Principal Research Results

Study on Wind Turbine Considering the Wind Characteristics (Typhoon and Wind Turbulence) in Japan

Background

Introduction of wind turbine generation systems is recently being advanced in Japan. Also, the scale of the wind turbines tends to be growing larger. There is the International Standard (IEC61400) for wind power generation systems including the wind turbine itself. The systems are generally supplied as a standard product fitting with the wind turbine class that satisfies the standard wind condition (combination of the wind speed and turbulence) provided in the International Standard. However, since this standard is based on the wind characteristics in Northern Europe, the influences of strong wind speed and turbulence by typhoon and complex terrain, which are specific to Japan, are not considered. The influences of strong thunderbolts in winter are also not satisfactorily considered. From such situations, many troubles concerning blade damage by typhoon or lightning have recently occurred in Japan. It is also thought that the influence of the troubles grows more serious as wind turbines become larger. From the viewpoint of securing the safety of wind power generation systems, there is a strong need to review the technological standards and devise the design guidelines considering the wind and thunderbolt conditions, specific to Japan. The development of a forecasting system for wind power generation and evaluation of the prediction error are also needed under such Japanese weather conditions.

Objectives

The purpose of this study is to develop an evaluation method of wind conditions and a wind power generation forecasting system considering the characteristic weather conditions specific to Japan in the wind turbine design.

Principal Results

1. Wind tunnel test using a small-scale wind turbine model

The wind turbine model of 1/30 scale corresponding to the 1,000kW class machine (2m diameter rotor and rotor rotational speed 600 rpm in the model) was made to verify the analytical accuracy and to evaluate the influence of the response of wind turbine by fluctuating wind. It had been experimented on at a large wind tunnel facility of Mitsubishi Heavy Industries, Ltd. As a result, the influences on the blades and the rotor axis of the fluctuating wind condition were well found, and the accuracy of the numerical analysis was confirmed (Figure 1).

2. Investigation of the evaluation techniques about wind turbulence that influence wind turbines over the complex terrain.

The wind speed and turbulence were analyzed in condition of the simple wavy terrain by our own four fluid-analysis-codes with the different numerical handlings about the turbulence modeling and the coordinates. It was found that each code well calculated the flow over the simple wavy terrain. It was also confirmed that the calculated results were good corresponding to the observed data over the complex terrain in a wind farm by using one code among them (Figure 2).

3. Development of the forecasting system for wind power generation in a wind farm

The GPV data of JMA, NCEP, ECMWF, meso-scale weather prediction model of UT, JWA, CTC, CRIEPI, and CFD model of JWA, CRIEPI were compared each other. Finally, the uncertain forecasting errors were discussed, and the forecasting system was improved. Based on these results, the forecasting system for wind power generation for each wind turbine and the total generation in a wind farm was developed.

4. Verification of the forecasting system

Using the forecasting system, the wind power for five wind farms (Tohoku 3 site, Kanto 1 site, and Kyushu 1 site) with different wind conditions was forecasted and compared. The target accuracy value (the improvement rate (20% or more on that day, 30% or more on the next day) and the prediction error rate (15% or less on that day, 20% or less on the next day)) were achieved.

Future Developments

The results of review on the wind resistance, fatigue, and lightning might be reflected in design manuals such as the "Ministerial ordinance on technical criteria for power generation wind equipment". The practical use of the forecasting system for wind power generation will be advanced and examined in new locations such as mountains and the ocean.

This study is executed as part of the research and development of “Project for Establishing Wind Power Guidelines for Japan” and “Wind Power Stabilization Technology Development Project - Development of Wind Power Prediction Models Based on Numerical Weather Prediction-” that is consigned by the New Energy and Industrial Technology Development Organization (NEDO).

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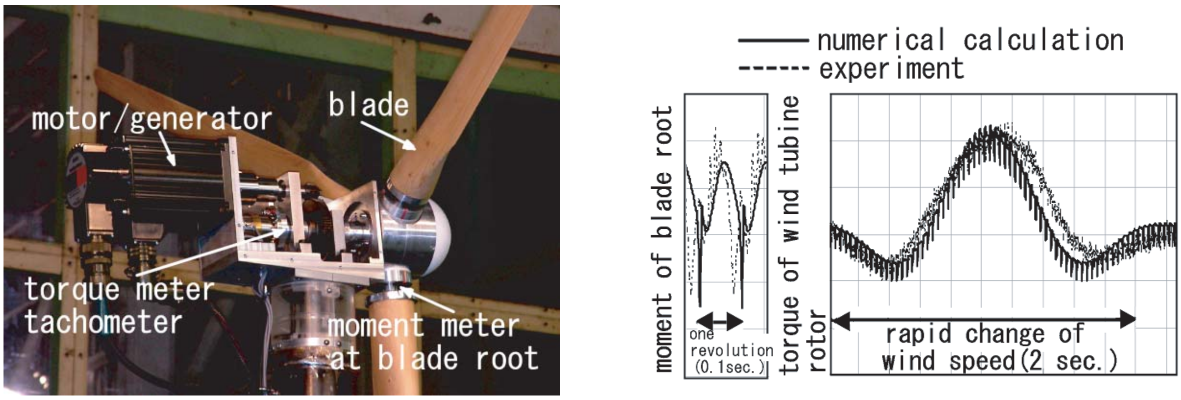

Fig.1 Wind load evaluation on a wind turbine at typhoon

Left: Photograph in the main part of a wind turbine model (1/30 reduced scale) used for wind tunnel test (state to open nacelle cover)
Right: Comparison of the simulation and the observation results corresponding to time change of the wind (The wind speed rapidly changes at the typhoon. The change of the load was confirmed to be accurately reproduced using the existing analytical code).

