Proceedings of The 10th International Green Energy Conference
May 24-27, 2015, Taichung, Taiwan
Paper No.: IGEC-2015-1557

Wind Turbine Operation Analysis under an Extreme Turbulence Wind Condition in Taiwan

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Abstract—Wind turbulence intensity can substantially affect the operation of a wind turbine. According to IEC design requirements, a wind turbine must withstand wind of class "xA" intensity, during which wind speed may change within seconds. These conditions can cause excessive fatigue on the system and substantially degrade operating performance. This study compared wind turbine operating performance between high and low wind turbulence conditions. The Taiwan data show that wind conditions are much more inconsistent than in other countries. Therefore, turbines imported from Europe must be modified to suit the Taiwan environment.

Keywords: Wind turbine, extreme wind condition, operation and maintenance.

INTRODUCTION

Modern megawatt size wind turbines have been installed in Taiwan since year 2000 by a government supported demo project. Since then, average wind turbine installation capacity has increased by approximately 60 MW annually. Cumulative capacity exceeded 600MW in 2014. All these turbines installed in Taiwan were imported from Europe and U.S. Manufacturers include Vestas, Gamesa, Enercon, GE, and Zephyros. All imported turbines meet international standards such as IEC or GL, and most have a proven track record throughout the world in terms of design, safety, and the quality.

A well-operated wind farm should have an availability higher than 95%. This percentage is considered reasonable in the global onshore wind market. After the commission and operation of wind farms in Taiwan, however, operators experienced operational problems that have not been encountered by wind farms in other countries. These phenomena have resulted in very low operation availability of the wind farms. Figure 1 shows the data for one local operator. Availability was only 73.21% in 2009 and then increased to 91.6% in 2013[1]. OR Although availability is improving annually, it is still far below the market average.

Clearly, the turbine design mainly for usage in Europe condition may not be totally suited for Taiwan. The small market and relatively small scale of wind farms make maintenance even more difficult. Logistics issues also decrease the availability due to increased waiting times for specific components from the original manufacturer. Therefore, totally availability substantially decreases.

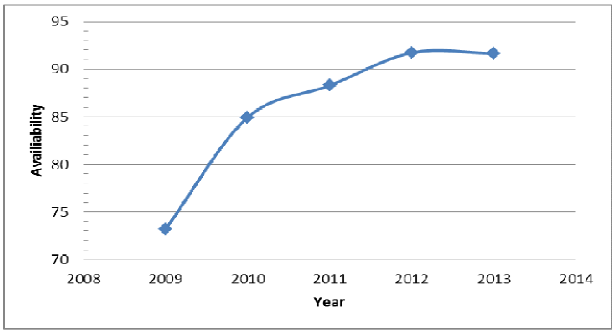

Fig.1:Example of availability in local wind farm[1]

A major factor in operational availability is the unique wind conditions in Taiwan. Taiwan has good wind resources and is suitable for wind power development. However, at some sites, the wind is highly variable. The most severe condition in the IEC standard is 0.16[2]. Since wind turbulence substantially affects turbine operation, pitch system design, and structural fatigue load, a detailed analytical method is needed.

This article analyzed the operational data from a turbine located in Taichung, Taiwan to estimate the effects of wind turbulence on a turbine and, more importantly, proposed a possible solution for this problem.

WIND FARM AND TURBINE DESCRIPTION

Figure 2 shows the wind farm discussed in this article, which is located in central Taichung, Taiwan. The turbine was manufactured by Zephyros (model Z72) in the Netherlands. The direct-drive turbine has a 2MW capacity. The basic specification can be checked from Tab.1. There are totally 21 Z72 turbines been purchased and imported then 18 were installed near Taichung Harbor and the rest 3 Table 1 shows the basic specifications. Out of 21 Z72 turbines purchased and imported to Taiwan, 18 were installed near Taichung Harbor, and the remaining three were installed in a coal fire power plant of the Tai-power company.

Fig.2: Z72 Wind farm in Taichung , Taiwan.

Tab.1:Technical Specifications for Z72 turbine[3]

General	
Rotor diameter	70.65 m
Rotor speed	Variable, nominal 22.5 rpm
Nominal power	2.0 MW*
Transmission	Direct drive generator, single main bearing
Rated wind speed	13 m/s
Cut-in / cut-out wind speed	3-25 m/s
Survival wind speed	70 m/s
Rotor speed control	Blade pitch
Wind class	2 and S according to IEC61400-1
Generator mass	49 tons
Rotor mass	36 tons
Nacelle mass	12 tons

Wind Condition Description

The specifications and references indicate that the Z72 turbine was designed for a class IB wind condition [4]. OR Therefore, Table 2 shows that the turbine should be suitable for a wind site with a yearly average wind speed higher than 10m/s and a turbulence intensity higher than 0.14.

This study collected operational data for the designated Z72 wind farm from October, 2013 to October, 2014. The effective data show an average wind speed of only 6.19m/s during this year and an average turbulence intensity 0.17 higher than the standard. (The turbulence intensity was calculated from the average wind speed data higher than 12m/s to emphasis the effect of the pitch action). Figures 3-4 show the wind speed and turbulence intensity data, respectively. The dotted lines in these two figures are the show the average wind speed and turbulence.

The statistical data indicate that high wind turbulence is common at this site. Therefore, fatigue caused by excessive load on the turbine may be a safety issue. Maintaining good performance of the pitch system is also challenging under the extremely turbulent wind conditions. This study found that the widely varying wind speed can cause an overspeed trip in this turbine. The pitch system may be unable to respond to wide variations in wind speed.

