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Monitoring Typhoon-induced Vibration and Tilt of Offshore Wind Turbine System for Batholith Seabed

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This study investigated a vibration and tilt monitoring system for an offshore wind turbine constructed using a high-rise-pile-cap supporting foundation, which is the first offshore wind power project in South China with a batholith seabed. The analysis of data collected by the system during the 2016 typhoon Meranti showed that the typhoon significantly affected vibration and instantaneous tilt of the supporting system without any significant change to the first natural frequency. Additionally, it did not produce any permanent inclination, indicating that no serious structural failure occurred under the influence of the typhoon. However, during the typhoon, the vibration acceleration, vibration intensity, and the effective inclination of the high-rise-pile-cap supporting system using rock-socketed piles were smaller than those with driven frictional piles, indicating that the former is better than the latter in terms of resistance to vibration and tilt.

INTRODUCTION

The construction of offshore wind power plants in China faces many challenges, including the raging typhoons in the East and South Seas. Each year, the Guangdong province experiences typhoons three times on average, accounting for 33% of the annual typhoons in China's coastal areas. The proportions of typhoon episodes in Taiwan, the Hainan province, the Fujian province, and the Zhejiang province are 19%, 17%, 16%, and 10%, respectively (Wu and Li, 2012). The extreme vibration and abnormal inclination of the offshore wind turbine supporting system as a result of typhoons sometimes lead to structural failures and can even result in the collapse of the wind turbine structure into the ocean.

Wu et al. (2010) analyzed several cases of destruction to the onshore wind plants caused by typhoons and concluded that the degree of destruction depends on the wind speed; the characteristics of the typhoon such as area of influence, change in wind direction, wind shear, duration, and heavy waves; the terrain of the wind farm; the structural design; and the control strategy for the wind turbine generators (WTGs). Compared with the generic wind condition used in the design of WTGs (International Electrotechnical Commission, 2005), the turbulence characteristic, the abrupt change in wind direction, the gust effect, the extreme wind speed, and synchronization with large typhoon waves can have a greater influence on the destruction of wind power equipment. Therefore, it is important to investigate these factors.

Sun and Gao (2016) proposed systematic design and countermeasures for anti-typhoon offshore wind turbines based on the basic typhoon characteristics and the failure mechanisms of offshore WTGs under the influence of a typhoon. Accordingly, the following two basic principles must be followed in the design process of anti-typhoon WTGs: (1) avoid fatal destruction of WTGs, and (2) determine a reasonable structural reliability. The anti-typhoon countermeasures such as establishing proper wind model of typhoon, considering the design load cases, choosing appropriate control strategies for both power on and power failure conditions, enhancing the load driving chain, and reducing the vibration of supporting systems of WTGs should be adopted throughout the life cycle of WTGs.

Past research studies on the influence of typhoons on the offshore wind turbine supporting system were theoretical, studying, for example, basic features of typhoon or back analysis of the destruction scenes of wind parks caused by typhoons. However, quantitative studies on this research domain are limited.

The aims of this study are to (1) investigate the performance of devices installed on the supporting structure of offshore WTGs for monitoring vibration and tilt during the construction of an offshore wind farm during a typhoon and (2) analyze the impact of a typhoon on the supporting structures.

MONITORING STRATEGY

This study was conducted in an offshore wind farm along the coast of the Fujian area in China. The project is the first offshore wind park in south China and has four 4 MW offshore wind turbine generators. The system consists of a high-rise-pile-cap foundation with eight steel-pipe piles with a diameter of 1.8 m penetrating into the seabed and a reinforced concrete cap with a diameter of 14 m to connect the piles beneath and the tower on top. The high-rise-pile-cap foundation is widely used in the cross-sea bridge and port engineering. A large-diameter monopile foundation is a common choice for most offshore wind parks in Europe, although a high-rise-pile-cap foundation is also an alternative in China. The Donghai Bridge offshore wind farm project is the first large-scale offshore wind park in Asia (Lang et al., 2014), in which this foundation type was used with silt formation and a sand strata seabed. Although the same foundation type is used in this project, the seabed is granite with different weathering degrees and with significant variation in the buried depth of rock strata. Consequently, new construction techniques are needed (Li et al., 2017). If the four WTGs are denoted as ASY1# to ASY4# sequentially, the foundation of ASY2# is the rock-socketed piles corresponding to shallowly buried rock strata, whereas the other three frictional piles correspond to relatively deeply buried rock strata (see Fig. 1).

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KEY WORDS: Typhoon, batholith seabed, offshore wind turbine, high-rise-pile-cap foundation, vibration monitoring, tilt monitoring.