Integrated Structural and Dynamic Optimisation of Floating Wind Turbine Platforms

Floating offshore wind turbines unlock deep-water sites with high, consistent wind resources but their full deployment is challenged by their associated high capital expenditure and reliability in the offshore environment.

While global motion and hydrodynamic behaviour have been extensively studied, structural analysis is less addressed in the public literature. Existing studies often lack comprehensive design load cases, geometry variations, and optimisation procedures. This is a critical gap, as accurate structural modelling is essential for reliable cost estimation, given that the floater accounts for approximately 16.8% of a wind farm's total cost. Reliable steel mass predictions require robust structural models capable of identifying cost-effective geometries without compromising structural integrity.

This PhD thesis introduces a novel application of Finite Element Analysis (FEA) in the design, analysis, and optimisation of floating offshore wind turbine platforms, with a focus on structural integrity and modal performance.

The present structural optimisation is employed to predict steel mass requirements and verify ultimate limit states in static conditions.

This analysis uses an accurate and efficient hybrid beam-shell finite element analysis to optimise the thicknesses of both the tower and platform. The optimisation process is divided into two parts: tower optimisation, governed by frequency constraints, and platform optimisation, which focuses on stress and buckling resistance. For the early-stage design phase, the study applies static wind loads within the FEA framework, offering a simplified yet effective method for preliminary structural assessment.

The final step involves the calculation of dynamic loads in a time domain analysis using state-of-art tools, where ultimate and fatigue limit states are assessed at the tower base, used as a representative point to assess the dynamic performance.

The methodology is applied to three floating platform concepts for the IEA 15 MW reference turbine: semisubmersible, spar, and tension leg platform (TLP). Comparative results show estimated steel masses of 2850 tons (semisubmersible), 1300 tons (TLP), and 4000 tons (spar), where the semisubmersible demonstrates a superior fatigue resistance. The findings provide early-stage design guidance and new insights into the influence of geometry on steel mass, modal characteristics, and structural integrity.