Research and application of quality assurance evaluation method for wind turbines based on operating data

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Abstract—With the rapid development of China's wind power, a large number of wind turbines will reach the warranty period in the next few years. As an important part of the acceptance evaluation work, power performance assessment is receiving more and more attention. In order to objectively and efficiently evaluate the power curve performance of wind farm units during the warranty period, this paper uses SCADA data to perform power curve evaluation, develops the evaluation method, and uses wind speed to correct the results. Finally, combined with the actual case of wind farm, the feasibility of this estimation method is verified. The method proposed in this paper provides a basis for conducting wind power quality assurance acceptance.

1. INTRODUCTION

Due to the rapid development of China's wind power industry, many problems have arisen in the actual operation of wind turbines, such as wind power disconnection, fault damage and other problems[1-3]. In order to promote the sustainable and healthy development of the wind power equipment manufacturing industry, China's National Energy Administration issued the policy guidance document to regulate the order of the wind power equipment market on September 5, 2014. The document requires strengthened testing and certification to ensure the quality of wind power equipment and regulate the quality acceptance of wind power equipment. At the same time, it emphasizes that the acceptance of the warranty period is an important part of the quality management of wind power equipment.

Compared with thermal power generation, wind power generation is an emerging industry, and related technologies need to be improved. At present, wind farm quality assurance acceptance lacks a unified standard and enforcement mechanism. This situation has led to differences between wind farm developers and wind turbine manufacturers, which has made it more difficult for wind turbines to have a smooth warranty.
Among them, the most prominent problem is the inconsistent understanding of the power curve of wind turbines. Some wind farm managers have many misunderstandings about the understanding of the wind turbine power characteristic curve. At the same time, in terms of the acceptance of wind turbines, the wind power industry currently lacks a complete standard system and testing and certification system[4-6]. Therefore, many unnecessary disputes occurred during the operation and quality assurance of the wind farm.

At present, wind power managers widely use data collection and monitoring SCADA system to monitor the operating status of wind turbines and their components[7]. The SCADA system can collect wind turbine operation information at high speed, and has massive monitoring data. By analyzing these data, we can achieve the working status of each wind turbine. At the same time, SCADA data evaluation can be used to find the differences between the actual operation and the design stage, and formulate corresponding rectification plans to improve the performance and quality of wind turbines.

2. REQUIRED ACCEPTANCE CONDITIONS
Aiming at the safety and stability requirements of wind turbines, according to the standard specifications, this paper mainly proposes the following technical requirements.

(1) The wind turbine must be able to meet the technical performance indicators specified in the contract, and no abnormalities have been found in various on-site inspections and auxiliary verification.

(2) The SCADA system is operating normally, and the automatic investment rate and protection investment rate are 100%. The system runs stably, and the indicators and control accuracy can meet the contract requirements. This can implement various functions required by the contract, such as real-time monitoring and operation of each wind turbine.

(3) Assessment indicators such as the availability and failure rate of wind turbines meet the contract requirements.

(4) Frequent failures caused by component quality or design problems have all been resolved. Prior to the wind power warranty acceptance, there were no controversial issues.

(5) The performance of wind turbines can meet the technical standards of the industry, and its technical indicators can meet the requirements of power grid companies, such as unit safety, power characteristics, power quality, noise and other performance in accordance with relevant national standards.

According to the actual situation, this paper proposes data collection and analysis and processing methods. First of all, it is necessary to collect the operating data of the wind turbine. These data are sorted and processed to obtain accurate and reliable operating data. Specifically, the module first accesses the wind farm data storage server and collects all historical operating data of each unit in the wind farm. These data are mainly wind resource parameters, such as wind direction, wind speed, and ambient temperature. In addition, a large number of unit status data can be obtained, such as the unit's blade speed, real-time power, pitch torque, and pitch angle. At the same time, various fault statistics of the unit will be collected to lay the foundation for a comprehensive analysis of the operating data of the wind turbine. Secondly, after completing the collection of unit operation data, these data must be sorted, cleaned, and standardized.

