



Failure investigation on a coastal wind farm damaged by super typhoon: A forensic engineering study



Xiao Chen*, Chuanfeng Li, Jianzhong Xu

National Laboratory of Wind Turbine Blade Research and Development Center, Institute of Engineering Thermophysics, Chinese Academy of Sciences, 11 Beisihuanxi Road, Beijing 100190, China

ARTICLE INFO

Article history:

Received 12 May 2015

Received in revised form

9 October 2015

Accepted 12 October 2015

Available online 27 October 2015

Keywords:

Wind turbine

Tower collapse

Blade breakage

Terrain effect

Stop position

Local buckling

ABSTRACT

This study presented a failure investigation on a wind farm which is located on the southeast coast of Mainland China and was severely damaged by two super typhoons: i.e., Dujuan in 2003 and Usagi in 2013. Failure characteristics of the wind farm in terms of rotor blade damage, tubular tower collapse and wind turbine (WT) burn were examined from a forensic engineering perspective. A systematic procedure was proposed to quantitatively investigate structural failure by calculating the extreme wind loads and re-constructing structural models for composite blades and steel towers. It was found that both extreme winds and the stop positions of WTs were critical to turbine failure due to the change of wind direction during typhoon impact. The overstrain/overstress was identified as the plausible root cause for structural failure of WTs. In addition, the dramatic reduction of shell wall thickness due to possible design defect was also found to be responsible for the tower collapse in this study.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Development of offshore wind farms in the southeast coast of China is gaining new momentum. In December 2014, the National Energy Administration of China announced 44 projects of offshore wind farms with a total power capacity of 10.53 GW to be constructed from 2014 to 2016 (National Energy Administration of China, 2015), which makes China's offshore wind energy further approaching the government's goal of 30 GW by 2020. Despite the enthusiastic development, offshore wind farms face some technical challenges, among them, typhoons, or tropical revolving storms, which frequently impact the southeast coast of China, are regarded to be major threats. Although failure accidents of wind turbines caused by typhoons have been constantly reported in recent years, there has been very little research carried out to investigate the casual mechanisms of wind farm failure. Ishihara et al. (2005) analyzed the collapse of two WT towers caused by typhoon Maemi in Japan in 2003 and found that the maximum bending moment of the towers was larger than the ultimate bending moment during typhoon impact. Chou and Tu (2011) and Chou et al. (2013) examined the likely causes of tower collapse and rotor blade damage of a WT during typhoon Jangmi in Taiwan in 2008 and found that insufficient strength and poor quality control of bolts were the causes of the tower collapse during strong winds,

and insufficient blade material strength, wind frequency and resonance effect and human error during turbine installation were identified as three main causes of blade damage.

Unfortunately, very little study has been conducted on failure accidents in Mainland China. As an average of nine typhoons make landfall on the southeast coast of China annually (Xiao and Xiao, 2010), wind farm damage in China as well as worldwide has been reported frequently by groups opposed to wind energy (Industrial Wind Action Group Corporation, 2015). There is an urgent need of systematic study on failure of offshore wind farms to provide more understanding of not only how and why wind turbines fail but also what possible measures one could take to reduce the potential risk. This study, with an aim to partly fill the gap between academic research and the fast-growing offshore wind energy industry in China, conducted a particular failure investigation on a coastal wind farm which was catastrophically damaged by two super typhoons, Dujuan and Usagi, successively in ten years. During this endeavor, a forensic engineering study on the wind farm was conducted together with data collection, analysis and interpretation. By integrating both wind characterization and structural analysis, a systematic procedure was developed to identify the plausible root causes of tower collapse and blade failure. Local wind records, terrain topography and turbine stop position were examined to understand their effect on structural failure. It is expected that some insights gained from this study could assist failure mitigation of wind farms in typhoon/hurricane-prone regions worldwide.

* Corresponding author. Tel.: +86 10 8254 3041; fax: +86 10 8254 3037.
E-mail address: drchenxiao@163.com (X. Chen).

