MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Using Wind Turbine Noise to Inspect Blade Damage through Portable Device

Tsung-Hsien Tu [1]
Fang-Chun Lo [2]
Taiwan, R.O.C.
Industrial Technology Research Institute
Center for Measurement Standards

Chia-Chi Liao[4]
Chiou-Fong Chung [5]
Ruey-Chyi Chen [6]
Taiwan, R.O.C.
Taiwan Power Company
Taiwan Power Research Institute

ABSTRACT

Maintenance and repair of wind turbine components are important in the wind power industry. The wind turbine blades are damaged gradually because of long-term operation in severe weather conditions, especially the typhoon season in Taiwan. Wind farm operators still rely on the in-situ technician's visual and auditory judgement to detect the wind turbine blade health condition. The traditional detection method by the human sense and subjective judge is inefficiency and inaccuracy. This paper is intended to provide the blade fault inspection method by using the wind turbine noise and to conduct on-site inspection of wind farm through designed portable devices. The advantage of this device is that it can inspect wind turbine blade during running operation. The routine inspection work can keep tracking the condition of each blade and the records furthermore could be used for maintain and repair in advance. It is expected that it will help improve the operational efficiency of Taiwan's wind power industry in the future.

Keywords: Wind turbine noise, Blade fault inspection, Portable device

1. INTRODUCTION

The politics and economics of renewable energy have played an important role in the development of the wind power harvesting in today. There is better economic competitiveness and development potential for wind energy owing to the high cost-performance ratio in renewable energies [1]. The wind turbine technology has grown rapidly in the past three decades [2,3]. In order to obtain more wind energy resources, wind turbine has gradually grown into large and offshore models recently [4]. Taiwan is an island with abundant wind resources, especially the monsoon zone in the west coast adjacent to the Taiwan Strait. The wind energy capacity has been experiencing rapid development since 1990. The total installed capacity of grid interactive renewable power was 4321.4 MW, and wind power accounted for about 18.3 %, that is 702 MW coming from 345 wind turbines, at end of 2018 [5]. As wind turbines have been installed and operated, economic data have shown that maintenance costs consume a significant portion of the total energy costs, which are borne by wind farm owners and operators [6]. The most efficient way of reducing these costs would be to continuously monitor the condition of these systems. This allows for early detection of the degeneration of the generator health, facilitating a proactive response, minimizing downtime, and maximizing productivity [7]. The conditions in severe environment, due to the affect of temperature, humidity and brine etc., are the key factors for the life of wind turbine [8]. There is a constant need for the reduction of operational and maintenance costs of wind turbines. Wind turbine blades are a vital composite component. Due to external conditions, internal stresses, improper manufacturing or forming process as well as fatigue that may gradually yield the delamination, crack and damage as time goes by, thus leading the performance deterioration of electrical energy generation. Unfortunately, wind turbine blades experience faults and damages that could not be monitored using the wind turbine generator terminals. In general, the blade is one of the damaged component in a wind turbine with high maintenance fee [9]. For a 2 MW wind turbine, the blade accounts for 24.9 % of the total cost and the damage percentage is as high as 25 % [10]. Until now, many studies have proposed wind turbine blade damage detection technologies, including tap testing [11], ultrasonic examination [12], penetrant testing [13] and laser shearography [14], etc. These detection technologies need to stop the wind turbines in advance or install sensors inside the blades to detect them. For large wind turbines, these methods have shown many limitations and inconveniences. Few detection techniques utilized the blade operating noise to detect blades in operating condition.

This paper is intended as a brief describing the diagnostic schemes for wind turbine blade damage by using the feature of emitted noise as the blade passing through the tower. This method by applying the sound signal time-domain averaging and the short-time Fourier transform to rapid diagnose the damage of the blades. The blade damage degree is evaluated through a series of algorithms by comparing the power intensities at different time intervals in the enhanced signal in according to the operation cycle. A portable monitoring device is present for the purpose to easy access and rapid screening the wind turbine blade health conditions.

2. MEASUREMENT METHOD AND ANALYSIS PROCESS

2.1 Noise event colletion

The target wind turbine was shown in Fig.1-a. The instrument setup was shown in Fig. 1-b. The sound level meter with data recorder was setup on the ground and located at the extension position where the blade was rotationally moving at nearby position (Fig. 1-c).

