Numerical and Theoretical Study on the Wind Response of Wind Turbine

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Since wind energy is viewed as a promising new energy source that is pure, clean, and inexhaustible, the rapidly progress of the energy power around the world in recent years has been impressive. Nowadays, more than 800 of large-scaled wind turbines for electricity generation were installed in Japan, and the number of wind turbines expectedly increases to 3000 turbines in 2010. However, accidents of wind turbines have also been reported consecutively. The damage of wind turbines in the Miyakojima Island by typhoon Maemi in 2003 is a typical example. It is strongly required to enhance the wind resistant design of wind turbines.

Difference from other traditional civil structures such as chimney towers and high building, large-scaled wind turbine has a heavy top of rotor and its behavior dominantly depends on the wind load on the rotor (for a middle large-scale wind turbine, the rotor has 31m of diameter with 21ton of weight, while tower has 35m of height with 20 ton of weight). Their design concept is based on the turbine control system (IEC61400-1), means that the turbines are controlled so that it can change its direction to get maximum wind power during their operations and minimize the wind load during the strong wind. However, the control system will become ineffective by the loss of electrical power which often occurs during typhoon and insensitive in the site with a large turbulence. As known, Japan is a country of mountains with complex terrains and dozens of typhoon comes every year. The wind resistant design of wind turbines is required to consider the critical wind load without any control in Japan. Nowadays, the examination and evaluation of designed wind load on wind turbine is based on the Building Standard Law in which it does not consider the characteristics of wind turbine. Therefore, it probably underestimates the design wind load on wind turbine.

Because of the usefulness and possibility of wind energy, I am most interested in the macroscopic aspects of large-scaled wind turbines, which involve the overall wind turbine behavior, designing and analysis. In my study, some onsite investigations were carried out to obtain the data such as configuration, dimensions and structural parameters of wind turbine, because the detail of the data are not provided sufficiently by manufacturer. Next, a field measurement was also carried out to measure accelerations of the tower of wind turbine to estimate the natural frequencies and damping ratios, and strains at the root of tower to estimate the wind load on wind turbine. A wind turbine model of finite beam elements was constructed and eigenvalue analysis was carried out. The performance of wind turbine model was examined by comparing the analysis results with measured natural frequencies. A finite element code was also developed for wind response simulation of wind turbine. The application and accuracy of the code was confirmed by comparing its results with measured wind load. Finally, the equivalent static load formulas for along-wind load, across-wind load and their combination in which the dynamic effects of wind turbine including first natural frequency and structural damping ratio were considered, were proposed. The proposed formula was shown a good agreement with the results of wind response simulation. Hence, the proposed formula can be an alternative method to the Building Standard Law for predicting the wind load on wind turbine.

Furthermore, I intend to study the interaction between complex terrain criteria, wind criteria in the design process to determine the relative importance of each aspect and to further assess structural optimization of wind turbine.