



Wave Energy Integration for Sustainable Port Development: The Case of Castellammare del Golfo, Sicily

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Abstract

Wave energy harvesting represents a promising opportunity to supply small islands and coastal areas with sustainable energy. Although numerous concepts have been proposed in recent years, most wave energy technologies still require further development. In this context, the manuscript investigates the feasibility of installing a Wave Energy Converter (WEC) within the existing harbor infrastructure of Castellammare del Golfo, located in Sicily, Italy. This approach aims to harness renewable energy from wave motion to support the energy needs of harbor users. The manuscript also presents the conceptual design of a prototype currently under development to demonstrate the technical viability of this solution.

Introduction

Marine wave energy represents one of the most promising yet underexploited forms of renewable energy sources (RES). Recent advancements in Wave Energy Converters (WECs) have paved the way for practical applications in coastal areas, especially small islands. Some common technology are listed below:

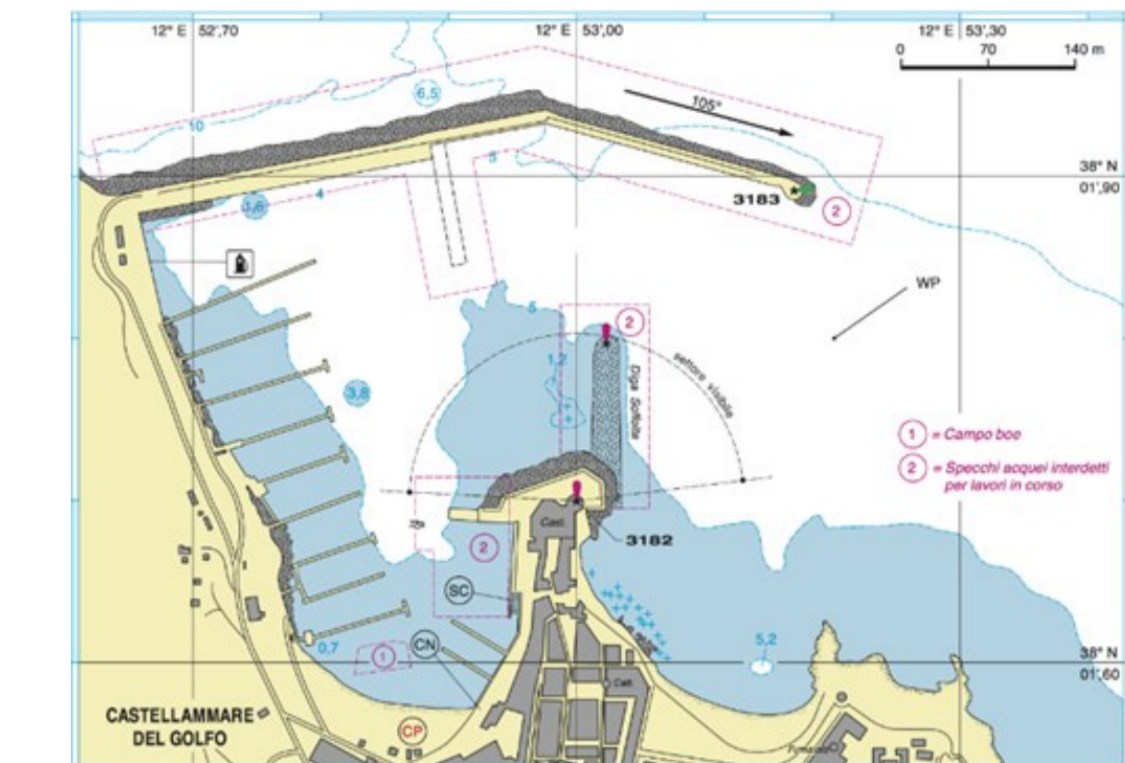
- **Oscillating Water Column (OWC)**, where waves enter a chamber causing the alternative compression and the decompression of the air inside, activating an air turbine.
- **Wave Activated Bodies (WAB)**, that typically consist of multiple floating segments connected by joints or hinges. Wave action induces relative motion between the segments, actuating hydraulic cylinders or mechanical linkages, which then convert the motion into pressurized fluid or mechanical energy.
- **Overtopping Device**, where waves overtop a ramp structure, filling a raised reservoir situated above mean sea level. The stored water is subsequently used to drive a low-head hydro turbine.

Case study: Castellammare del Golfo power plant

In this context, the manuscript proposes a project focused on the implementing a wave energy harvesting system at the Port of Castellammare del Golfo. This small town is located along the northern coastline of Sicily (Italy), between the cities of Palermo and Trapani.

