Creating Design Standards for Offshore Floating Wind Turbines

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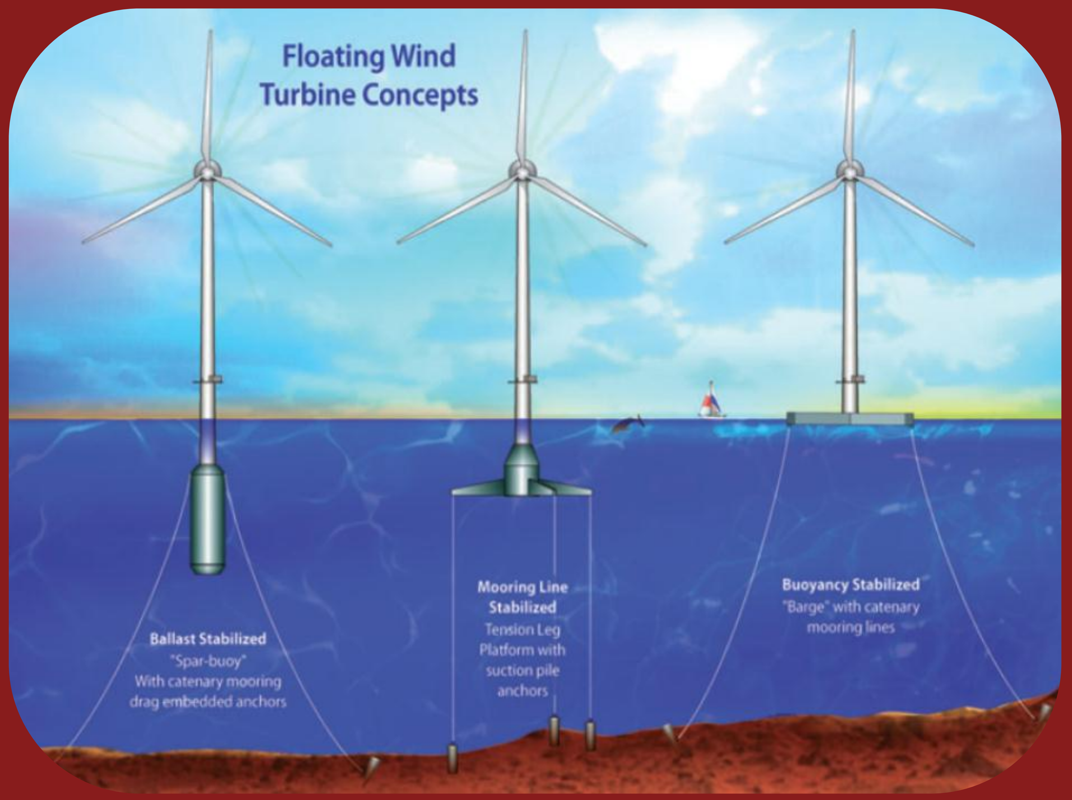
Abstract

Offshore wind turbines have the potential to be an important part of the United States' energy production profile in the coming years. In order to accomplish this wind integration, design standards for offshore wind turbines need to be in place. To capitalize on high speed and high quality winds over deep water, floating platforms for offshore wind turbines have been developed, but the current International Electrotechnical Commission (IEC) design standards do not consider floating platforms. This gap in the standards will be addressed, paying particular attention to the modeling of floating offshore wind turbines as well as the simulation of met-ocean conditions.



Floating Wind Turbine Designs

- Spar Buoy- Ballast stabilized
- Tension-Leg Platform- Mooring line stabilized
- Barge- Buoyancy stabilized

Problems with Current Offshore Design Standards for Floating Wind Turbines

- IEC 61400-3 describes the design standards for fixed bottom offshore wind turbines.
- Due to the slow periods of the floating platforms, longer simulations may be needed to capture enough platform oscillations to be statistically significant.
- Wind and wave directionality may be more important for floating platforms due to platform motion in directions other than the wind direction. Current offshore standards consider co-directional wind and waves to be the worst case, but this may not be true for certain floating platforms.
- Simulation tools for modeling floating wind turbines have had little validation due to lack of experimental data.

