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Unsteady blade loading behaviour of a benchmark tidal turbine in regular wave and current

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ABSTRACT

Tidal energy is regarded as an important renewable energy source that could contribute to meet net-zero targets. The design and optimisation of tidal stream turbines requires consideration of unsteady flow effects due to the influence of waves, shear, turbulence, seabed-induced vortices, turbine-structure interference, wake interactions, wave-induced platform motions in the case of floating devices, etc. Among those, waves are potentially the largest driver of performance and load fluctuations, affecting fatigue life and the quality of power delivery. Several studies have analysed tidal rotor performance under the effects of currents and surface waves using both experiments (Scarlett & Viola 2020, Galloway et al. 2014) and numerical approaches like BEM (Guo et al. 2018) and CFD (Zilic de Arcos et al. 2023). Most studies only presented blade integrated performance metrics such as thrust, power and root bending moments, reporting case dependant fluctuations about mean values from 10% to 200%, while only a few studies investigate loading variations and flow characteristics at local blade sections (Zilic de Arcos et al. 2023).

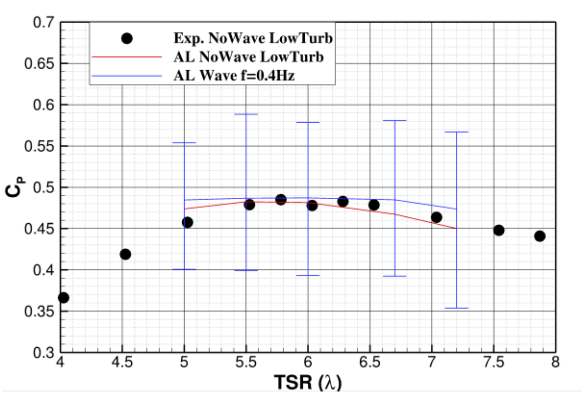

Figure 1: Time-averaged power coefficients, error-bar showing the min and max of fluctuations introduced by a regular wave.

The presented paper investigates the unsteady loading of a benchmarking turbine (Tucker Harvey et al. 2023) operating under a regular wave on top of a constant current using computational fluid dynamics (CFD) approach. The numerical model combines the k-w SST RANS turbulence model with an Actuator Line (AL) model for rotor representation, and a Volume of Fluid (VoF) approach with the waves2Foam library (Jacobsen et al. 2012) and Generating-Absorbing Boundary Conditions (GABC, Borsboom and Jacobsen 2021) for wave generation and modelling. It is found that the time-averaged integrated thrust and power coefficients are similar between the case with and without wave, but cases with wave introduces fluctuations of 10% on thrust and 20% on torque. Detailed analysis is carried out on the azimuth- and phase- averaged blade local loadings, suggesting that the tip region experienced the highest loading fluctuations.

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