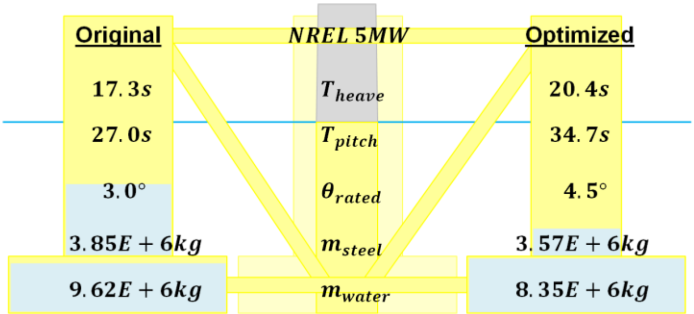
Technische Universiteit Delft

European Wind Energy Master
Offshore & Dredging Engineering

Rational upscaling and modelling of a semi-submersible floating offshore wind turbine

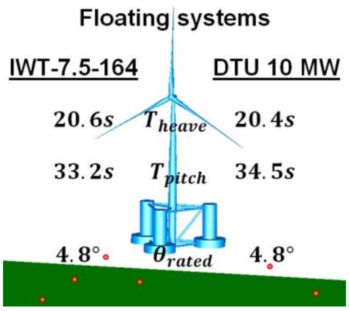
Floating offshore wind turbines are in focus as the industry moves towards larger turbines, farther offshore, in deeper water. Larger turbines can reduce the cost of energy, but require larger support structures. In order to avoid time-consuming and costly redesign of the floater, this work presents a guideline for optimization and upscaling of a semi-submersible floating platform, addressing special challenges related to floating systems and technical changes in turbine design.

The OC4 semi-submersible platform is used as starting point. After examining the results of a simple initial upscaling, the main criteria for a semi-submersible floating platform are specified. Aiming for longer natural periods in heave and pitch (at least 20 s and 30 s), a lighter and cheaper platform, and a less over-conservative but still stable and safe system, the original OC4 semi-submersible platform is optimized by reducing the upper column diameter and changing the ballast position within the columns.



Based on this optimized design, a guideline for an upscaling procedure for any other turbine is given. The main scaling factor is determined from the mass ratio of the top structures in order to account for technological development. The main column is scaled so that it fits the new tower base diameter. The scaling factor for the upper columns is computed based on the ratio of the overturning moments, and considers the contribution of the different columns to the stiffness component in pitch. The mooring line length is scaled to obtain a predefined stiffness.

Finally, the controller gains are recalculated based on the expected natural frequency in pitch. The optimization and upscaling process is carried out for Fraunhofer's offshore IWT-7.5-164 and the DTU 10 MW reference wind turbines. The floating systems are analyzed by means of simplified spreadsheet methods, linear frequency-domain calculations (in DNV's software HydroD), and detailed time-domain equation-based models (in Fraunhofer's software Modelica).



The systems are evaluated regarding their eigenfrequencies, nominal pitch, stability and global performance in selected sea states. The results obtained from both computer programs and the initial hand calculations are comparable and satisfying. The structural integrity is checked for the upper columns by a simplified approach, using tank and sea pressure for computing the equivalent stress. Detailed strength checks for fatigue and ultimate limit states, as well as optimization of the mooring system, are left for future work.

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