Research on wind turbine power performance based on the operation Data

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Abstract. The power characteristics are important for evaluating the operating state of the wind turbine. In order to accurately evaluate the performance of the actual 2.0MW wind turbine, this paper firstly collects the measured wind speed, power and other operational data reflecting the performance of the wind turbine, and analyzes the data according to the standard specification. On the basis of data analysis, this paper obtains the actual power curve of wind turbine, and then compares it with the theoretical power curve. Finally, this paper carries out comparative analysis and performance evaluation of wind turbine operation performance, and propose improvement measures on this basis.

1 Introduction

The generation capacity of a wind turbine depends on its power characteristics and wind energy utilization coefficient characteristics. Due to the big difference between the actual wind farm wind conditions and environmental conditions, there is a certain difference between the actual operation conditions and design conditions of wind turbines. In addition, there are other factors affecting the unit performance, such as the operation mode of the wind farm, equipment operation. Therefore, these factors will lead to the difference between the actual operation characteristics and the design of the wind turbine, which will affect the actual generating capacity of the wind turbine [1-3]. By measuring the actual operating parameters of the wind turbine, the characteristics of the wind turbine can be evaluated. This can not only verify the design performance of wind turbine units, but also judge the variation trend of unit performance in the long run.

2 Project overview

Wind turbine power characteristic test is mainly based on IEC61400-12-1. On this basis, the running state of the unit can be evaluated accurately. Based on these data, the annual generating capacity of wind turbines can be estimated, so as to analyze and explore potential faults of wind turbines. Therefore, it is very urgent for wind farm operators to test the power characteristics of wind turbines.

The power characteristics of wind turbines are mainly reflected in the following factors, such as power curve, annual generation capacity and power coefficient[4-5]. The external factors that affect the power characteristics of wind turbines are mainly composed of terrain, air density, atmospheric pressure and wind conditions [6-7]. Therefore, in order to accurately test the power characteristics, it is necessary to collect enough data covering a certain range of wind speed and atmospheric conditions. On the basis of these data, the power output characteristics of wind turbine are determined accurately through analysis and calculation. According to IEC61400-12-1 standard, this paper carried out the power characteristic test of wind turbine. The test flow is shown in Figure 1.

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Figure 1. The process of wind turbine power characteristic testing

3 Testing principle

The wind turbine absorbs the wind energy through the wind turbine and converts it into the rotating mechanical energy of the wind turbine, which drives the generator to generate electricity and realize energy conversion [4-6]. When the wind velocity is v , the wind energy acting on the impeller in unit time is calculated by the following formula.

$$E = \frac{1}{2} \rho S v^3 \quad (1)$$

In this formula, S is the swept area of the wind wheel; ρ is the density of air.

Restricted by aerodynamic characteristics, wind turbines can only absorb part of the wind energy. According to Baez theory, under ideal wind turbine conditions, the maximum power that a wind turbine can obtain from wind energy can be calculated by the following formula[6-9].

$$P_{\max} = \frac{8}{27} \rho S v^3 \quad (2)$$

Thus, the theoretical maximum efficiency of the wind turbine is calculated as follows.

$$C_p = \frac{P_{\max}}{E} = \frac{2P_{\max}}{\rho S v^3} = \frac{16}{27} \approx 0.593 \quad (3)$$

In the above formula, it shows that the ideal wind wheel can only absorb a part of the energy from the natural wind, and other unabsorbed parts can be interpreted as the rotational kinetic energy left in the wake.

Because the wind turbine blade structure does not meet the ideal wind wheel conditions, and there are losses in the energy conversion links such as the transmission system and the generator. Therefore, for the actual wind turbine, the actual wind energy utilization factor is lower than the theoretical wind energy utilization coefficient. The useful power output actually obtained by a wind turbine can be expressed as follows.

$$P = \frac{1}{2} \rho S v^3 C_p \quad (4)$$

Considering the limitation of generator capacity, the actual maximum output power of a wind turbine is called rated power. The relationship between the output power of the wind turbine and the wind speed is shown in the solid line in Figure 1. This relationship is called the power curve of the unit. This indicator is mainly used to reflect the performance of the wind turbine. As shown in Figure 1, the theoretical wind energy curve and the wind energy curve absorbed by the ideal wind wheel are given separately.

