DYNAMIC RESPONSE OF 5, 10 AND 15 MW FIXED-BOTTOM OFFSHORE WIND TURBINES IN WIND AND WAVES

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INTRODUCTION

In recent years, the offshore wind turbine industry has become more active in response to the movement toward carbon neutrality by 2050, and technological development of large-scale offshore wind turbines (OWTs) with improved power generation efficiency and high economic efficiency has progressed. However, little is known about their response characteristics and the relationship between the scale of power generation and the response characteristics of OWTs. The purpose of this study is to clarify the differences in the dynamic response of fixed-bottom OWTs with different power generation scales in wind and waves through load-coupled analysis.

OUTLINE OF METHOD

We selected 5, 10 and 15 MW monopile OWTs that were adopted in the analysis code comparison and validation of the International Energy Agency Wind Technology Cooperation Program (IEA Wind TCP). For this study, we assumed a water depth of 20 m for all wind turbines. The analyses were performed using OpenFAST developed by NREL in the U.S, a load-coupled analysis code that consists of aerodynamic analysis based on blade elementary momentum theory, hydrodynamic analysis using the modified Morison equation, and structural analysis of the wind turbine tower section based on the modal method and the monopile section based on the finite element method. In the hydrodynamic analysis, wave breaking forces were not considered, and only drag and inertia forces were used to calculate wave forces. The fluctuating winds characterised by a Kaimal spectrum (mean wind speed at the hub height 4 to 24 m/s, wind direction 0 deg), and the uni-directional irregular waves characterised by a JONSWAP-type spectrum (wave height 2 to 8 m, period 6 to 16 s, wave direction 0 deg) were given as the input data. The data sampling frequency was 20 Hz and the analysis time was 600 s. The analysis focused on the bending moment in wind-inflow direction at the mudline, where the influence of waves is large.

RESULTS AND DISCUSSION

Figure 1 shows the relationship between the mean wind speed at the hub height u_m normalized by the rated wind speed u_r and the bending moment corresponding to each individual wave M_w in wind and waves. The results are for all wave conditions, and the star, circle and hatch indicate the maximum, mean and standard deviation of the bending moment, respectively. The bending moments for each OWT increase with increasing wind speed below the rated wind speed, and when the wind speed exceeds the rated wind speed, they decrease due to the blade pitch control. All three OWTs show the similar response characteristics. In addition, the larger the scale of power generation, the larger the bending moment because the wind load on the rotor surface of the wind turbine

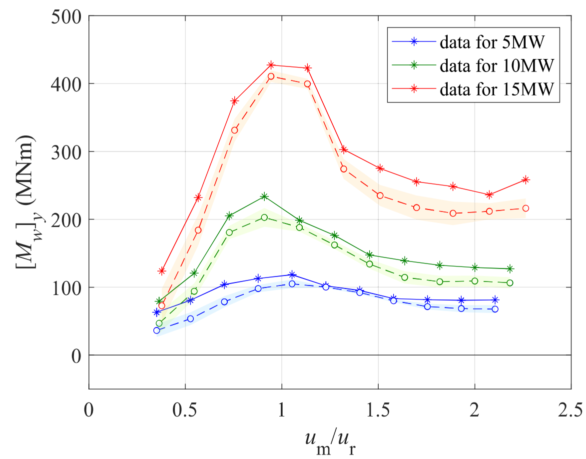

Figure 1 - Dynamic response of fixed-bottom OWTs in wind and waves (each color: power generation scale, star: maximum value, circle: mean value, hatch: standard deviation)

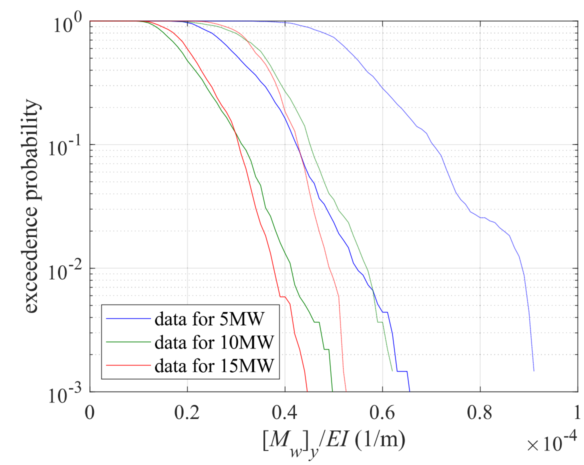

Figure 2 - Exceedance probability distribution of curvature corresponding to individual waves (each color: power generation scale, solid line: u_m = 6.0 m/s, dotted line: u_m = 16.0 m/s)

increases with blade length.

To check the stability of the OWTs, Figure 2 shows the exceedance probability of curvature corresponding to each individual wave, which is the bending moment divided by the bending stiffness *EI*. Regardless of the wind speed range, the larger the power generation scale, the smaller the exceedance probability of curvature. This imply that as the scale of power generation increases, larger OWTs can be expected to be structurally more stable against wind and waves.

The detail applications of OpenFAST on the fixed-bottom OWTs with different power generation scales in wind and waves will be presented at the conference.