(a) Vestas-V80 *(b)* instrument *(c) location*

Fig. 1 – The measurement instrument setup

2.2 Analysis process

The signal processing strategy was shown in Fig. 2. An operating sound signal was obtained from wind turbine. If sound signal *u (t)* consists of a periodic signal *f (t)* and ambient noise *n (t)*, the equation can be expressed as:

$$u\ (t) = \mathrm{f}\ (\mathrm{t}) + \mathrm{n}\ (\mathrm{t}) \tag{1}$$

The signal *u (t)* was divided into *K* cycles by the periodical rotational features, then to summarize the each single period cycles with corresponding discrete points. The signal $x\ (t_k)$ is obtained due to low correlation between an ambient noise $n\ (t_k)$ and a periodic signal $f\ (t_k)$.

$$x\ (t_k) = K\mathrm{f}\ (t_k) + \sqrt{K}\mathrm{n}\ (\mathrm{t}_k) \tag{2}$$

Then $x\,(t)$ is averaged to get the output signal *y (t)*:

$$y\ (t) = \frac{x(t_k)}{K} = \mathrm{f}\ (t) + \frac{\mathrm{n}\ (\mathrm{t})}{\sqrt{K}} \tag{3}$$

The ambient noise is reduced to $1/\sqrt{K}$ times in enhanced signal.Then the Short-Time Fourier Transform, STFT, is applied on output signal *y (t)* to obtain the time-frequency spectrum $S\ (\tau, f)$, in which *w (t)* is the window function.

$$S(\tau, f) = \int_{-\infty}^{\infty} w(t-\tau)\, y(t)\, e^{-i2\pi f t}\, dt \tag{4}$$

The marginal spectrum *H (f)* is obtained by the time integration of the time-frequency spectrum $S\ (\tau, f)$.

$$H(f) = \int_{0}^{T} S(\tau, f)\, d\tau \tag{5}$$

Three distinct peaks can be observed in the Fig. 3, in which each peak represents the wind shear sound of the blade while passing through. Finally, the energy at different time intervals in the time-frequency spectrum was calculated, and normalized to obtain the blade damage degree. This damage degree index will act as the parameter to inspect the blade condition.

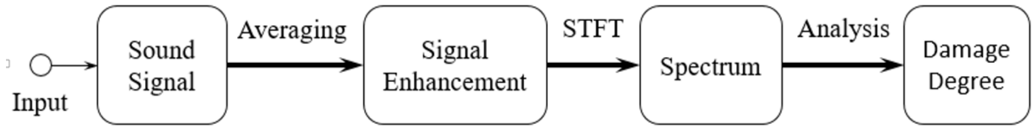

Fig. 2 – Blade diagnosis analysis flow chart

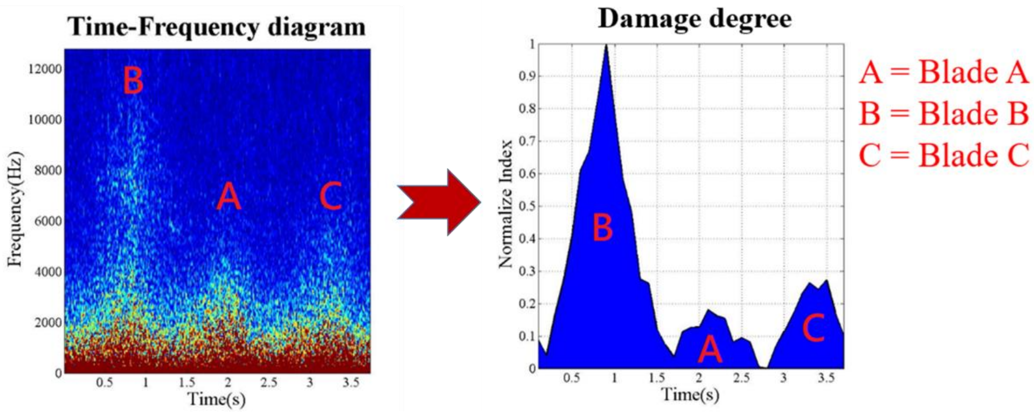

Fig. 3 – Result of time-frequency analysis

Through a series algorithms to calculate the blade damage degree, which is the parameter to be used to judge whether the blade is damaged or not. This rapid inspection method for the diagnosis of wind turbine blade damage. The diagnostic results of this study was in agreement with in-situ inspection results. This technique has been successfully verified by on-site inspection on wind turbine farm in Taiwan.

2.3 Portable Device Design

For easier noise events capture and rapidly blade damage detect beneath the wind turbine in-situ, a portable and compact device, as shown in Fig. 4, was proposed and was under developing now. The device was packed into a carrying box in which microphone and single board computer was installed. The calculation core for the blade damage index was embedding into the computer also the storage device was reserved. In accordance with the marker interval, the continuously signal will be divided into several cyclically repeated signal segment. The blade damage index evaluation was using the several signal segment through the signal enhanced processing. The layout for the graphic user interface was shown in Fig. 5. The operator was requested to key-in or selected the identification for wind farm, wind turbine, then click the start button to proceed the noise events captured. Within the measuring interval the operator need to mark the blade A using the blade identification. The measurement period, ordinarily the 20 seconds, can be setting in advance by software or manually stop via hardware. The blade damage index was available within 1 minute after the measurement stop.