The power curve of a wind turbine can be divided into several wind speed segments. Meanwhile, the operation mode and characteristics of each wind speed segment are different. The main performance in the following aspects.

1) when the wind speed is lower than the incised wind speed, the wind power is too low to drive the wind turbine to rotate to generate electricity, and the wind turbine is in a static or idle state. In this case, the control system needs to monitor the wind speed. When the wind speed meets the condition of cut - in wind speed, the wind turbine starts to generate electricity.

2) when the wind speed is between the cut-in wind speed and the rated wind speed, the wind turbine can be

integrated into the power grid. In this case, the wind power is lower than the rated power of the unit. In order to capture the maximum wind energy, the blade pitch Angle of the wind turbine remains unchanged at the maximum position. By controlling the speed of the impeller through the torque of the generator, the wind turbine can maintain the best tip speed ratio, which can ensure that the wind turbine can obtain the best wind energy utilization coefficient, and finally make the power curve as close as possible to the baez limit energy curve. Therefore, the performance of wind turbine mainly depends on the design and operation control effect of this wind speed section.

3) when the wind speed is between the rated wind speed and the cut-out wind speed, due to the limitation of the rated power of the generator, the output power of the wind generator set no longer increases with the increase of the wind speed, but keeps the output power constant through the control of the pitch Angle of the variable pitch.

4) when the wind speed is higher than the cutting speed, in order to avoid the damage of mechanical parts, the wind turbine is cut off and stopped, and the blade is adjusted to the position in the direction of the blade.

4 Field test

4.1. Power characteristic Test of Wind Turbine

A wind farm in Jiangsu province, is located in a coastal area rich in wind energy resources. The total installed capacity of the wind farm is 99MW. 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 1.228kg/m³, and the average annual wind speed at the height of 70m is 7.4m/s.

The wind tower is installed at a distance of 2.5d from 159.35 degrees (due north is 0 degrees) of the unit under test. The air flow at the distance wind tower is less affected by the impeller disturbance of the unit and has a good correlation with the output power. The measuring tower is installed in strict accordance with the IEC standard to ensure the accuracy of measurement data. The power transmitter used to measure the power is installed at the wind turbine outlet.

Table 1. Conditions of other wind turbines around the test unit

Number of wind turbine unit	Distance from the unit under test	Relative bearing of the unit under test	Rotor diameter
FD05	723.39m	186.34	82m
FD06	411.48m	238.89	82m
FD08	617.79m	24.81	82m
FD09	367.7m	333.15	82m
FD10	664.44m	359.78	82m
FD05	723.39m	186.34	82m

4.2. Data Processing

Based on the collected data, the power characteristics are evaluated to accurately determine the power output characteristics of the wind turbine. These data should include parameters such as wind speed, wind direction, temperature, humidity and other external conditions. In addition, parameters for the operating state of the wind turbine such as the power output should be included. These data require that the hours of normal operation of the wind turbine need to be much longer than 180 hours.

The acquisition frequency is 10 minutes. The time interval is from October 9, 2017 to November 29, 2017, and the acquisition frequency is 10 minutes.

During the test cycle, the wind speed of the wind turbine appeared less frequently, so this test uses only one database for power characteristics testing.

4.3. Test results

The data sets selected from the test need to be converted back to the data at the two reference air densities [5]. One is the average value of the air density measured at the test site, the magnitude of the change is close to 0.05 kg/m³, and the other is the air density value at sea level, refer to the ISO standard air density (1.225 kg/m³). If the measured air density is in the range of 1.227 kg / m³, there is no need to convert the air density. The power curve test results are shown in Table 2.