In order to process the data efficiently, this paper first classifies the data. Secondly, the cleaned-up data can be cleaned through software-based automatic cleaning and manual intervention as a supplement, according to the relevant cleaning rules. The abnormal data and erroneous data in the data will be eliminated, and related data cleaning reports will be issued. Finally, this paper conducts standardization of data. Decompose, summarize and average the data of different attributes according to a certain time interval. After the above process, the data meets the standardization requirements, and the data is mapped to the corresponding data structure of the running data analysis software, which ultimately promotes the subsequent work.
3. IMPLEMENTATION PLAN

As an important part of the quality assurance acceptance of wind turbines, power performance assessment directly determines whether the wind power project can successfully pass the warranty period. Generally, wind turbine manufacturers usually provide the guaranteed power curve of wind turbines at standard air density[8]. As shown in Fig. 1, this is the standard power curve for wind turbines promised by wind turbine manufacturers. Some wind turbine manufacturers also provide guaranteed power curves for wind turbines with different air densities. The wind farm builder needs to make curve corrections based on the actual air density of the wind farm. In this way, the wind turbine can be guaranteed to follow the maximum power tracking mode.

![Theoretical Power Curve of Wind Turbine](image)

Figure 1. Theoretical Power Curve of Wind Turbine

In order to calculate the theoretical power generation of the computer group, it is necessary to calculate the theoretical power generation of the unit under actual wind conditions based on the power curve. In the actual calculation process, it is necessary to eliminate the situation that the unit does not have active power limitation and the grid command power limitation. At the same time, based on the wind speed of the cabin anemometer, the power curve of the unit is calculated using a statistical regression algorithm, and the corresponding theoretical power generation is calculated based on the power curve.

Relying on the actual wind turbine power curve, the annual power generation of the actual wind turbine can be calculated and measured, and compared with the annual power generation under the premise of ensuring the power curve. This ratio is mainly used to evaluate the power curve of a single wind turbine. In addition, wind turbine manufacturers will make further requirements for uncertainty and turbulence intensity.

Through research and information review, wind farm developers and wind turbine manufacturers usually adopt the following assessment methods[9]. First of all, the two sides have determined the implementation period of the assessment. It is generally stipulated that the wind turbine will only officially enter the start time of quality assurance acceptance after 240 hours of reliable operation. The assessment period can only end when a full year operating period is reached. After consultation between the two parties, a certain percentage of wind turbines can be selected for spot checks, or all units can be selected to participate in the assessment. Secondly, in order to provide work efficiency, based on the negotiation between the two parties, SCADA data can be used for performance evaluation. If the evaluation result is not approved, the power curve measurement can be performed using the IEC61400-12 standard. Finally, the evaluation results of the wind turbine power curve were obtained, and improvement measures and rectification periods were formulated. If the contract requirements have not been met, the wind turbine manufacturer needs to pay compensation.
4. TYPICAL CASE ANALYSIS
A wind farm in Shandong province, is located in dongying area rich in wind energy resources. The total installed capacity of the wind farm is 50MW. The units are all of a certain type of permanent magnet direct drive variable pitch 2.0MW. The diameter of impeller is 82m. According to wind data from the wind farm, the air density in this area is 1.225kg/m³, and the average annual wind speed at the height of 70m is 7.4m/s.

