Review of Hybrid Wind and Wave Energy Systems

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Introduction

- Wind energy has been moving offshore due to the strong resource and open space at sea.
- There is also strong wave energy at sea, many locations have both strong winds and waves.
- A hybrid wind and wave energy system is defined as an offshore wind turbine combined with a wave energy converter (WEC) on a shared platform.
  - Floating offshore wind turbines (FOWT) are the focus of this review. Types of FOWT platforms include spars, semisubmersible, and tension leg platforms.
  - Wave energy converters are in an earlier development stage than wind energy. WECs span nearshore and offshore locations; and shallow, intermediate, and deep water depths.
  - WEC categories include oscillating bodies, oscillating water columns, and overtopping devices. Oscillating bodies move relative to a stationary body, oscillating water columns use the changing water pressure to compress air, and overtopping devices convert wave energy into potential energy.

Advantages and Challenges

- A FOWT is subjected to wave loading, but hub motion should be suppressed for maximum power output.
  - A WEC can passively absorb wave energy, 'sheltering' the FOWT [1].
  - WECs can be actively controlled to suppress platform motion from waves [2-5].
- Floating offshore wind needs a small amount of supplemental power (e.g., wind turbine controls, ballast operation) [6].
  - WECs currently produce an order of magnitude less power (kW compared with MW). This is useful for supplemental power and has future potential for greater power production.
- There are challenges to hybrid wind and wave energy systems, especially the increased cost and complexity to a FOWT. However, this research area could prove beneficial for the future of offshore wind energy.

Case Study 1: W2Power Hybrid System

Table 1. W2Power Hybrid System Ocean Demonstration and Full Scale

	W2Power demonstration	Future W2Power
Scale	1:6	Full scale
Ocean tests incl. WECs	no	yes
Wind power (kW)	Unknown	7,200
WEC power (kW)	-	2,000
Wind turbine type	Unknown	Siemens 2x 3,600 kW
WEC type	Oscillating body	Oscillating body

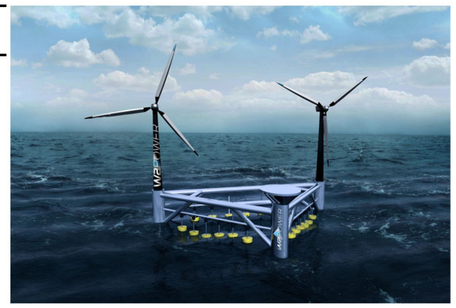

Figure 1 - W2Power by Pelagic Power [1]

- The W2Power system by Pelagic Power includes a semisubmersible wind turbine platform, two wind turbines, and multiple oscillating body WECs. [1]

Case Study 2: Poseidon Hybrid System

Table 2. Poseidon Wind and Wave Ocean Demonstration and Full Scale

	Poseidon37	Future Poseidon80
Scale	1:4	Full scale
Ocean tests incl. WECs	yes	yes
Wind power (kW)	33	2,300
WEC power (kW)	30	2,600
Wind turbine type	Gaia 3x 11 kW	Unknown
WEC type	Oscillating body	Oscillating body or oscillating water column

Figure 2 - Poseidon37 by Floating Power Plant [7]

- The Poseidon devices by Floating Power Plant have a buoyancy stabilized (barge) platform, three wind turbines, and multiple WECs: oscillating body or oscillating water column. [1,7]

Conclusion

- Hybrid wind and wave energy systems have potential to be part of the grand vision of offshore wind energy.
- Two case study hybrid systems are shown to demonstrate the potential to develop these systems. Both have been ocean tested at demonstration scale.
- Several research studies [2-5] have shown that WECs can be actively controlled to suppress FOWT platform motion.
- More research is needed to develop hybrid wind and wave energy systems, especially with platform motion suppression and supplemental power as the main goals.

Future Work

- Mid-fidelity numerical modeling of a hybrid wind and wave energy system.
- FOWT platform motion suppression by actively controlling WECs.
- Identify supplemental power generated by WECs.

Thank you

- Thanks to my doctoral committee.

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