Study of a point absorber wave energy converter technology: modeling, simulation, control and experimental validation of the system

Summary

The work carried out in this thesis can be defined as a holistic study of the point absorber wave energy converter (WEC) technology. The research activity focuses on the mathematical modeling of the point absorber devices, the application of control strategies to enhance the power performance of the system and the dynamic analysis of innovative technological concepts. The study initially presents a historical review and a description of the basic WEC technologies in order to provide a better understanding of the state of the art of the wave energy sector. A mathematical model in three degrees of freedom (3DOF) for a submerged point is described in detail, which can be used as a design tool for the development of the technology. The numerical model is based on the potential flow theory while all the hydrodynamic properties such as the added mass and the radiation damping are calculated using the Boundary Element Method (BEM) software Ansys Aqwa. Moreover, the current study introduces a fully resolved computational fluid dynamics (CFD) model using the wave structure interaction (WSI) framework implemented within IBAMR, an open-source C++ library. The simulations of the WEC are carried out using the the fictitious domain Brinkman penalization (FD/BP) method. The thesis presents a comparison between the two numerical models and while the CFD model is used to estimate the performance of the system in various conditions. In order to validate the technological concept of the point absorber and gain initial experience in the prototyping of such devices, an experimental campaign is presented. Furthermore, a design procedure of a point absorber for the coast of Pantelleria is presented since the current thesis considers the Mediterranean Sea for WEC deployment. Extremum seeking control (ESC) approach is applied in order to optimize the power extraction demonstrating that model-free strategies can effectively enforce the function of the devices. Finally, the technological concepts of the multi-tether point absorber and the interconnected WEC array are introduced showing that by using multiple tethers and PTO units, the energy production of the technology increases significantly.