection equipment   | 11                | 90.23       | 0.01            | 8.2         | 0.13        |
| communication system other       | 2                 | 25.7        | 0               | 12.85       | 0.04        |
| circuit breaker operating mechanism | 2              | 25.05       | 0               | 12.53       | 0.04        |
| reactor other                    | 1                 | 15.82       | 0               | 15.82       | 0.02        |

A large number of operational and statistical data indicate that gearbox failure is one of the key factors for long-term outages of offshore wind power and onshore wind turbines. According to the relevant literature, the average repair time of the gearbox of the onshore wind turbine is 256.7 hours,
and the repair and replacement time of the offshore wind turbine gearbox is longer, which may take 360 hours [17].

The control system is one of the main components in the offshore wind turbines and onshore wind turbines that cause high shutdown frequencies.

2.4. Gearbox common fault
Common faults in wind turbine gearboxes include gearbox vibration and sound anomalies, high bearing temperatures, and leakage oil. The main components of the gearbox failure are: rotating parts such as bearings, toothed parts, etc., second, lubrication and sealing systems such as oil pumps, cooling fans, etc.; third, fastening parts such as bolts.

- The vibration and sound of the gearbox are mainly due to the relative motion. The gears and bearings are the main components of the gearbox transmission. Therefore, the vibration and sound of the gearbox are mainly caused by the gear section and the tooth surface. Gluing and pitting caused during the operation of the gear, rusting of the gear surface caused by long-term stagnation of the gear box, bearing quality problems, misalignment of the coupling, and too much dynamic balance.

- The bearing temperature is high, or the temperature difference between the bearings on the same shaft is large, mainly related to the lubrication point oil quantity, the lubricating oil temperature, the temperature sensor damage, the bearing's own clearance, the injection hole diameter, the bearing damage and other factors. It should be checked item by item whether the amount of lubricating oil in the part is normal, whether the injector is blocked, whether it is aligned with the bearing ball, whether the temperature sensor is working normally, whether the bearing is damaged, whether the oil temperature is too high, and whether the oil return is smooth, etc. Find the reason for the high temperature.

- The high temperature of the gearbox oil is a common fault of the wind farm in the gearbox. The main reason is that the oil pump temperature control valve fails, so that the lubricating oil does not pass through the cooling fan but returns directly to the gear phase. In addition to cooling, it is also necessary to check whether the oil level of the gearbox is normal, whether the oil level sensor is damaged, whether the oil cooler is working or the setting value is too high.

3. Wind turbine maintenance
Wind farms generally use an operation and maintenance strategy that combines preventive maintenance and post-repair.

3.1. Preventive maintenance
Preventive maintenance has two types of regular maintenance and status maintenance. Regular maintenance is a preventive inspection and maintenance of the fan based on a pre-established maintenance plan, mainly to check the status and function of each part of the fan. Regular maintenance keeps equipment in optimum condition and extends the life of the turbine. In order to improve the utilization of wind resources in wind farms, regular maintenance is generally scheduled to be carried out with a small wind speed. It is understood that the regular maintenance of offshore wind farms in the UK is generally scheduled for summers with small wind speeds, while China's offshore wind farms generally adopt a regular maintenance strategy twice a year [18]. Taking into account the characteristics of the climate of the wind farm, regular maintenance needs to avoid the tropical cyclone and wind energy enrichment period, generally arranged in May and November of each year, the onshore wind farm is arranged in the small wind season from July to September.

State maintenance refers to the maintenance strategy formulated by the wind state monitoring system and related state information combined with the results of online or offline health diagnosis or failure analysis system. In the operation and maintenance of wind farms, in addition to the preventive maintenance of the state of the wind farm components, the state maintenance can be combined with
the weather information, wind farm multi-unit status information, fault information, maintenance. The optimal balance point between decision-making at cost, resource loss and production efficiency is comprehensively considered to determine the most efficient maintenance method.

3.2. Post-repair
Trouble-shooting refers to the maintenance that occurs after a fault occurs. It is a common maintenance method for current onshore and offshore wind turbines. Since most of the after-sales repairs need to be boarded for processing, there are certain requirements for offshore wind turbines to understand sea weather conditions, traffic and maintenance tools, etc. Maintenance time, maintenance costs, and power outage losses will vary greatly from time to time.

4. Suggestions on improving the reliability of wind turbine operation
- First of all, from the state, industry to power generation management enterprises to the grassroots power generation enterprises to raise the importance of the importance of wind turbine operation reliability management from top to bottom. The reliable operation of wind turbines is the guarantee and premise of the economic benefits of wind power enterprises.
- Strengthen the operation and maintenance level of wind farms. It is understood that the operation and maintenance of wind farms in China has a significant gap compared with the production operations of foreign wind turbines and domestic thermal power units, and there is a lack of detailed records and analysis of problems and faults that occur during operation. However, with the rapid expansion of wind turbine assembly machines, the Chinese government has recognized these problems, and wind power development will usher in a qualitative leap in the near future.
- Strengthen the integration of traditional wind power plants and big data Internet of Things. Accelerating the construction of smart wind farms is a new trend in liberating the labor force of power generation enterprises in China, and allowing professionals to undertake more important professional work.
- Focus on key component status prediction techniques. Since the probability of unplanned outages of wind turbines caused by key components is much higher than that of general components, it is necessary to focus on the prediction technology of critical component health status.

5. Conclusion
In the future, the energy supply structure will change from fossil energy to non-fossil energy, from traditional energy sources such as water and fire to the synergy between new energy and traditional energy such as scenery, and gradually achieve clean alternatives to energy.
- Nowadays, the unplanned outage time and unplanned outages of wind turbines in China are relatively high. The reliability of gearbox, pitch adjustment system and control system and other components should be emphasized. Wind turbine condition monitoring and health diagnosis in combination with the fan operation and maintenance strategy for optimization research, the maintenance cost of the fan is the smallest and the reliability is the greatest.
- It is recommended to carry out reliability research based on fatigue life of wind turbines. Fatigue failure is the main failure mode of wind turbines, so it is necessary to study the fatigue life and reliability of the whole machine.
- Under the current situation of large-scale grid connection of domestic wind power, rational use of the peak shaving capacity of thermal power units to promote the consumption of wind power is crucial to the development of China's new energy industry.

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