Doctoral Dissertation
Doctoral Program in Mechanical Engineering (36^{th}cycle)

Sloshing tank to enhance WEC performance

Modelling, validation and integration

By

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Abstract

This thesis examines the potential for enhancing the ISWEC device by integrating a U-shaped sloshing tank to expand its operational bandwidth. The conventional linear model for sloshing tanks is augmented with nonlinear effects, which were explored using high-fidelity computational fluid dynamics (CFD) simulations. The employment of advanced CFD simulations includes hybrid RANS-LES models, which are used to analyse highly non-linear phenomena in the U-tank. This advances the state-of-the-art in sloshing simulation, with a significant improvement in the computational costs.

The tuning of the dynamic response of the U-tank system is achieved with a novel passive control logic using discrete volumes. The solution is defined theoretically and then integrated in the ISWEC system with a feasibility check and design to improve the system capabilities. The integration of the U-tank resulted in an increase in the ISWEC device's pitch motion of up to 35%. Improvements in Annual Energy Production (AEP) of up to 18% were observed in locations with broad wave period ranges, such as Alghero and Balder. In areas with narrower wave spectra, such as Pantelleria, a 9.3% AEP increment was achieved.

A cost of energy (CoE) analysis demonstrated potential energy cost savings between 8% and 16% with the U-tank integration. However, the absolute CoE figures remain a limitation for industrial-scale implementation.

This work represents a step towards expanding the ISWEC system's operational bandwidth, enhancing its adaptability to various sites and pushing it closer to industrial-scale application in diverse wave energy environments. The objective is to facilitate the mass production of a single device, reduce its cost and then tune its response through the controlled U-tank technology.