Research on the method and data analysis of wind power characteristic test

Ning Hu*  
1State Grid Dongying Power Supply Company, Dongying, Shandong Province, 257091, China  
*Corresponding author’s e-mail: sdyhn19@sohu.com

Abstract. The actual operating power curve of wind turbine is affected by many factors. Therefore, it is difficult to measure the power characteristics accurately. Firstly, this paper mainly analyzes the main factors that affect the power curve of wind turbine in the operation process, develops the power curve test scheme of wind turbine, and establishes the simulation analysis model. Finally, combined with the actual operation of the wind farm, the field test of a certain type of wind turbine is carried out. The data results verify the validity of the test method, and provide reference for improving the operation efficiency of wind farms.

1. Introduction
Because of the rapid progress of wind power technology, the position of wind power in the power system will become increasingly important. When the wind turbine is connected to the power grid, accurate modeling of the wind turbine has important implications for power balance, power quality, and system stability. The accuracy of the model and parameters will affect the stability and safety of the power grid and the optimal operation of the wind power system[1-2].

As an important evaluation index for evaluating the power generation capacity of wind turbines, the wind power curve is the design basis of wind turbines. When a wind power generator manufacturer provides customers with wind power equipment, the manufacturer must first provide the standard power curve of the wind turbine. If the actual power curve obtained during the test is higher than the set standard power curve, the wind turbine will be overloaded. This situation will lead to overload operation of the wind turbine unit, and long-term overload operation will shorten the service life of the wind turbine unit. If the measured power curve is lower than the standard power curve provided by the manufacturer, the generating capacity of the generator set will decrease, which will affect the total power generation of the wind farm. Therefore, it is necessary to evaluate the operating status of the wind turbine based on the power curve of the wind turbine. At the same time, according to the environment at different wind power sites, optimizing the wind turbine power curve is of great significance to improve the utilization level of wind power equipment.

At the stage of design evaluation or design certification, most domestic manufacturers did not carry out field test of power curve of wind turbines. The theoretical power curve is mostly obtained through design simulation[3-4]. However, due to factors such as on-site wind conditions, transmission chain damping, and system wind measurement, the actual power curve of the unit will differ from the theoretical power curve. Due to the difference in wind conditions, different units of the same model in the same wind farm will also cause the operating power curve and power generation of the units to be
different[5-6]. Therefore, it is very important to establish a wind speed-power characteristic curve that can accurately reflect the actual operating characteristics of a wind turbine.

2. Implementation plan and data analysis
Randomness and intermingles are characteristics of wind speed. The frequency distribution of wind speed can assess whether the region has abundant wind energy resources. In order to reflect the relationship between the wind speed of the wind farm and its output power, a calculation and analysis model of the wind farm is established[7]. Through the control system and remote monitoring system, the power curve is continuously recorded during the operation of the wind turbine. Due to the influence of environmental factors and unit characteristics, the power curve of wind turbines is not completely consistent, especially at different points in time and in different seasons. The calculation formula is shown below[8-9].

\[ P = \frac{1}{2} C_p A \rho \nu^3 \]  

(1)

In this formula, \( P \) represents the theoretical maximum output power of a wind turbine, \( l \); \( C_p \) is the wind energy utilization coefficient, with a maximum value of 0.593. \( A \) is the blade sweep area, \( \rho \) is the air density, and \( \nu \) is the force wind speed of the wind turbine.

According to the Bezi limit, the theoretical maximum value of \( C_p \) is 0.593. This means that wind turbines can convert up to 59.3% of wind energy into electricity[9-10]. Due to various conditions, the wind turbine cannot reach the maximum output power. The output energy of the wind turbine's wind turbine is usually 65-70% of the theoretical output of the wind farm. This is caused by various factors such as electric field electricity consumption, equipment loss, wake, air density, wind turbine usage rate, power curve accuracy, climate and other factors[10-11].

As an important indicator, the power curve can assess the economics of wind turbines, which can improve the level of operation management. By comparing the horizontal data of the wind turbines in the same area, managers can not only verify whether the wind turbines' operating conditions meet the manufacturer's design values, but also find problems with the operation of the wind turbines, which can ultimately increase power generation.

The actual operating power curve, which reflects the performance of the unit, takes a long time to form. Due to the limitation of objective conditions, the unit cannot form a complete and accurate power curve that reflects its performance in a short period of time. According to GB/T 18709-2002 "Method for Measuring Wind Energy Resources in Wind Farms", the collection of measurement data should meet the requirements of continuity and integrity. On-site measurements should be made continuously and should not be less than one year. The complete rate of measurement data collected on site should reach more than 98%. The time interval for collecting data should not exceed 1 month.

3. Field test

3.1 Test Data
SCADA (Supervisory Control And Data Acquisition) system is widely used in data acquisition, process control, monitoring and control. In the wind power industry, the SCADA system can help operators monitor the operating status of the system, quickly diagnose whether the system is faulty, and improve operational efficiency.