Table 2. Power curve data of wind turbine unit measured

Serial number	Bin (m/s)		frequency	active power (kW)	wind speed (m/s)	Power variance	power coefficient	Class A Electrical Power Uncertainty	Class B Comprehensive Uncertainty	Comprehensive Uncertainty
1	1	1.5	109	0	1.253	0.01	0	0.001	6.1	6.100
2	1.5	2	169	0	1.75	0.01	0	0.001	6.2	6.200
3	2	2.5	207	0.2	2.226	0.68	0.002	0.044	6.298	6.928

4	2.5	3	231	1.6	2.728	2.81	0.031	0.181	6.308	6.939
5	3	3.5	215	12.3	3.218	10.35	0.152	0.7	6.807	7.488
6	3.5	4	242	35	3.738	15.01	0.27	0.958	8.059	8.865
7	4	4.5	292	60	4.227	26.35	0.341	1.515	9.42	10.362
8	4.5	5	367	96.2	4.757	38.97	0.376	2.009	10.417	11.459
9	5	5.5	309	154.9	5.246	30	0.43	1.681	16.586	18.245
10	5.5	6	362	209.6	5.742	38.53	0.445	2.008	15.668	17.235
11	6	6.5	363	276.2	6.247	59	0.456	3.081	18.525	20.378
12	6.5	7	329	353.4	6.736	70.56	0.466	3.876	22.53	24.783
13	7	7.5	330	441	7.25	91.72	0.474	5.03	24.755	27.231
14	7.5	8	346	546	7.746	98.85	0.482	5.295	31.231	34.354
15	8	8.5	240	665.7	8.223	105.52	0.488	6.799	36.115	43.338
16	8.5	9	271	779.8	8.72	148.16	0.48	8.924	35.288	42.346
17	9	9.5	198	942.5	9.212	146.28	0.492	10.291	51.502	61.802
18	9.5	10	161	1073.30	9.733	179.33	0.466	13.991	40.49	48.588
19	10	10.5	149	1200.20	10.227	212.36	0.448	17.121	21.895	26.274
20	10.5	11	138	1329.50	10.716	162.28	0.431	13.813	44.634	53.561
21	11	11.5	129	1354.00	11.144	250.62	0.377	22.137	12.36	14.832
22	11.5	12	115	1385.00	11.627	259.04	0.337	24.238	14.57	17.484
23	12	12.5	78	1366.00	12.125	283.99	0.291	32.443	11.487	13.784
24	12.5	13	65	1364.80	12.669	312.75	0.276	38.075	9.381	11.257
25	13	13.5	30	1501.30	13.177	72.54	0.27	12.524	50.591	56.662
26	13.5	14	23	1515.50	13.68	7.78	0.243	1.28	11.152	12.490
27	14	14.5	26	1498.40	14.133	97.52	0.218	19.228	12.114	13.568
28	14.5	15	16	1521.30	14.557	7.18	0.195	1.579	12.506	14.007
29	15	15.5	16	1522.10	15.023	7.14	0.162	1.569	9.843	11.024
30	15.5	16	8	1526.30	15.54	6.5	0.145	2.48	10.244	11.473
31	16	16.5	10	1530.20	16.127	2.95	0.131	0.902	10.25	11.480
32	16.5	17	2	1524.20	16.352	4.95	0.12	2.515	10.589	11.860
33	17	17.5	3	1531.50	17.453	1.64	0.106	0.73	10.464	11.720
34	17.5	18	7	1525.50	17.896	6.92	0.092	1.243	10.31	11.547
35	18	18.5	2	1512.30	18.346	5.76	0.087	0.026	16.116	18.050
36	18.5	19	4	1562.40	18.872	244.83	0.068	173.036	78.926	88.397

The power coefficient of wind turbine reflects the ability of the unit to capture wind energy, and to a certain extent, which can reflect the operation state of the unit and even the design level of the machine. The power coefficient of the test unit is shown in Figure 2.

Figure 2. Calculation results of power curve interval

5 Conclusion

In view of the actual operation of 2.0MW wind turbines, this paper presents a performance evaluation method based on the measured data of wind turbines. After processing the data, the power curve of wind turbines is obtained, and the operation performance of the units is analyzed and judged. This paper provides an effective method for evaluating the performance of wind turbines and reliable data support for the evaluation of wind power generation.

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