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Performance Evaluation of Three Semi-Submersible Floating Offshore Wind Turbine Designs for the Taiwan Strait

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Abstract

This study evaluates the performance of three semi-submersible floating offshore wind turbine (FOWT) systems—disk-type, barge-type, and column-type—in the Taiwan Strait under a range of metocean conditions. All target FOWTs are equipped with an SNL 13.2 MW wind turbine, a 3×3 mooring system, and have a total mass of 35,875 tons. Assuming wave alignment with the wind direction, the wind and wave conditions are characterized using the API wind spectrum and the JONSWAP wave spectrum, respectively. The performance of the FOWT systems, considering four wind directions—45°, 135°, 225°, and 315°—is evaluated under three scenarios: (1) the RC scenario, with a significant wave height of 1.7 m and a zero-up-crossing period of 5.5 s; (2) the 50C scenario, with a significant wave height of 12.72 m and a zero-up-crossing period of 8.83 s; and (3) the LTC scenario, based on statistical data from the Hsinchu offshore area collected between 2015 and 2021. A numerical framework integrating AQWA, STAR-CCM+, and ORCAFLEX is employed to estimate the motion responses, power output, and mooring line tensions of three FOWT systems. The effect of viscosity is evident in the standard deviation of performance metrics, while the capacity factor is minimally affected by viscosity. The barge-type FOWT exhibits the highest capacity factor, followed by the column-type and the disk-type. Viscosity has a non-trivial impact on mooring line fatigue damage, where the barge-type FOWT experiences the least damage, followed by the column-type and the disk-type. The results indicate that the disk-type FOWT exceeds the allowable tilt angle under the RC scenario. In the 50C scenario, the barge-type FOWT surpasses the limits for maximum offset and mooring line tension. The column-type FOWT, configured with a 105° system arrangement, is identified as the optimal design, achieving a capacity factor of 0.446 and a maximum damage level corresponding to 26.97% of the allowable threshold.