Co-design of Controllers in Wave Energy Converters

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1. Why Co-design?

Co-design has been successfully utilised in wind turbines to improve efficiencies and reduce levelised cost of energy (LCoE). Currently, wave energy converter (WEC) controllers are designed once the physical device is mostly finished. Introducing a co-design philosophy to WEC design could help bring down it's LCoE to competitive levels.

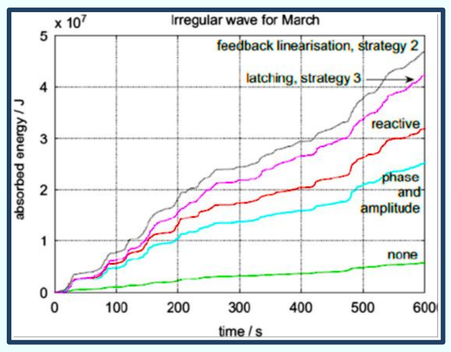


Figure from [1]

The figure above shows the improvement in energy capture from controlling a WEC. Studies have suggested improvements in energy capture ranging from 14 – 50% depending on technology [1]. Using a co-design methodology could lead to further enhancements.

HAPiWEC

This PhD is aligned with the EPSRC funded HAPiWEC (Holistic Advanced Prototyping and Interfacing for Wave Energy Control) project.

The HAPiWEC team is proposing that through the implementation of rapid-prototyping hardware and remotely accessible user control, novel control algorithms can be created, demonstrated, and validated at unprecedented levels of efficiency.

FloWave Ocean Energy Research Facility at the University of Edinburgh [5]

A 'comparative evaluation' will be launching later this year, where participants will be able to test their own control algorithms remotely on a WEC based at the FloWave research facility. The comparative evaluation, called 'HAPiGYM,' will have a variety of available metrics for participants to pick from, allowing them to decide which factors are most important to their control scheme.

Aligning with the HAPiWEC project will allow for the opportunity to contribute controllers to the HAPiGYM reference controller set, providing the opportunity to validate the PhD's controllers in a wave tank.

2. Pieces of the puzzle

Wave Resource

Very little can be done to alter the wave resource, having a solid understanding of it's nature will influence choices made elsewhere in the design process.

For example, in bimodal sea states (those with two dominant wave frequencies), the conditions a WEC experiences is much more complex, possibly requiring the use of a more sophisticated controller. On the right, the figure shows the occurrence of bimodal seas across the English coastline, showing at some sites, the occurrence is significant enough to need to be considered [2]. More broadly, in the North Atlantic, bimodal seas occur 40% of the time in low wave heights [3].

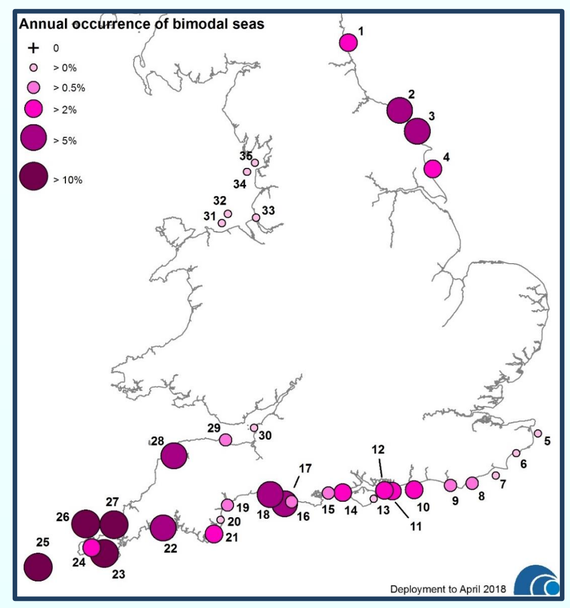
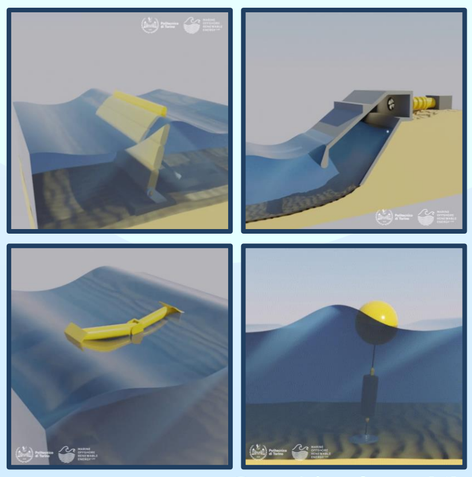


Figure from [2]

Power Take-off (PTO)

There is a multitude of different PTO technologies to choose from, for example hydraulics, linear generators, or rotary generators. The choice of which depends upon many factors, such as the expected forces upon the PTO, and optimal operating frequency.



Graphics from [4]

Geometry

There are many different types of WEC, each with their own optimal conditions and control strategies. On the left, there are four completely different designs that all fall under the banner of 'WECs.'

Deciding on which design, and then the dimensions of that design have implications for the other components, for example the forces the PTO will experience, and the resonant frequency of the device.

Controller

Controllers are in charge of making the moment by moment decisions in how a WEC operates, so it is important it has been designed with a detailed description of all of the WEC's components to ensure it can operate at peak efficiency.

Similarly, different control algorithms operate better under different situations, for example in model predictive control a model is used to predict the best decisions to make. Designing the WEC with a simpler geometry would allow for this model to operate much more effectively.

3. The PhD

This PhD will investigate the potential improvements from taking a holistic approach to the design of a WEC.

Designing controllers that incorporate PTO efficiency → Package controllers into a toolbox for use by others → Validation of controllers as part of HAPiGYM → Investigation of the interaction between different WEC geometries and controllers → Review of the benefits of a holistic design process →

[1] – Hong et al, Review on electrical control strategies for wave energy converting systems, *Renewable and Sustainable Energy Reviews*, 2014
[2] – Mason & Dhoop, Occurrence of Bimodal Seas around the English Coastline, 2018
[3] – Guedes Soares, Representation of double-peaked sea wave spectra, Ocean Engineering, 1984
[4] - Marine Offshore Renewable Energy (MOREnergy Lab), Politecnico di Torino
[5] – FloWave Ocean Energy Research Facility, https://www.flowavett.co.uk/