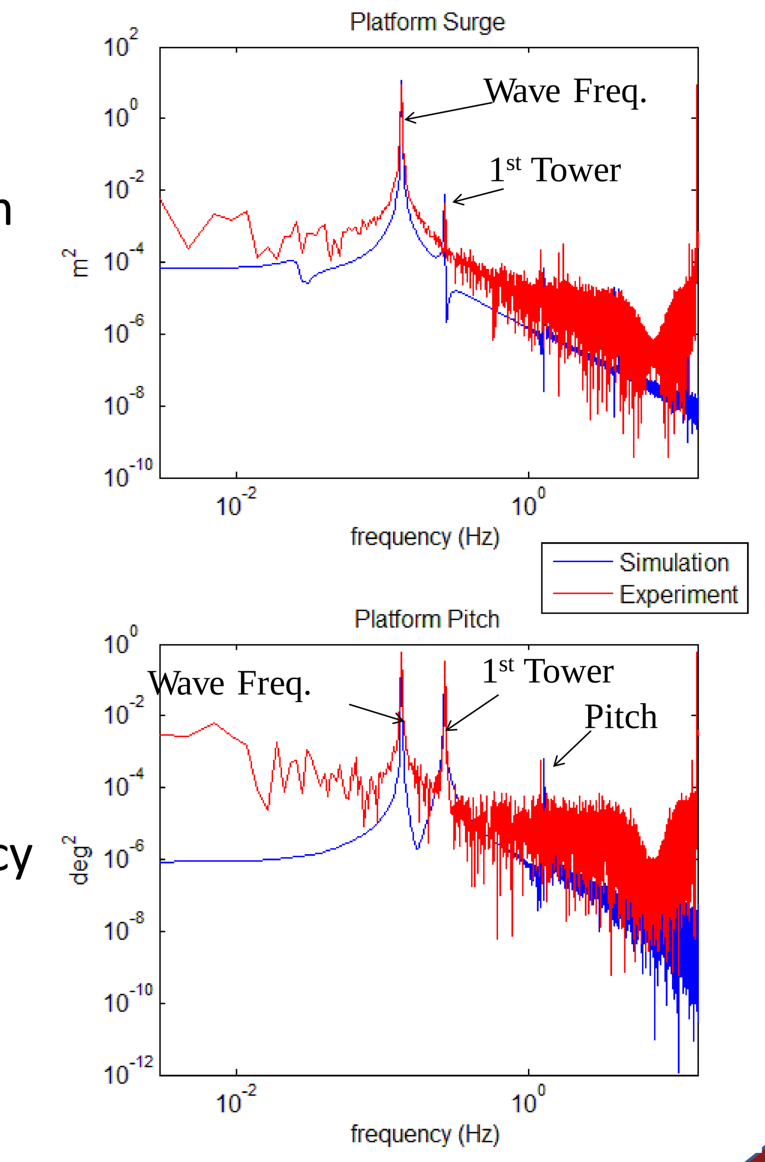
Methods

- First, FAST, a wind turbine simulation tool developed by the National Renewable Energy Laboratory will be validated using data from a $1/50^{th}$-scale experiment conducted by UMaine.
- Next, using data from NOAA's National Buoy Data Center, investigate correlation between wind speed, wave height, wave peak spectral period, wind and wave directionality, and current in order to use FAST to run fatigue investigations for the three platform designs and a variety of different sites.

