Wave Energy Converters (WECs) for powering offshore aquaculture

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This work presents the challenges and opportunities of co-locating Wave Energy Converters (WECs) with offshore aquaculture farms and identifies the promising WEC and Power Take-Off (PTO) candidates to power them.

OFFSHORE AQUACULTURE

- The concept of Powering Blue Economy (PBE) applications refers to energy solutions and technological innovations that enable the development and operation of key economic activities in the ocean [1].
- In the case of offshore aquaculture PBE applications, farms can benefit from reliable and autonomous energy sources, as many fish farms operate in remote environments far from the traditional power grid [2].
- Offshore aquaculture operations require energy to support feeding systems, instrumentation, and sensors associated with safety, navigation, and maintenance [2], which can be met partially or fully using WECs [2].

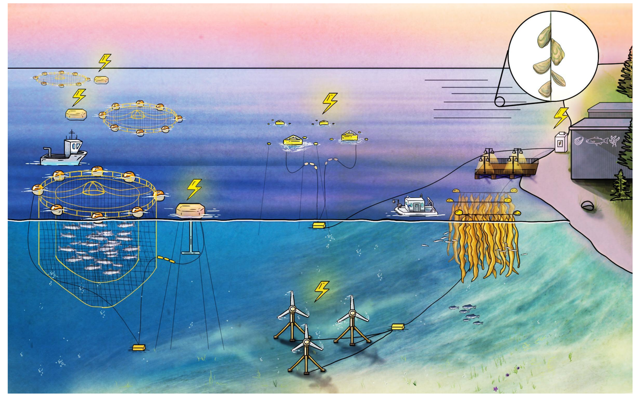

Figure 1: Marine energy technologies, co-located with offshore aquaculture operations [3].

WAVE ENERGY CONVERTERS (WECs)

Point Absorbers (PA): In these devices a floating buoy moves relative to a submerged structure under the action of ocean waves. The resulting relative motion is used to drive a PTO system [4].

Oscillating Surge Wave Converter (OSWC): These device that captures energy from the horizontal motion of ocean waves near the surface. This model consists of a large submerged oscillating flap that is hinged on a moored submerged platform. As waves pass through the device, the surge motion of the water forces the flap to oscillate [4].

Oscillating Water Column (OWC): In these device, the wave motion induces the increase and fall of pressure inside the capture chamber, which conducts the air through an Air Turbine (AT), activating a Power Take-Off (PTO) system [4].

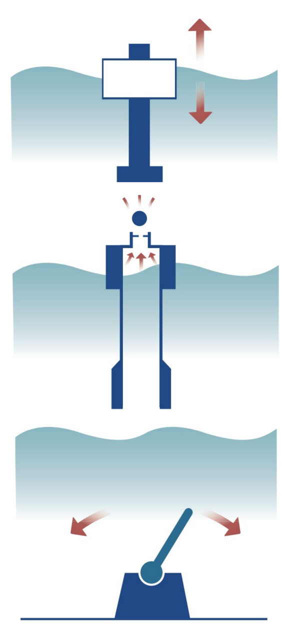

Figure 2: WECs illustration. PA (Up), OWC (Center) and OSWC (Down) [5].

POWER TAKE-OFF (PTO) SYSTEMS

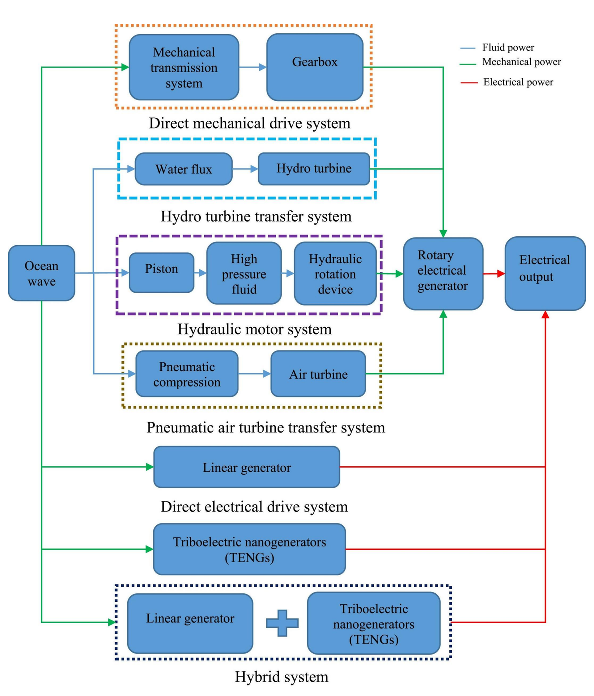

Figure 3: The working principles of the PTO system [6].

