Sensitivity analysis of the dynamic response of a floating wind turbine

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Introduction

The dynamic response of HYWIND Demo due to the combined action of wind and waves is numerically simulated by the computational tool SIMA (Simulation of Marine Operations). The numerical model has previously been compared to full scale measurements by Skaare et al. [1]. To better understand the sensitivity of the responses to the various environmental parameters, a sensitivity study is performed. In this preliminary study, the sensitivity of various motion parameters are investigated as function of the wave conditions, wind speed, turbulence intensity, wind shear as well as the spatial resolution of the numerical wind field. A more comprehensive study is under way.

Objective

This study was conducted by performing sensitivity studies to identify the relative importance of each environmental parameter to the total structural responses of HYWIND Demo based on study made by Skaare et al. [1].

Methods

- The environmental conditions studied by Skaare et al. [1] are used as base cases. Both below rated and above rated wind speeds are considered. Firstly, results were checked to be consistent with the results in Skaare et al. Then, the environmental characteristics are varied around the values corresponding to the base cases while the length of simulations were 30min.
- Environmental parameters such as wave peak period and significant wave height, the exponent (α) in wind shear profile power law, the spatial resolution of the numerical wind field and turbulence intensity of wind were changed. To perform sensitivity study of a parameter, only that parameter was changed while other environmental parameters remained unchanged.
- For each parameter, responses of the structure such as electrical generator output, platform pitch motion at nacelle level and blade out-of-plane tip motion were recorded.
- Mean and standard deviation of each response were compared to understand the importance of each parameter.

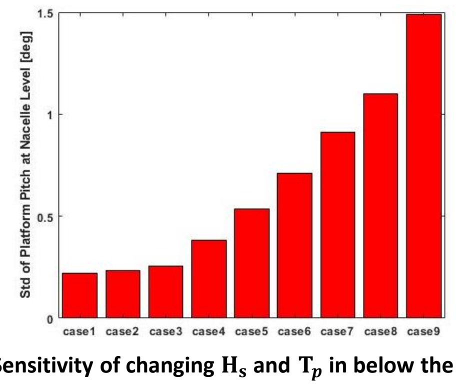

Figure 1. Sensitivity of changing H_s and T_p in below the rated wind speed (wave characteristics vary from case 1 where H_s=0.75m and T_p=6.5s to case 9 where H_s =12.25m and T_p=15.5s)

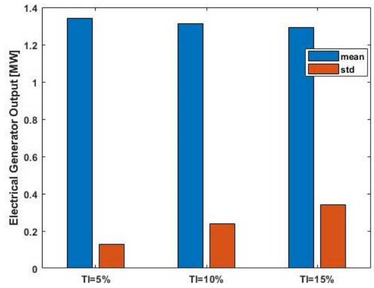

Figure 2. Sensitivity of changing turbulence intensity in below the rated wind speed (turbulence intensity varies from 5% to 15%)

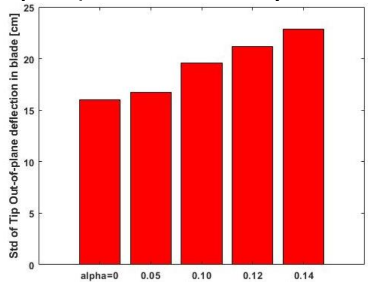

Figure 3. Sensitivity of changing alpha while TI=1% in above the rated wind speed (alpha varies from 0 to 0.14)

Results

- Higher H_s and T_p generated higher standard deviation in evaluated responses. For instance, while mean platform pitch at nacelle level is almost the same equal to 1.55 degrees in all cases, Figure 1. shows that standard deviation of platform pitch at nacelle level in case 9 where H_s=0.75m and T_p=6.5s is 1.49 degrees compared to 0.22 degree for case 1 where H_s=12.25 and T_p=15.5s.
- Higher turbulence intensity produced higher standard deviation in evaluated responses. For example, it is shown in Figure 2. that by increasing the turbulence intensity from 5% to 15%, the standard deviation of electrical generation output increases from 0.1275 to 0.341 MW, while the mean electrical generation output slightly decreases from 1.339 to 1.291 MW.
- Varying α in wind shear profile power law and the spatial resolution of the numerical wind field had no significant effect on the responses.

Conclusions

- The wave characteristics and turbulence intensity had significant influence on the dynamic behaviour of HYWIND Demo. However, within the range of parameters considered in this study, the wind shear exponent, alpha, and the spatial resolution of the numerical wind field did not show to have any significant impact on the dynamics. However, more detailed analysis is planned to investigate the impact of the wind field parameters on the dynamic response.
- High turbulence intensity of wind could be an important player that variation of alpha has no significant effect on the responses. For instance, when turbulence intensity reduced from 11 % to 1% in above the rated wind speed base case, Figure 3. shows that the standard deviation of blade out-of-plane tip motion increased from 15.98 to 22.85 cm when α increases from 0 to 0.14.

References

[1] B. Skaare, F. G. Nielsen, T. D. Hanson, R. Yttervik, O. Havmøller and A. Rekdal, "Analysis of measurements and simulations from the Hywind Demo floating wind turbine," Wind Energy, no. 18, p. 1105–1122, 2015.