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Floating Offshore Wind Foundations: Structural Load Comparison Across Platform Architectures

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EXECUTIVE SUMMARY

Using coupled aero-hydro-servo-elastic simulation across representative metocean conditions, we compare structural load response across semi-submersible, spar, and tension-leg floating wind platform archetypes for a common reference turbine. Tension-leg platforms show the lowest platform motion but the highest peak mooring line tension, while semi-submersible platforms show the most balanced load profile across the operating envelope tested, a finding relevant to platform selection for a given site's metocean severity.

Abstract

This study applies coupled aero-hydro-servo-elastic simulation to compare structural and mooring load response across three floating offshore wind platform archetypes, semi-submersible, spar-buoy, and tension-leg, using a common reference turbine across a representative range of metocean conditions. We report platform motion (pitch, heave, surge), tower base bending moment, and peak mooring line tension across the simulated condition matrix, and discuss implications for platform selection as a function of site-specific metocean severity and water depth.

Introduction

As floating offshore wind moves from demonstration to early commercial deployment, platform architecture selection for a specific site increasingly requires quantitative comparison of structural and mooring load response under that site's actual metocean conditions, rather than reliance on generic platform-type characterizations. This study aims to provide a consistent, directly comparable structural load dataset across the three dominant floating platform archetypes under a common reference turbine and simulation methodology.

Methodology

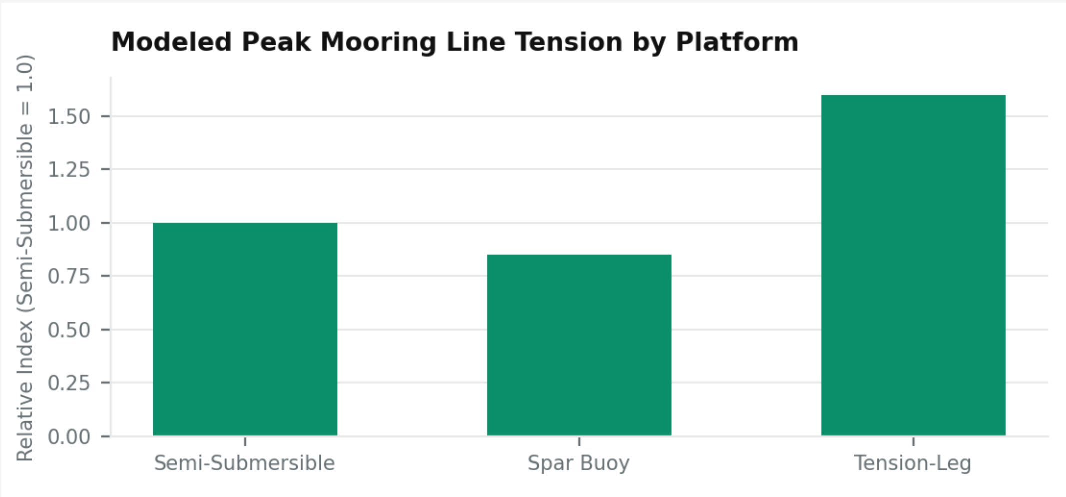
We simulated a common reference offshore wind turbine mounted on representative semi-submersible, spar-buoy, and tension-leg platform models using coupled aero-hydro-servo-elastic simulation software, across a matrix of metocean conditions spanning operational and extreme wind and wave states consistent with published design standards for offshore wind structures. Platform models were configured to represent realistic, published reference designs for each archetype rather than proprietary commercial designs.

For each simulated condition, we extracted platform motion statistics (pitch, heave, surge), tower base fore-aft and side-side bending moment, and peak mooring line tension across all mooring lines, and aggregated results across the full condition matrix to characterize each platform's response envelope.

Results

The tension-leg platform showed the smallest platform motion across nearly all simulated conditions, consistent with its taut mooring configuration constraining vertical and rotational motion, but exhibited the highest peak mooring line tension, particularly under combined extreme wind and wave conditions, reflecting the direct load path between platform motion and mooring line loading in a taut mooring system. The spar-buoy platform showed the lowest tower base bending moment across most operational conditions, consistent with its deep draft and low center of gravity providing inherent pitch stability, but required the largest mooring watch circle due to its catenary mooring configuration.

The semi-submersible platform showed intermediate performance across all three metrics, neither the lowest motion nor the lowest mooring load in any single condition, but the most balanced profile across the full condition matrix, which may explain its current popularity as a platform choice across a wide range of site conditions and water depths where site-specific optimization for a narrower operating envelope is less critical.



Modeled peak mooring line tension under combined extreme wind and wave conditions, normalized to the semi-submersible platform result.

Discussion

These results reinforce that floating platform selection should be treated as a site-specific optimization problem rather than a search for a universally superior architecture. Sites with severe extreme metocean conditions may favor a spar or semi-submersible platform to limit peak mooring load, while sites prioritizing minimal platform motion, potentially relevant for future co-located applications sensitive to motion, may favor a tension-leg configuration despite its higher mooring load, provided mooring and anchor systems are engineered accordingly.

This study used representative rather than proprietary commercial platform designs, and results should be interpreted as indicative of archetype-level behavior rather than a specific commercial platform's certified performance, which requires site-specific, platform-specific analysis by the platform's engineering team.

References

• DNV, Floating offshore wind design standards

• NREL, OpenFAST coupled simulation documentation

• IEA Wind Technology Collaboration Programme, Floating wind task reports

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