Air Turbine-Based (AT): In AT systems, air is alternately compressed and decompressed within a sealed chamber due to the vertical motion of the water column caused by incoming waves, forcing the air to flow through a bidirectional turbine [12].

Direct Mechanical Drive-Based (DMD): The DMD system generates energy by directly converting the motion induced by ocean waves into electrical power, typically achieved using a gearbox [12].

Direct Electrical Drive-Based (DED): The DED system relies on the interaction between a translator and a stator, acting like a linear generator, producing electricity through electromagnetic induction [12].

Hydraulic Motor-Based (HMB): The HMB PTO system typically consists of a hydraulic cylinder or ram, a hydraulic motor, an accumulator, and an electric generator. In general, oscillatory motion acts on the hydraulic cylinder, which compresses a working fluid (usually hydraulic oil) [12].

REVIEW

Table 1: Key opportunities and challenges in co-locating WECs with offshore aquaculture farms, along with power demand ranges for Offshore Aquaculture as a PBE application and real-world examples.

OPPORTUNITIES [2]	CHALLENGES [2]	REANGE OF POWER DEMAND	REAL-WORLD EXAMPLE [2]
- Cost savings on energy use and shared operations with multi-use platforms. - Potential for reduced environ-mental effects. - WECs may provide shelter to the fish farms for the waves.	- High costs and investment barriers. - Safety risks must be studied considering the co-location in fish farms areas - Low commercialization of WEC devices	**Small-Scale Farms:** 10 kW – 50 kW Power demand: Basic feeding, instrumentation and sensors, aeration. **Medium-Scale Farms:** 50 kW – 500 kW Power demand: Automated feeding, lighting, instrumentation and sensors. **Large-Scale Farms:** 500 kW – 5 MW+ Power demand: Automated feeding, lighting, instrumentation and sensors.	**Chilean Farms:** 100-250 kW generators, 370 kWh/day. **Scottish Farms:** 1,000 tons production, 730 kWh/day. **Norwegian Farms:** 3,120 tons production, 700 kWh/day. Feeding systems consume over half of total energy.

Table 2: WEC and PTO Selection for offshore aquaculture applications, where OWC is Oscillating Water Column, PA is Point Absorber, OSWC is Oscillating Wave Converter, AT is Air Turbine, DMD is Direct Mechanical Drive, DED is Direct Electrical Drive and HMB is Hydraulic Motor Based.

WEC	PTO	CONSIDERATIONS	REAL-WORLD EXAMPLE
OWC	AT	- As the water depth increases, the efficiency of the OWC decreases, limiting its expansion to nearshore areas. - The AT is the most suitable option for this device and has no environmental impact since it operates with air, preventing pollution of the surrounding waters near fish farms. It can be placed in strategic locations for easy maintenance. However, its high axial thrust, and noise levels could negatively affect fish health.	
PA	DMD, DED, HMB	- The adaptability of PAs to offshore conditions, based on their design and the parametrization of physical and mass properties, makes them a promising technology for this PBE application. - For the PTO system, DMD, DED, and HMB can be implemented on PAs, with DMD and HMB being the most common choices. - For DMD, the gearbox size is a key design parameter for Pas. - For DED, the main challenges are the low power-weight ratio and the unequal voltage generation. - For HMB, the working fluid (typically hydraulic oil) may leak due to compression and decompression cycles, potentially polluting the water and affecting fish production.	- SINN Power. Shrimp and prawn aquaculture and wave energy – Cabo Verde [2]. - Aqua Power Technologies Nearshore finfish aquaculture and wave energy – Scotland [2]. - Carnegie Clean Energy Offshore aquaculture and wave energy – Australia [2].
OSWC	None	- Since OSWECs are designed for nearshore use in water depths of less than 20 m, they are not a suitable choice for offshore aquaculture applications.	

CONCLUSIONS

This study reviewed the challenges and opportunities of co-locating WECs within offshore aquaculture farms, introduced different types of WECs and PTO systems, and identified a promising WEC–PTO pair for powering them. Based on the review, the most suitable WEC is the PA due to its adaptability to varying offshore conditions. The main challenge lies in selecting the appropriate PTO system, considering factors such as efficiency, maintenance, environmental impact on surrounding water, and total power output. The HMB system offers significant advantages, including ease of maintenance and scalability of hydrodynamic performance.

FUTURE WORKS

This project aims to develop a tunable wave energy reference model (WEC-RM) of a two-body point absorber (PA) for Offshore Aquaculture application. The first stage consists of generating an analytical model, which defines the governing equations of the WEC-RM, to be implemented in a potential flow code based on linear wave theory, considering its performance . In the next stage, a physical WEC-RM will be constructed, and experiments will be conducted at the UNH wave tank. Finally, the project concludes with a final report detailing the validated numerical model, performance of the physical prototype, and case study result.

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