FAST Model Calibration and Validation

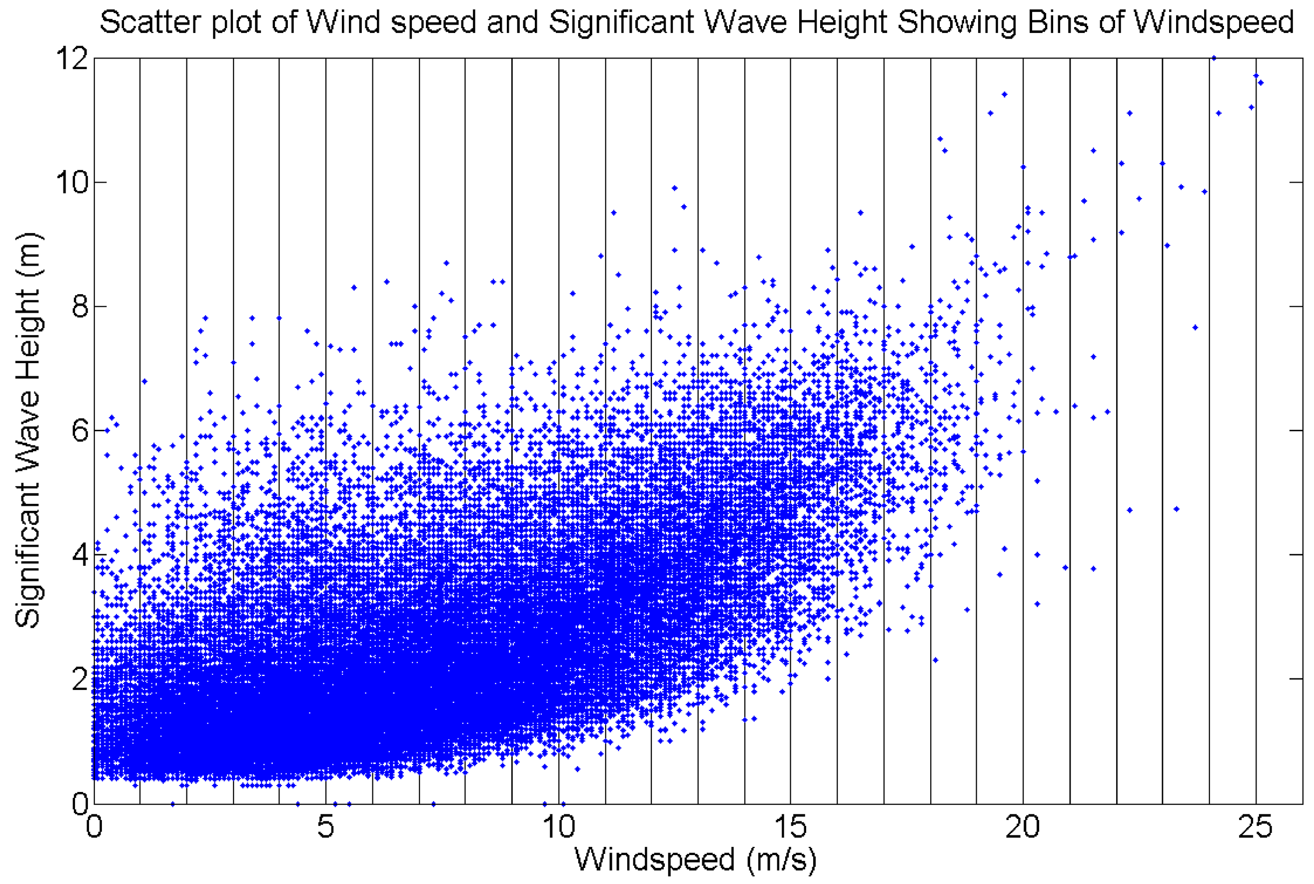
Experimental model of the Tension Leg Platform