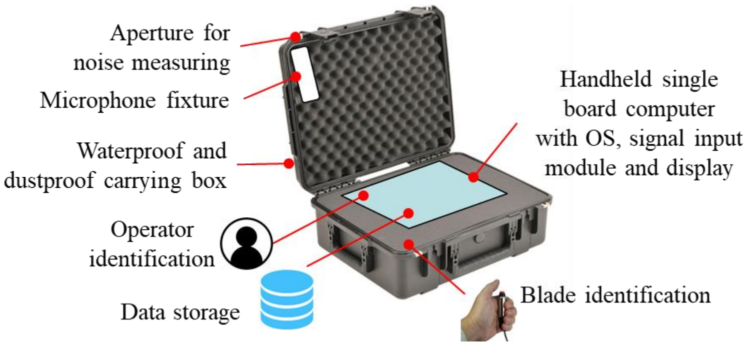

Fig 4 – The design of the portable device for wind turbine blade damage detection

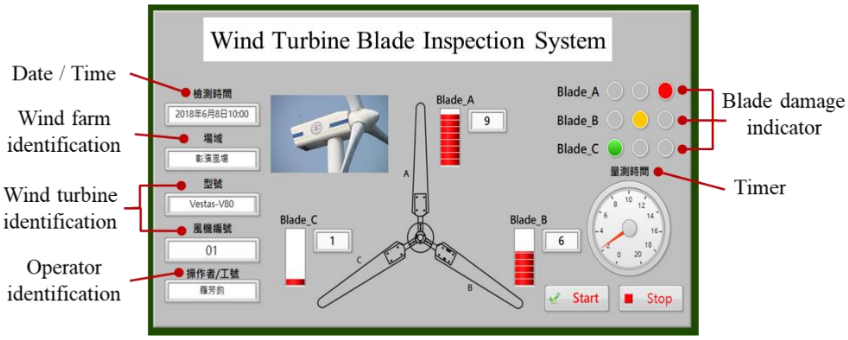

Fig 5 – The graphical user interface for portable device

3. DISCUSSION

The increasing demand for the rapid and easy blade damage detection device come from the wind turbine owner and operator. The main advantage of this proposed method using the noise feature to detect the wind turbine blade surface and damage was easy access and implementation in-situ. To eliminate the unwanted noise components this study compared the power intensities at different time intervals in the enhanced signal to calculate damage degree. The blade damage degree has been practically verified by on-site inspection on wind turbine blade. In the near future, the complete of the portable device will be significantly help to reduce the working hours for the wind turbine blade inspection.

4. ACKNOWLEDGE

We acknowledge the financial support from the Bureau of Standards, Metrology and Inspection (BSMI) of the Republic of China.

5. REFERENCE

1. M. I. Blanco, "*The economics of wind energy*", Renewable and Sustainable Energy Reviews, vol. 13, pp. 1372-1382, 2009.
2. Y. A. Kaplan, "*Overview of wind energy in the world and assessment of current wind energy policies in Tuirkey*," Renewable and Sustainable Energy Reviews, vol. 43, pp. 562-568, 2015.
3. T. Ackermann, L. Söder, "*An overview of wind energy-status 2002*", Renewable and Sustainable Energy Reviews, vol. 6, pp. 67-127, 2002.
4. C. Perez-Collazo, D. Greaves. G. lglesias, "*A review of combined wave and offshore wind energy*", Renewable and Sustainable Energy Reviews, vol. 42, pp. 141-153, 2015.
5. www.taipower.com.tw/content/new_info/new_info-b31.aspx?LinkID=8.
6. European Wind Energy Association, "*Wind energy—the facts: costs & prices*", vol. 2. Oxford, UK: Earthscan, 2012.
7. Y. Amirat, M.E.H. Benbouzid, etc, "A brief status on condition monitoring and fault diagnosis in wind energy conversion systems", Renewable and Sustainable Energy Reviews, 13, pp. 42629-2636, 2009.
8. B. Hahn, M. Durstewitz, K. Rohrig, "*Reliability of Wind Turbines: Experiences of 15 Years with 1,500 WTs*", ISET, Germany, 2005.
9. W. Yang, C. Crabtree, "*Cost-effective condition monitoring for wind turbines*", IEEE Transactions on Industrial Electronics, vol. 57, pp. 263-271, 2010.
10. F. Pedro et al, "*Wind turbine reliability analysis*", Renewable and Sustainable Energy Reviews, pp. 463-472, 2013.
11. G. E. Georgeson, S. Lea, and J. Hansen, "*Electronic Tap Hammer for Composite Damage Assessment*", SPIE, pp. 22-338, 1996.
12. A. Juengert and C. U. Gross, "*Inspection Techniques for Wind Turbine Blades Using Ultrasound and Sound Waves*", presented at NDTCE'09, Nondestructive Testing in Civil Engineering, 2009.
13. M.A. Drewry, G.A. Georgiou, "*A review of NDT techniques for wind turbines Insight*", pp. 137-141, 2007.
14. J. W. Newman and J. T. Lindberg, "*Laser Shearography of Wind Turbine Blades*", Materials Evaluation Magazine, pp. 828-837, 2010.