This paper selects a wind farm in Dongying City, Shandong Province for case analysis. This area is close to the sea and is a key area for wind power development in Shandong Province. A total of 24 wind turbines are installed in this wind farm. The rated capacity of each wind turbine is 2MW. The total installed capacity is 48 MW. The electricity generated by each wind turbine is boosted to 35 kV
through a transformer, and sent to the 110 kV substation of the wind farm to boost the voltage to 110 kV through two lines, and then finally connected to the grid. Before the construction of the wind farm, southerly and northerly winds were detected in the area, and about 70% of the time is suitable for wind power. According to this calculation, the average power generation time of each fan is about 2000 to 2300 hours per year.

According to the method proposed in this paper, the power characteristic test of the wind farm is carried out. The experimental results are shown in the following table.

| Number of wind turbine unit | Distance from the unit under test (m) | Relative bearing of the unit under test | Rotor diameter (m) |
|-----------------------------|------------------------------------|---------------------------------------|------------------|
| FD03                        | 722.16                             | 179.32                                | 82               |
| FD06                        | 408.48                             | 242.65                                | 82               |
| FD07                        | 622.11                             | 25.12                                 | 82               |
| FD09                        | 376.52                             | 312.26                                | 82               |
| FD12                        | 672.44                             | 339.48                                | 82               |
| FD15                        | 736.29                             | 182.16                                | 82               |

3.2 Data Processing

High-precision wind power curve is an important basis for wind farm fan site selection, wind turbine design, assessment of wind turbine generating capacity, and estimation of wind turbine losses. During the test, the power generation and wind speed of the wind turbine are measured simultaneously. Based on these test data, this paper determines the power curve, power coefficient, and annual power output of the wind turbine. The following processing results are based on test data from January 13, 2018 to April 15, 2018. According to relevant standards, a 10-minute average was used for calculation.

This paper analyzes the characteristics of wind speed characteristics, wind power generation, and abnormal data in wind farms. Secondly, use the spectral clustering algorithm to identify and eliminate abnormal data. Finally, the wind power curve is established and the wind power output is predicted. Based on the test data, the wind power curve was optimized and the error evaluation index was improved.

3.3 Test results

The data sets selected from the test need to be converted back to the data at the two reference air densities. The standard power curve is obtained under the conditions of standard atmospheric pressure 1013.3 h Pa and 15 °C. The relationship between wind speed and power is obtained through the design parameters of the wind turbine. However, the actual working conditions of the wind farm do not meet the conditions for drawing the standard power curve, so the standard power curve is different from the actual operating power curve.

Before the power characteristic test is carried out, the site calibration is performed to determine the wind speed relationship between the position of the wind turbine and the position of the wind measurement tower. The power coefficient of the test unit is shown in Figure 1.

It can be seen from the figure that the power changes with the wind speed. In the operation of a wind turbine, the power curve is an important index parameter to measure the performance of the wind turbine. The power curve mainly depends on two parameter points. One of the parameter points is the slope of the curve of the wind turbine before reaching the rated power, which reflects the power output of the unit in the low wind speed section. The larger the slope, the better the low wind performance of the unit. Another parameter point is the wind speed when the rated power is reached.
4. Conclusion

The actual output power of a wind turbine is not only related to the arrangement of the wind turbine and the weather environment, but also to the performance of the wind turbine. This paper analyzes the influencing factors of the power curve, formulates the field test plan, and analyzes the field data to draw the power curve of the wind turbine. Based on this test data, wind power prediction can be performed. By improving and optimizing the power curve, the wind turbine can be adjusted to a better working state.

References

[1] Yin, Zonglin., Xiao, Zhenhai., et al. (2017) Research and practice on control strategy optimization and power generation enhancement of wind turbines. Wind Energy, 2:66-69.
[2] Wang, Haichao., Zhou, Shuangxi., et al. (2009) Calculation of wind power penetration level based on dependent chance goal programming. Modern Electric Power, 26:54-57.
[3] Datta, R., Ranganathan, V. T. (2007) Discussion on configuration optimization of wind power capacity. Electric Power Automation Equipment, 27:36-38.
[4] He, Dongsheng., Liu, Yongqiang., et al. (2008) Study of the shunt-connected wind power generation system. High Voltage Engineering, 34:3347-3354.
[5] Li, Peng., Liu, Chun., et al. (2015) Study on the modeling method of wind power time series based on fluctuation characteristics. Power System Technology, 39:208-214.
[6] Wang, Mingjun. (2017) Analysis of power curve and power generation of wind turbine. Wind Energy, 10: 50-54.
[7] Yang, Mao., Yang, Qiongqiong., et al. (2018)Review of modeling of wind speed-power characteristic curve for wind turbine. Electric Power Automation Equipment, 38:34-43.
[8] Zou, Jin., Lai, Xu., et al. (2014) Time series model of stochastic wind power generation. Power System Technology, 38: 2416-2421.
[9] Rao, Risheng., Ye, Lin., et al. (2016) Wind farm power curve optimization based on actual operating data. Electric Power, 49: 148-153.
[10] Lou, Jianlou., Xu, Jia., et al. (2016) Synchronous sampling method based on measurement of switch data transmission delay. Automation of Electric Power Systems, 40: 23-28.
[11] Zhao, Yongning., Ye, Lin., et al. (2014) Characteristics and processing method of abnormal data cluster caused by wind curtailments in wind farms. Automation of Electric Power Systems, 38: 39-46.