When the quality assurance acceptance is carried out, four wind turbines are randomly selected. According to the previous description, this paper uses the data of the SCADA system to draw the power curve of the wind turbine on the basis of one year's wind speed and power, and evaluate the annual power generation. The evaluation results show that the annual generating capacity of the five units has reached more than 98% of the contracted generating capacity at the average annual wind speed, which meets the warranty requirements. The evaluation results are shown in Table 1.

| Number of wind turbine unit | Data results of 2# wind turbine | Data results of 9# wind turbine | Data results of 12# wind turbine | Data results of 26# wind turbine |
|-----------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
| 3m/s                        | 101.4                          | 102.7                          | 101.7                          | 99.0                           |
| 3.5m/s                      | 103.0                          | 102.8                          | 101.6                          | 101.3                          |
| 4m/s                        | 98.6                           | 102.8                          | 99.5                           | 102.4                          |
| 4.5m/s                      | 100.2                          | 99.0                           | 101.8                          | 103.2                          |
| 5m/s                        | 101.7                          | 102.6                          | 98.7                           | 103.7                          |
| 5.5m/s                      | 100.3                          | 98.5                           | 102.0                          | 100.3                          |
| 6m/s                        | 100.1                          | 102.9                          | 100.3                          | 101.6                          |
| 6.5m/s                      | 98.3                           | 102.2                          | 100.9                          | 101.6                          |
| 7m/s                        | 98.1                           | 101.9                          | 100.0                          | 98.8                           |
| 7.5m/s                      | 99.0                           | 100.3                          | 102.2                          | 102.5                          |
| 8m/s                        | 99.1                           | 99.0                           | 100.0                          | 103.7                          |
| 8.5m/s                      | 101.0                          | 100.1                          | 102.4                          | 98.4                           |
| 9m/s                        | 101.8                          | 101.7                          | 102.3                          | 102.6                          |
| 9.5m/s                      | 100.1                          | 102.1                          | 101.3                          | 103.4                          |
| 10m/s                       | 102.7                          | 100.4                          | 102.3                          | 98.7                           |
| 10.5m/s                     | 99.0                           | 99.1                           | 99.7                           | 102.0                          |
| 11m/s                       | 100.3                          | 102.9                          | 102.9                          | 103.5                          |
| 11.5m/s                     | 101.3                          | 103.2                          | 103.6                          | 103.8                          |
| 12m/s                       | 101.6                          | 103.4                          | 103.8                          | 103.9                          |
| 12.5m/s                     | 101.7                          | 103.5                          | 103.9                          | 103.9                          |
| 13m/s                       | 101.9                          | 103.8                          | 104.0                          | 104.1                          |
| 13.5m/s                     | 102.0                          | 103.9                          | 104.2                          | 104.2                          |
| 14m/s                       | 102.1                          | 104.0                          | 104.3                          | 104.3                          |
| 14.5m/s                     | 102.2                          | 104.2                          | 104.4                          | 104.5                          |
| 15m/s                       | 102.3                          | 104.2                          | 104.5                          | 104.5                          |

From the above data analysis, comparing the SCADA data with the evaluation results and the standard power curve measurement results, it is found that there is a large difference between the actual power curve of the wind farm measured by this model in the warranty wind farm and the power curve. After several investigations and data analysis, it was found that the turbulence of the quality assurance wind farm was greater than the design value. Therefore, the manufacturer modified the control strategy, which caused the unit's actual power curve to be lower than guaranteed.
From the above data, it can be concluded that the operating power curve of a wind turbine can determine the operating characteristics and power characteristics of the unit. This can effectively evaluate the power generation efficiency of the unit and the actual annual power generation. In the design stage, the overall performance of the wind turbine can be tested by the power curve of the overall parameters of the wind turbine, and the overall performance of the wind turbine can be predicted. In addition, control system design, generator selection and transmission coefficient efficiency are all closely related to the power curve.

5. CONCLUSION
The validity of the proposed method is verified by carrying out the actual wind power power curve acceptance evaluation. This paper uses SCADA system data to evaluate the performance of wind turbines. This evaluation method is not limited by the site and sampling units, and has a wide range of applications. At the same time, it is also found that there is a deviation between the cabin wind speed data and the actual wind speed. This situation has a great impact on the evaluation of the direct use of operating data, and it is necessary to ensure that the anemometer measurement is accurate.

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