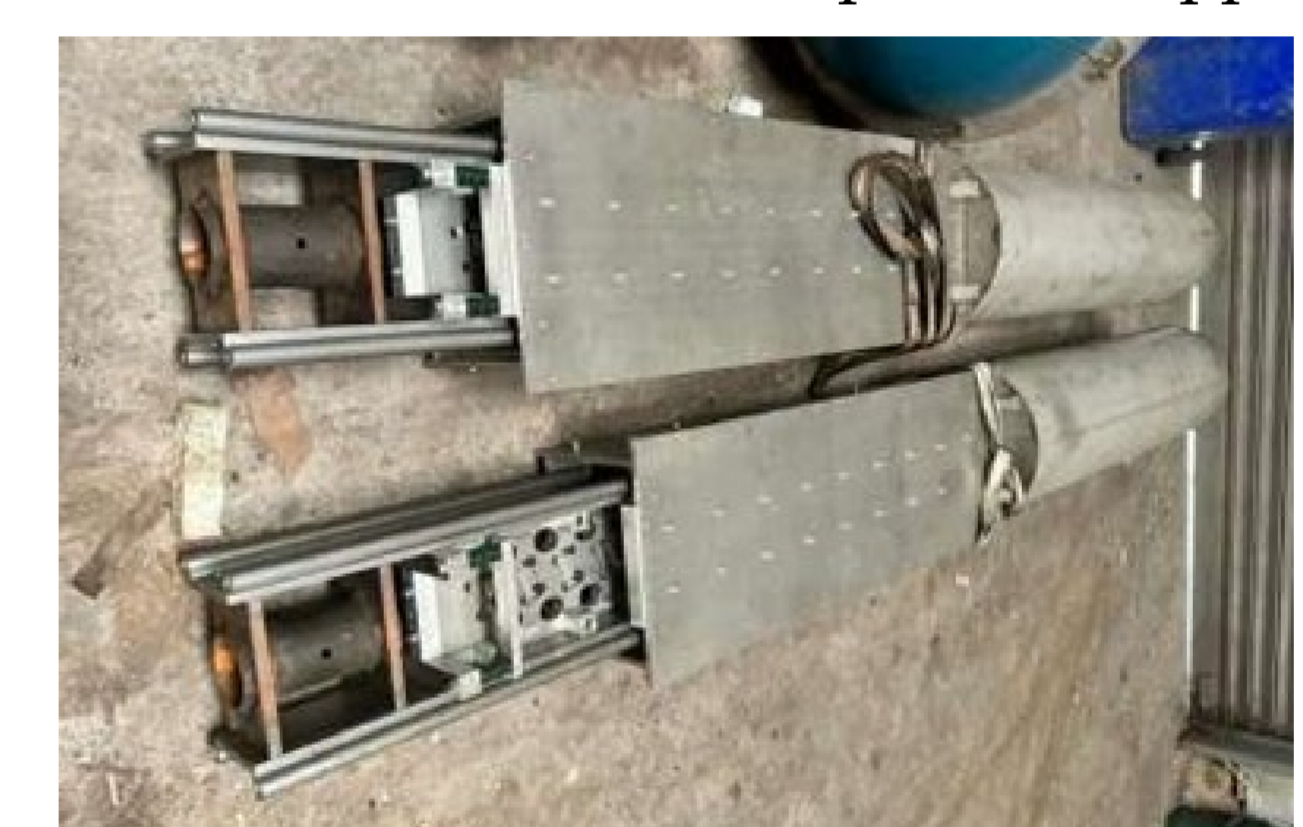
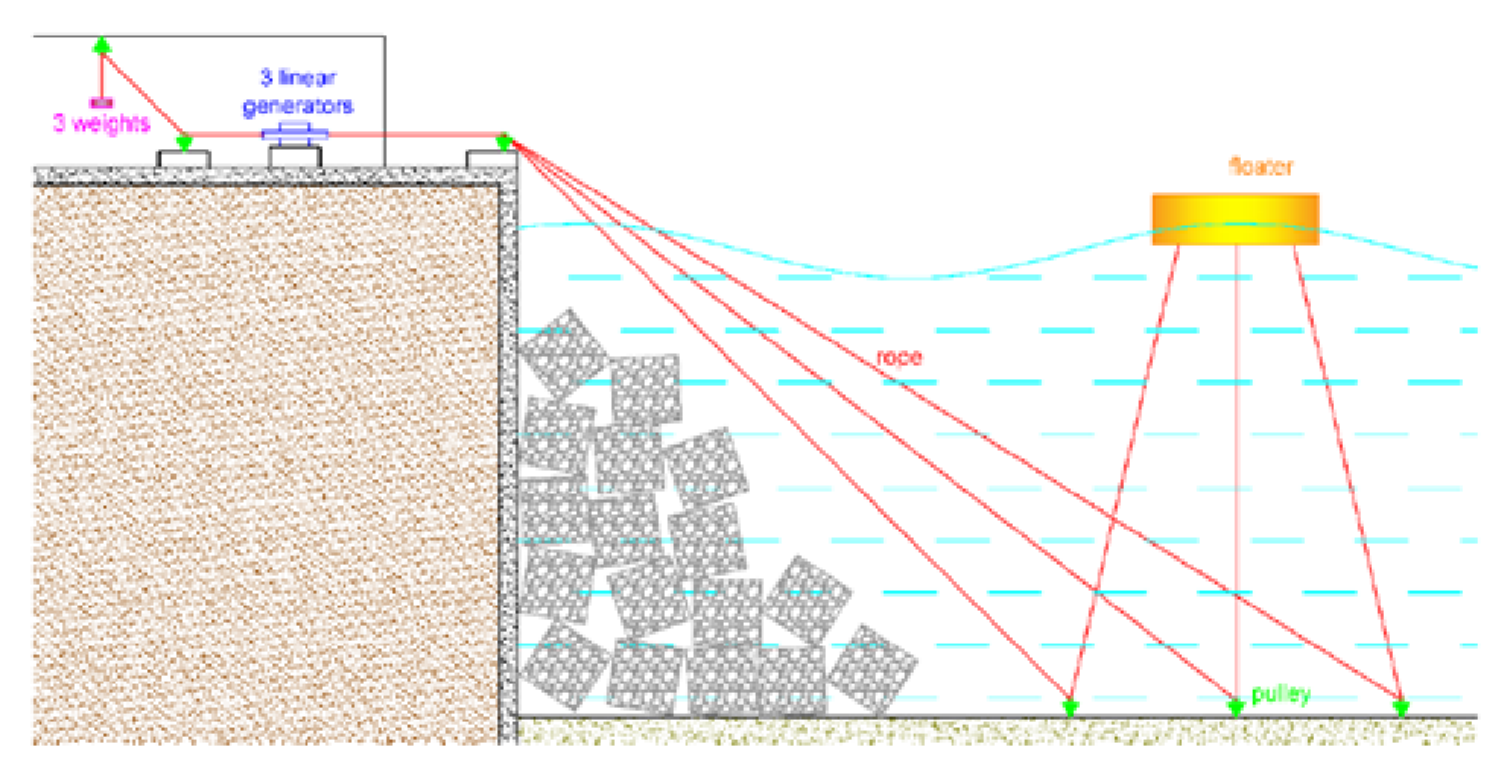


