Experimental study on durability of small wind turbine

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Abstract. Through the basic theory of durability test technology for small and medium sized wind power generation units, and the durability of 3KW wind turbine, this paper analyzed the test method of time available rate of unit and studied the power generation capability of the wind turbine. No power attenuation trend has been found, and a lot of experimental data and rich experience in engineering practice has been obtained with the success of experiments.

1 Introduction

In recent years, with the rapid development of small wind turbine technology, the small wind turbine and the performance testing has become an active field because of the importance of small wind power generation units in distributed power applications in the world. The small wind turbines researched and produced by this technology, which is mainly developing in Europe, North America and Asia, are being applied all over the world. Compared with large wind turbines, the small wind turbines are not rich in the international standards of the relevant certification, which makes them lag behind the large ones. In order to ensure the security of the small wind generator system, guarantee the high reliability of the electric quantity, and meet the requirements of users, it is essential to test and certify the production of wind turbines[1,2]. Domestic technology in durability testing started late and the technology is not mature enough, so the research for this test is necessary[3].

2 Durability test requirements

The purpose of durability test is to study the structural integrity and material aging (corrosion, cracks, deformation) in the operation of the wind turbine, the environmental protection quality of the wind turbine, and whether the dynamic behavior of the fan is measured.

The test conditions are: reliable operation of the wind turbine during the test period, running for at least 6 months, generating at least 2500 hours at different wind speeds, stable operation above the design wind speed of more than 1.2 times for at least 250 hours and more than 1.8 times more than the design wind speed at least 25 hours. According to IEC 61400-2 of reliable operation is defined as: operation time ratio of at least 90%; no major faults of wind generator system in whole or part; wind power generator has no obvious wear, corrosion or damage; in the wind speed can be compared, the power generated by the generator is not obviously decreased. In the process of the test, the instrument is used to observe the characteristics of the fan, the accurate running time, the power curve and the vibration of the unit are measured. It is necessary to detect whether the fan is worn, corroded or damaged after the test[4]. If the manufacturer needs to replace the parts in the test process to deal with the fault, the certification side will determine and solve the problem[5]. Durability test in the test data requirements and the definition of replacement parts is different in IEC61400-2:2013, AWEA and BWEA[6,7,8], as shown in Table 1.
Table 1 different standard requirements for durability testing

| Testing requirements                                           | Component replacement                      |
|---------------------------------------------------------------|--------------------------------------------|
| Nomal operation under design wind speed of 1.8 times in 25 hours | Not allowed replacement of larger parts    |
| Normal operation under 15m/s above the wind speed for 25 hours | Not allowed replacement of large parts, records can be replaced with small parts |

3 Research on the reliability of the wind turbine

3.1 Operation time analysis of wind power generator
It is necessary to record the shutdown, fault, and maintenance time of the wind turbine in the durability test. The operation time of the wind turbine could be obtained by the statistical time, and the time utilization rate could reach more than 90%. And the statistics of time relationship is shown in Figure 1:

![Statistical Methods of wind turbine available time](image)

3.2 Data elimination
In order to ensure the wind turbine data analysis would be real and effective, to remove some cases data (such as the data of machines not run because of their own reasons, the data of turbines artificially shut down or maintenance, the data of testing equipment failure, the data of invalid measurement sector, as well as the data of fan start and stop process) is essential.

According to IEC 61400-2, the normal running time included: wind turbine power generation time; the system auto start and shutdown time because of low wind speed and high cutting; idle or stop state of the wind is too small or too large ; time-delay between normal shutdown of the turbine (non fault) to restart.

3.3 Available statistics of unit time
Run time ratio $O$ is defined as:
In the formula: $T_r$ is a wind generator running time; $T_n$ is a wind power generator not running time; $T_u$ is the time of wind generator status is unknown; $T_e$ is the time should be excluded of the analysis process. Through statistical calculation as shown in Table 2.

### Table 2 statistical table of durability test time

| Running time greater than the following wind speed | Maximum wind speed intensity | $T_r$ | $T_n$ | $T_u$ | $T_e$ | $O$ |
|-----------------------------------------------|----------------------------|------|------|------|------|-----|
| Times | 0m/s | 14.4m/s | 21.6m/s | (m/s) | % | times | times | times | times | % |
| Total | 3364 | 452 | 34 | 25 | 31.2 | 5088 | 243.1 | 79.6 | 98.7 | 94.83 |
| 2014.6 | 174 | 4.5 | 0.0 | 16.4 | 21.9 | 720 | 84.5 | 34.4 | 47.2 | 86.8 |
| 2014.7 | 276 | 7.5 | 3.0 | 24.9 | 28.9 | 744 | 76.3 | 22.5 | 37.4 | 88.8 |
| 2014.8 | 430 | 87.4 | 5.8 | 25 | 29.4 | 744 | 22.9 | 1.0 | 0.3 | 96.9 |
| 2014.9 | 324 | 35.8 | 4.2 | 22.1 | 33.5 | 720 | 59.4 | 20.7 | 12.9 | 91.3 |
| 2014.10 | 744 | 98.4 | 6.2 | 23.5 | 33.6 | 744 | 0.0 | 1.0 | 0.4 | 100 |
| 2014.11 | 720 | 112.5 | 7.3 | 22.8 | 35.1 | 720 | 0.0 | 0.0 | 0.5 | 100 |
| 2014.12 | 696 | 105.9 | 7.5 | 23.4 | 36.0 | 696 | 0.0 | 0.0 | 0.0 | 100 |

Statistical results are shown in Table 2 for durability test time. The test began in June 1st 2014 to December 29, 2014, the entire test period of 201 days and wind turbine tests were run for 3364 hours. Figure 2 is the wind turbine availability graph, it could be seen from the figure the utilization rate were minimum in June and July 2014, which were less than the standard 90%, and the other months were greater than 90%. The average utilization rate was 94.83% reached the standard requirements.

![Fig. 2](image)

### 4 Research on wind power generation capacity

In order to check the decay of power generating capacity hidden in the wind turbine characteristics, the power level of the turbine should be divided into the range according to the wind speed for each month of the durability test. For each wind speed, it is essential to draw a diagram of the power level as a function of time in the wind speed range. If there is a clear trend in the graph, to study the cause of the problem is necessary. Figure 3 is Power characteristic test curve. The rated wind speed of the tested 3KW wind turbine was 12m/s, when the wind speed was greater than 12m/s, the standard deviation increases and the fan operation was relatively unstable. With the increase of wind speed, the power increased continuously and the wind speed reached 15m/s. Due to the use of electronic control system, the maximum power of the fan was between 4KW~4.5KW, which was less than 1.5 times the rated power.
Figure 4 is the line diagram of power and time under different wind speed in the durability test. Judged from the diagram, at the end of the test period of 7 months, it was not find power attenuation trend and the small changes were caused by changes in air density and interval number.

5 Conclusions
In this test, the 3KW wind turbine total run for 3364 hours, which run stably for 452 hours in more than 1.2 times of the design wind speed (14.4m/s, and less than 18m/s), and the time is in line with the standard. Due to the measured wind turbines installed over speed protection and over voltage, over current protection device and the cut out wind speed is 18m/s, wind generator under 1.8 times the design wind speed stop running, the wind power generator in the windy impossible is destroyed, wind machine durability test is not affected. From the test data analysis of point of view, the wind generator in the test of output power with no obvious fading, and the wind power generator can utilization rate was 94.83% greater than the IEC standards required 90%. In addition, no obvious damage, corrosion and wear were found in the tested 3KW wind turbine unit.. The generator under test was running in good condition.

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