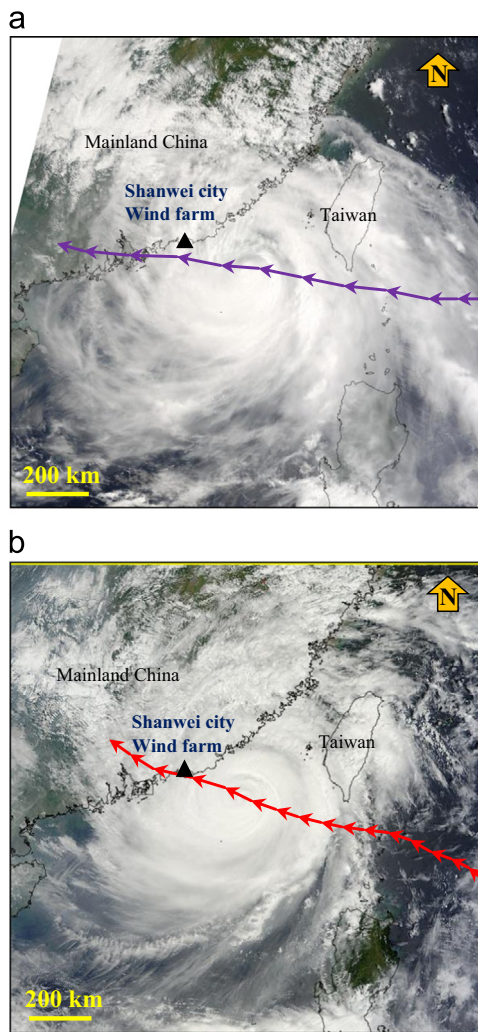


Fig. 1. Typhoon tracks and the wind farm location (satellite images from NASA (2015)). (a) Super typhoon Dujuan in 2003; (b) super typhoon Usagi in 2013.

2. Background information

2.1. Super typhoon Dujuan and Usagi

Typhoon Dujuan developed on August 27, 2003 to the east of Taiwan. It quickly intensified after turning and moving to the west-northwest of the Philippines. It reached a maximum wind speed of 63.9 m/s on September 1, and shortly thereafter passed just south of Taiwan (U.S. Naval Pacific Meteorology and Oceanography Center/Joint Typhoon Warning Center, 2003). Dujuan weakened to a severe tropical storm status before making landfall on September 2 in southern China, just east of Hong Kong near Shenzhen city, Guangdong province. Ten years later, a similar but stronger typhoon, Usagi, affected Taiwan, the Philippines, Mainland China, and Hong Kong. Developing into a tropical storm east of the Philippines late on September 16, 2013, Usagi began intensification on September 19 and ultimately became a violent and large typhoon (U.S. Naval Pacific Meteorology and Oceanography Center/Joint Typhoon Warning Center, 2013). Based on satellite estimates of intensity by the National Aeronautics and Space Administration (NASA), within 24 h Usagi intensified by 33.3 m/s and reached a maximum wind speed of 69.4 m/s (NASA, 2015). Usagi made landfall on September 22 as a super typhoon in China's Shanwei city. The typhoon tracks of Dujuan and Usagi are shown in Fig. 1.

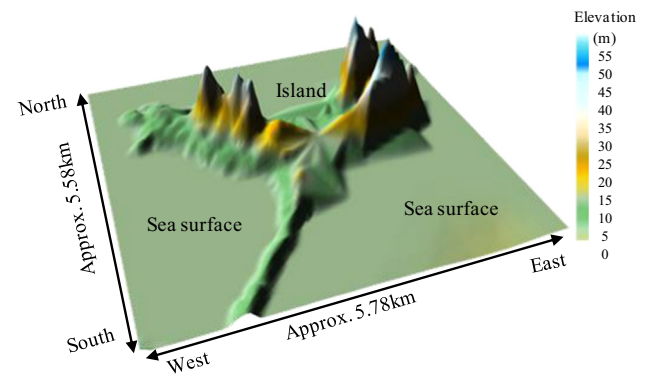


Fig. 2. Three-dimensional topographic terrain model of the coastal wind farm with upscaled elevation.



Fig. 3. The distribution of wind turbines over the wind farm.

According to the Saffir–Simpson hurricane intensity scale (National Hurricane Center, 2015), both Dujuan and Usagi were on category 4 which specifies a sustained wind speed from 58.1 to 69.7 m/s. Accordingly, Dujuan was in the middle range of the category and Usagi was close to the upper bound of the category. Both typhoons were classified as super typhoon according to China Meteorological Administration (2015).

2.2. Wind farm

The coastal wind farm under study consists of 25 wind turbines and it was commissioned in 2003. It is located on an island on the east coast of Shanwei city. The wind farm was under direct impact of two typhoons as it was only approximately 45 km and 10 km away from tracks of Dujuan and Usagi, respectively.

Using Global Positioning System (GPS) data, the concerned terrain was re-constructed in a three dimensional topographic model. It is important to note that the peak elevation of the terrain was about 56 m and it was small compared with the horizontal size of the terrain, which has a length of 5.78 km and a width of 5.58 km as shown in Fig. 2. In general, the terrain is flat with small ridges at the west and the east sides and a plain region in the middle. The maximum ridge inclination is approximately 6.5° and it is located at the east ridge of the island. The terrain elevation is upscaled in the figure for a better visualization of terrain characteristics.

The distribution of 25 wind turbines over the wind farm is shown in Fig. 3. It can be seen that WT#1–11 were located along the ridge at the west side and WT#12–21 were located in the

Download English Version:

<https://daneshyari.com/en/article/6757406>

Download Persian Version:

<https://daneshyari.com/article/6757406>

[Daneshyari.com](https://daneshyari.com)