Leveraging existing coastal infrastructure and minimizing interference with recreational boating, the proposed solution is tailored to local wave conditions, as characterized by bathymetric and wave exposure analyses. The harbor consists of a pier and a wharf built at the foot of the Norman Castle (Punta Castello) to the east, and a rocky pier (Molo Nord), anchored at Punta dell'Acqua with an adjacent wharf to the west. Between these structures lies a stretch of natural coastline composed of beaches or rocky areas.



A prototype is currently under development at the University of Palermo. The proposed solution involves a floating buoy connected via pulleys and cables to the electrical generators. Specifically, linear generators have been chosen for this application due to their capability to convert the alternating motion of the ropes directly into electrical energy. In this configuration, magnets are installed on the movable part (the shifter), while coils are placed on the stationary part (the stator).

The entire system is currently being developed in order to achieve a rated power of approximately 30 kW.



Using the data reported above, a preliminary analysis was conducted with Ansys Aqwa. Results indicate that the proposed prototype could generate between 75 and 100 MWh/year.

Conclusion

The integration of Wave Energy Converters into existing infrastructure, such as harbor breakwaters, represents an attractive opportunity to reduce the costs associated with developing this technology. The brief review of the state of art reveals a variety of solutions for wave energy harvesting. In this context, the authors have presented a novel concept currently under development, intended for installation at the harbor of Castellammare del Golfo. Preliminary analyses suggest that the prototype has the potential to produce between 75 and 100 MWh/year. Future steps will include laboratory tests aimed at optimizing the control system, followed by on-site testing.

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