Wave Energy Transmission Module

WES Power Take Off
Stage 1 Project
Public Report

Romax Technology Ltd

This project has been supported by Wave Energy Scotland

1 Project Report

1.1 Project Introduction

The aim of this project was to demonstrate the feasibility of developing a robust, effective Power Take-Off (PTO) solution comprising a gearbox and generator which may be applied to a wide range of Wave Energy Converter (WEC) types and deliver a low cost of energy. The key advantages of this technology are its extremely high transmission efficiency and ability to take advantage of the highly cost-competitive global supply chain which already exists to supply similar products to the wind energy industry.

The project was carried out by a consortium comprising Romax Technology Ltd, Sea Power Ltd, Limerick Wave Ltd, and Pure Marine Gen Ltd.

Romax Technology Ltd are world leaders in the design and simulation of mechanical and electro-mechanical drivetrain systems for a wide range of industries including automotive, off-highway vehicle, rail, renewable energy and others. They have a particularly strong track record in providing bespoke and licenced drivetrain designs for wind turbines, with – by some margin – the highest number of Germanischer Lloyd certified designs of any organisation in the world.

Sea Power Ltd are developers of the SeaPower Platform, a floating attenuator type WEC. Their principals, Joe Murtagh and Tom Lyne, have been pioneers in wave energy development since 1990. The team is augmented by a small team of design and structural engineers led by design engineer, Cian Murtagh (BE. M.Eng MIEI).

Limerick Wave Ltd are IP holders for a novel gearbox layout which was simulated and assessed as part of this project.

Pure Marine Gen Ltd are experts in marine engineering and simulation, and were responsible for the hydrodynamic simulation of the WEC/PTO combination.

1.2 Description of Project Technology

The core technology is a multi-stage, speed-increasing gearbox connecting the WEC prime mover to a permanent magnet generator. The layout is similar to a modern, 'medium-speed' wind turbine drivetrain.

The use of a gearbox to increase the rotation speed permits the generator to be significantly smaller than one directly driven by the prime mover. For a WEC of similar scale to the Sea Power platform, it is unlikely that a directly driven generator could practically be manufactured, given the extreme torque capacity required. Even for smaller WECs, the reduction in generator cost is expected to more than outweigh the cost of the gearbox.

A geared transmission is considerably more efficient than a hydraulic transmission, with transmission efficiencies of greater than 97% (from prime mover to generator) typical in wind turbine applications. Crucially for the WEC application, the efficiency does not vary significantly with part-load operation.

The proposed layout permits both gearbox and generator to be contained within a single robust, well-sealed housing. There is only one rotating seal in the whole design, where the input shaft enters the gearbox. The shaft arrangement and size is compatible with mature marine propeller shaft sealing technology, which is well-proven for extended lifetimes and permits fully submerged operation (essential for oscillating wave surge converter type devices).

The PTO layout has no limitations on travel (and in fact could be continuously driven through complete rotations). This means there are no requirements for end stops to be incorporated into the WEC to protect the

PTO, and it is able to survive (and indeed continue to generate power in) the highest sea states.

1.3 Scope of Work

The project started with the creation of Product Design Specification, defining the requirements of the PTO and identifying the roles, responsibilities, and risks.

The focus of initial stage 1 work was to determine the key characteristics required of an electro-mechanical (gearbox and generator) power take off (PTO) arrangement for installation on a wave energy converter (WEC), and how these compare with those of a wind turbine. The next phase was to review the existing wave data that had been collated by the consortium members: Pure Marine from hydrodynamic modelling; and SeaPower from live WEC testing. Once this was understood the Romax in-house developed design tools were modified take into account the WEC requirements.

These design tools were then used for:

- Identifying potential concept layouts for a mechanical/electrically driven PTO
- Conducting simulation on each layout, sufficient to determine the viability of each.
- Estimate the LCoE for each of the layouts, using a full-system cost model incorporating Romax's experience in real wind drivetrain production and OpEx costs into Sea Power's WEC-level model.
- Sizing the most appropriate layout and detailing to a level suitable for developing at stage 2.
- Hydrodynamic modelling based on the selected concept under various damping strategies.

Additional to the above, a function and failure mode study was conducted to understand the causes and effects of the operating states of the PTO.

1.4 Project Achievements

The main aim of the project to understand the key characteristics and requirements of a PTO mounted onto a WEC was achieved, and demonstrate that these requirements could be met using similar gearbox and generator technology to that used in wind turbines. This was found to be the case, which means Romax is in a good position to use its extensive experience and capability in wind energy to develop a competitive WEC PTO. This existing capability has been significantly enhanced during this project by the development of an effective workflow for WEC-specific duty cycle calculation and PTO analysis with close interaction between PTO developer, WEC developer, and WEC simulation provider.

1.5 Applicability to WEC Device Types

The PTO is expected to be compatible with any WEC type which produces relative motion between two bodies around a single rotation axis. This primarily includes the 'attenuator' and 'oscillating wave surge converter' device classes, but could also include devices in the 'point absorber' and 'submerged pressure differential' classes if the linear motion is converted to rotary motion by means of passing the mooring cable around a drum.

The project has demonstrated the feasibility of providing an extremely large torque reaction capacity (up to 40MNm) to the SeaPower platform, which is a large (100m length at full scale) attenuator class device. However the technology may readily be scaled down to suit even the smallest WEC devices while retaining the principle advantages of high efficiency and established, cost-competitive supply chains.

1.6 Summary of Performance against Target Outcome Metrics

Affordability – the project has demonstrated the feasibility of developing a WEC PTO based entirely on technology which is already in mass production globally – primarily serving the wind energy industry, with certain specialist requirements met using technology from other industries such as marine propulsion. A full-scale WEC PTO would immediately be able to take advantage of these competitive supply chains, without the start-up costs associated with wave-specific technologies.

Performance – The PTO has extremely high transmission efficiency under a wide range of loading conditions, maximising power transmission from the WEC to the generator. The simulation and data processing techniques and tools developed during this project, combined with pre-existing Romax tools for wind turbine drivetrain design, permit optimisation of the generator design to the characteristics of a WEC and even a specific wave resource, maximising power extraction.

Availability – The core technology is well proven to enable long-term operation in remote locations with high uptime. The installation of a condition monitoring system to the PTO will enable the operator to monitor the performance (temperature & vibration measurements) of the PTO remotely, and determine maintenance requirements ahead of a potential failure (In addition to their design and analysis expertise, Romax are a major global supplier of condition monitoring services to the wind industry).

Survivability – In addition to the inherent advantage of having no travel limitations, this project has simulated the loading induced in the PTO by WEC motions under the highest sea states occurring at a real, North Atlantic wave resource. The PTO is expected not only to survive in these sea states, but to continue producing electrical power.

1.7 Communications and Publicity Activity

Sea Power Ltd press release: http://www.seapower.ie/2016/06/15/seapower-latest-update-june-2016/

1.8 Recommendations for Further Work

Two immediate priorities have been identified for further work at WES Stage 2:

- Investigate design variations (both in the mechanical layout and the generator/electrical configuration) to further enhance energy capture across all sea states.
- Conduct tank-testing with a representative PTO model on the scale-model SeaPower platform to build confidence in predictions of Annual Energy Production from simulation, and thus estimates of long-term cost of energy.