TU Delft

Offshore & Dredging Engineering

Technische Universiteit Delft

Structural Performance of a 10MW Turbine in Offshore Hurricane Wind Conditions - A Case Study for the Gulf of Mexico

Offshore wind farms are being deployed in ever more challenging conditions. Relatively unexplored are wind farms deployed in hurricane-prone regions. That is exactly the challenge that Mexican government faces as they want to expand their renewable energy resources by developing offshore wind in the Gulf of Mexico. The increased variability in wind resources, due to a combination of a reduced energy-yield design wind speed and increased hurricane structural design wind speed, pushes the overall design challenge of the turbines. Of key importance is the limited knowledge on how hurricane wind affect structures, particularly OWT's.

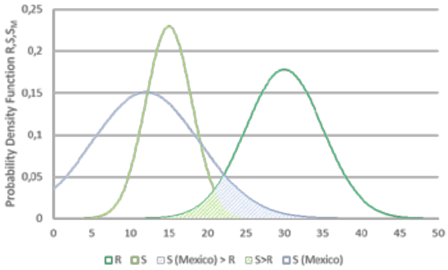
This study aims to identify how main characteristics of hurricane winds differ from models of regular extreme winds used in engineering simulations, to more accurately quantify hurricane winds loads and response effects on a 10MW turbine and to assess, albeit in a simplified manner, the structural ULS and SLS performance of the turbine under these extreme conditions.

The most important distinction found between hurricane winds and regular extreme winds is the turbulence spectrum: Yu [18] found turbulence energy is shifted towards the lower frequencies for hurricanes while Li [16] found that turbulence energy is shifted towards the higher frequencies. Both agreed that, although disagreeing on the turbulence spectra, that these wind parameters are likely storm-dependent and/or location-dependent. In this study, hurricane parameters are incorporated into a wind generation model adopted from Cheynet [2] and altered to incorporate the hurricane spectra. The wind model is limited to the 1D longitudinal case due to limited available information on other wind components for the hurricane winds. To quantify the loads and response effects due to the different spectra, a numerical approach is considered, using a finite-element blade model developed by Pim van der Male [21] applying the DTU's 10MW reference turbine's structural and simplified aerodynamic properties.

Within the boundaries of the inaccuracies present in the numerical input adn simulations, it was found that both the Yu and Li hurricane spectra show an increased load effect on the turbine blade, the response effect being equally large for both and roughly 20% larger compared to the Kaimal cases. This difference is proven to be predominantly due to the selection of the surface roughness length for hurricane conditions which was found to be larger by both Yu and Li studies [16, 18] for hurricane conditions. The difference due to the spectral change is negligible since the turbulent energy is nearly equal around the natural frequency of the considered 10MW blade thus not giving rise to significant changes in a dynamically amplified response. Selection of accurate hurricane wind parameters such as roughness length are thus equally important as the identified difference in turbulence spectra as they also result in significant changes of about 20% in the final results. Blade orientation has a considerable effect on reducing the response of a single blade if oriented downward. Averaging the thrust forces over all three blades however, effectively negates this advantage.

Structural performance was assessed through failure probabilities of the blade given the results of the aforementioned simulations. It was found that the hurricane wind simulations resulted in the largest failure probabilities, showing a non-linear increase in failure probabilities for larger wind speeds. Bending is the governing failure mode of the blade as these failure probabilities are considerably larger compared to the shear failure probabilities for wind speeds exceeding 50 year return period conditions.

Verifying the blade model response, it was found that the initially assumed three modeshapes were insufficient to accurately described the blade deformations. The model was therefore also not able to capture the correct internal root shear forces and root bending moments affecting the final results presented.



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