Tab.2: Basic parameters for wind turbine classes [2]

Wind turbine class		I	II	III	S
V_{ref}	(m/s)	50	42,5	37,5	Values
A	I_{ref} (-)	0,16			specified
B	I_{ref} (-)	0,14			by the
C	I_{ref} (-)	0,12			designer

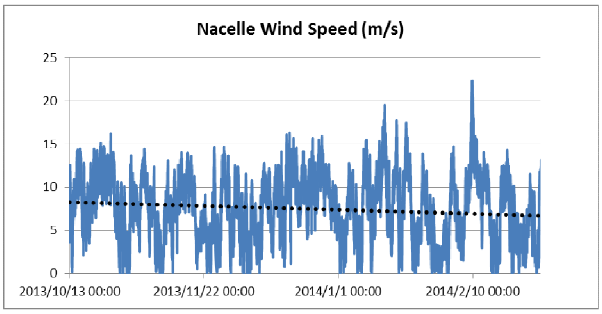

Fig.3: Average wind speed measured at nacelle

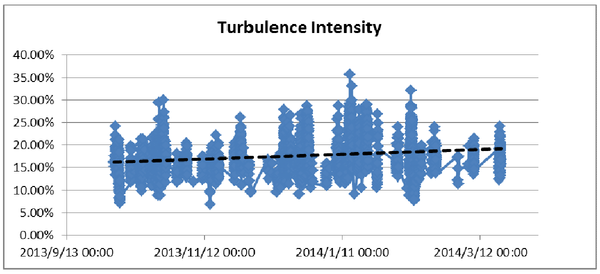

Fig.4: Turbulence Intensity of the site at nacelle

Operation under Highly Turbulent Wind

This study analyzed of the effects of extremely turbulent wind conditions that occurred on October 4, 2014. Table 1 shows that the rotational speed of the turbine is 22.5 rpm. In Tab.3 below, at 18:20 (minute: second), the turbine runs with 22.1 rpm under wind speed 16.01. At 18:25, wind speed decreased to 13.14m/s. This also changed the pitch angle from 12.2 to 8.1 degrees, which increased wind power. AT 18:31, the wind speed further decreased, and the system changed the pitch to collect more wind energy. However, the next time stamp indicated that the wind speed changed to 17.02 m/s at 18:36. The data in the table clearly show that, when the rotor runs up to 30.2 rpm, the maximum rotational speed of the turbine approximates 26.0 rpm, which causes an emergency trip in the turbine. The turbine then quickly shuts down when the pitch angle increases to 90 degrees. Figure 5 illustrates the above actions.

Table 4 also shows that the turbulence intensity in this short period is 0.228, which is much higher than the design value of 0.16. Therefore, if the original manufacturer did not consider this unique but common wind condition in the controller for the pitch system, the system would not operate efficiently in this situation. An overspeed trip would occur frequently in this turbine and in this site. When the wind speed decreases and then suddenly increases, the pitch system needs to stop in one direction then reverse operation to start pitching. Since these consecutive actions increase the time needed to change the pitch, rotational speed increases to an abnormal value.

Tab.3: Example of operation under high turbulence

Time	RPM	Wind(m/s)	Pitch angle
18:20	22.1	16.01	12.2
18:25	21.6	**13.14**	8.1
18:31	21.5	**10.85**	2.92
18:36	30.2	**17.02**	10.4
18:41	8.3	14.04	50.8

Tab.4: Turbulence Intensity on 4th, Otc., 2014.

STD	3.11
Turbulence Intensity	0.228

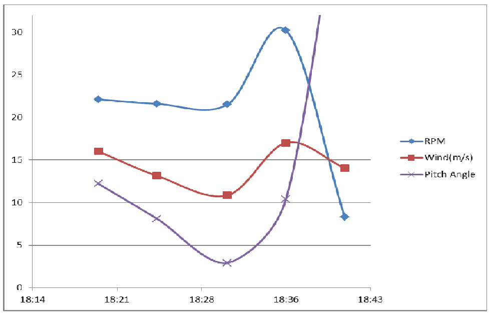

Fig.5: Response to wind turbulence

Performance Improvement Analysis

An overspeed trip causes the turbine controller to perform an emergency shutdown to protect the turbine structure since overspeed is likely to excite resonant vibration in the tower. From an operational perspective, however, this should be avoided because it would reduce available power generation. After an emergency shutdown, the turbine cannot be restarted until a technician present at the turbine site acknowledges the trip. The historical data indicate that more than 30 overspeed trips occurred in one turbine in a 4-month period, which can damage the turbine.

The original manufacturer of the Z72 turbine no longer provides support. Therefore, original design information, including control logic and codes, are unavailable. Reverse engineering the codes and modeling all other subsystems would be very time consuming. Doing so would be the best way to redesign the system and to respond to the updated wind condition. However, the operator can make hardware changes to solve this problem quickly. For example, the output of the pitch drive can be examined to determine whether the maximum output can be increased by a fixed ratio to increase the speed of the pitching action. If not, the pitch drive can be replaced to fit the pitching requirement.

Conclusions

This study investigated the case of a wind turbine operated under highly turbulent wind conditions. OR case study investigated a wind turbine operated under highly turbulent wind conditions. Analysis of operating data indicated that the wind variation at this site is higher than the design standard with an average value of 0.17. This case study further showed that high turbulence, which is very common, can prevent the turbine controller from slowing the rotor rotation. Thus, an overspeed trip would cause an emergency shutdown, which is undesirable for efficient OR which can prevent efficient wind turbine operation. Finally, possible solutions were proposed and will be evaluated onsite in further studies.

Acknowledgment

The financial support provided by Bureau of Energy, Taiwan (Grant No. 104-D0106) is gratefully acknowledged.

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