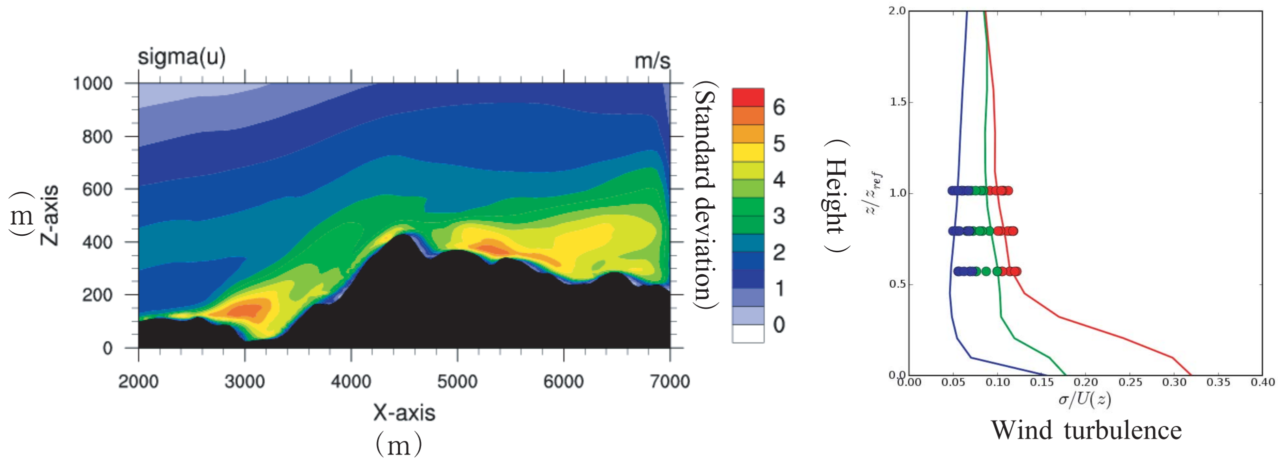

Fig.2 Evaluation of the wind turbulence that uses numerical analysis code intended for wind farm on complex terrain

Left: Vertical space distribution of standard deviation of fluctuating wind obtained by numerical analysis (The value of red areas is strong, and the value of blue areas is weak. It is understood that the standard deviation of the change velocity of the wind that is one of the evaluation parameters of the fatigue strength of the wind turbine has changed spatially).
Right: Vertical distribution of standard deviation of fluctuating wind in wind turbine installation point (It agrees well, and it is understood that the fatigue evaluation of the wind turbine that originates in the wind turbulence by using the numerical analysis is possible with the observation value (circles) and the analytical result (solid lines)).

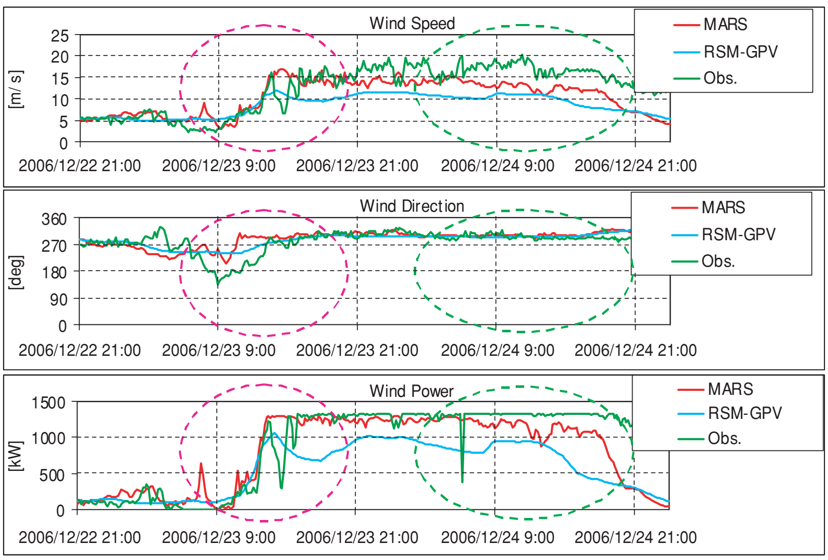

Fig.3 Example of the forecasting result of using the weather forecasting model.

The comparison of the calculation and observation value of wind speed, direction, and power generation forecasted by our own weather forecast system (MARS). And, meteorological data (RSM-GPV in figure) were compared. It was found to be able to capture local weather phenomena such as passing low-pressure by using the weather forecasting model. (Red: Change by passing of small low-pressure, Green: Steady increase of power generation output according to flow of local wind, typical to these area)