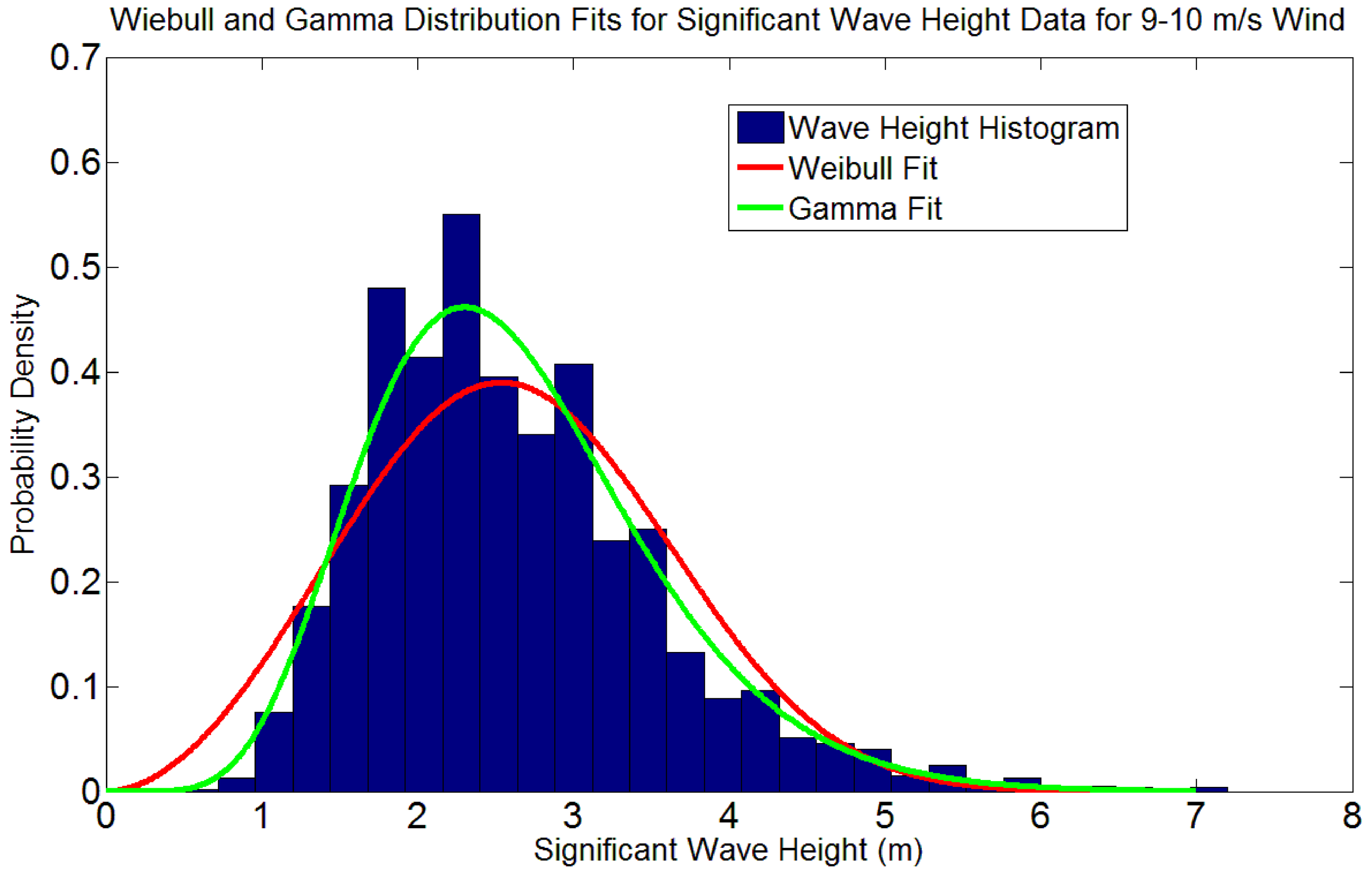
- In collaboration with NREL and UMaine, work on validating the current version of FAST was conducted.
- Using parameters from the UMaine $1/50^{th}$-scale tension leg platform model, an equivalent FAST model was created.
- The experimental data included free-decay tests, plane-progressive wave tests, and full turbulent wind and wave tests.
- Using a frequency domain analysis of the free-decay and plane progressive wave tests, the natural frequencies of the experiment were determined and the FAST model was tuned to give the same frequencies.
- The plot on the right shows one the frequency response of the experimental turbine and the simulation model. The wave forcing frequency, the first tower bending frequency, and the pitch frequency match very well for the simulation output and the data. Work is ongoing for validation cases using the turbulent wind and random wave experiments.



Metocean Data Analysis

- Work is currently being done to determine a set of wind and wave inputs to use for the loads analysis of the floating platform.
- Wind and wave correlation of actual offshore conditions is being studied in order to provide realistic inputs to the model. As a first look at the available data, a deep water site from a NOAA buoy near Georges bank off the coast of New York is used.
- An example of this work is shown in the plots below, on the left is a scatter plot of 10 years of data sampled hourly showing wave heights and wind speeds. There is clear correlation between wind speeds and wave heights, which is intuitive because the wind causes waves. It can be seen that as the wind speed increases, there is a tendency toward larger waves.
- In order to quantify this effect, the wind speeds are binned with 1 m/s widths, and probability density plots for wave height are fit over the data for each bin of wind speed. The plot on the right shows one such wave height probability density function (PDF), for a wind speed of 9-10 m/s. These PDF models will be used in future FAST simulations.





Future Work

Work is currently being conducted on further validation of the hydrodynamics of FAST, as well as determining correlation of wind data with other metocean parameters, such as wave direction and peak wave spectral period.