Politecnico di Torino | ScuDo
Scuola di Dottorato - Doctoral School
WHAT YOU ARE, TAKES YOU FAR

Doctoral Dissertation

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

A Novel Synergy: Integrating Oscillating Water Column Wave Energy Converters with Floating Wind Turbines - Experimental and Numerical Investigations

By

Beatrice Fenu

Supervisor:
Prof.ssa Giuliana Mattiazzo

Doctoral Examination Committee:
Prof. Francesco Ferri, Referee, Aalborg University (Denmark)
Prof. Alessandro Corsini, Referee, Università degli studi di Roma 'La Sapienza' (Italy)

Politecnico di Torino

ABSTRACT

In the context of ocean engineering, hybrid systems have garnered increasing attention due to the necessity of improving and optimizing floating wind turbines in response to the growing demand for renewable energy. Modeling highly nonlinear complex systems that integrate different types of devices is challenging. A significant gap in the current hybrid platform field is the lack of experimental benchmarks necessary for validating numerical models, thus providing reliable numerical representations upon which to base optimizations and technological advancements.

This thesis focuses on a proof of concept for a novel wind-wave floating system that integrates Oscillating Water Columns (OWCs) with a spar buoy floating platform. The central research question is whether OWCs can positively influence the hydrodynamic behavior of floating wind turbines. The numerical model developed in this study investigates the complex interactions between subsystems, including wind turbine aerodynamic loads, OWC pressure loads, and hydrodynamic loads. A frequency domain model is developed to investigate the influence of PTO size on platform motions and OWC power performance. The results indicate that careful sizing of the OWC air chambers and their PTO can enhance platform stability and overall energy production. However, the frequency domain model is not suitable for capturing the system's complex nonlinear physics.

Experimental tests in a wave tank provided crucial insights into the system's behavior and nonlinear effects, highlighting the importance of accurate experimental representation. The experimental investigation focused on platform dynamics with various OWC PTO sizes, establishing a foundation for optimization. The comparison of experimental data with numerical results showed that while the frequency domain model offers satisfactory results for a simplified representation, a nonlinear model is necessary for accurate depiction.

The experiments underscored the critical importance of actively managing the power take-off system dimensions to harness the stabilizing benefits provided by OWCs on floating platforms. This led to the development of a real-time control system for the OWC air chambers, initially tested on a fixed OWC, marking a significant step forward in understanding and optimizing the performance of integrated hybrid platforms. The novel technique for dynamically controlling the orifice size during experimental simulations, applied initially to a Wells turbine, successfully replicated the desired flow rate curve and offers a feasible alternative to previous methods, overcoming constraints in studying full-scale dynamics in a wave flume.