New Electric Automotive Power Extraction Device (NEAPED)

WES Power Take Off
Stage 1 Project
Public Report

Marine Design International

This project has been supported by Wave Energy Scotland

1 Project Outputs

1.1 Project Introduction

Technology Idea: The objective for NEAPED (New Electric Automotive Power Extraction Device) is to bring the low price point, high reliability and high efficiency of modern electric vehicle motor/generators and transmission systems to the wave energy sector. Recent technology advances and the mass market commercialisation of electric vehicles, coupled with interest within the marine industry in sub-MW devices, make this a particularly timely moment for the feasibility of this approach to be examined in some detail. NEAPED seeks to utilise Commercial-Off-The-Shelf (COTS) electric automotive technology to the maximum extent in order to reduce Power Take-Off (PTO) capital and operating costs, and hence the Levelised Cost Of Energy (LCOE) from wave energy capture through Wave Energy Converter (WEC) devices.

Project Team: The project is led by Marine Design International (MDI), a team of experienced naval architects whose core business is the design of practical and efficient vessels. With roots in the Clyde shipbuilding industry and over 100 years of heritage to call upon MDI provides full design and consultancy services to the marine industry from its drawing office in Glasgow. MDI's experience lies in vessel motion analysis and launches several new highly efficient designs each year in the fields of passenger ships, workboats and eco-tourism. They have extensive experience in custom design and expertise in electric boats - including development of the current British Water Speed Record-holding electric powerboat.

Lead partner to MDI is 4c Design, an award-winning product design engineering consultancy with particular experience in the concept design and development of wave energy conversion technology through extensive work with AWS. 4c's innovative approach to problem solving is underpinned by its culture, created by a close knit team of highly motivated, talented and practical people. 4c straddles the technology development gap which exists between traditional design agencies and engineering consultancies – 4c Design can design, build and test products to the customer's specifications in-house.

Additional specialist expertise is drawn from a small number of highly experienced engineers and entrepreneurs with more than 50 years of combined experience in the development of wave power technology.

Measures of Project Success: At this Stage 1 Feasibility Study (Concept Characterisation & Refinement) two potential arrangements for the NEAPED PTO were identified:

1. Direct drive – mechanical link between prime mover and generator
2. Indirect drive – mechanical disconnect between prime mover and generator

Both of these arrangements can be broken down into sub-systems.

The technology risk associated with each of the sub-systems contained in both approaches was assessed at no greater than 3 in a scale of 4 as defined by DNV-RP-A203 Technology Qualification Definition, meaning that the risk profile concerns the application of proven technologies into a new environment (marinisation of automotive components).

A simulation exercise using the Carbon Trust Marine Energy Cost (CT MEC) estimation was carried out which indicated that a NEAPED approach had an advantage approaching 10% against the CT MEC base rate at both 8% and 15% discount.

A spreadsheet tool was developed to predict the efficiency and power output of a NEAPED PTO device. The NEAPED simulator tool provided the ability to assess quickly the efficiency and power output potential for a combination of the simplified WEC and PTO.

In order to provide a practical demonstration of the two arrangements outlined above a desk-top demonstrator model was constructed. This provided a clear indication of the potential of the NEAPED concept from an oscillating prime motion source, and also highlighted some of the challenges which may arise in a scaled-up version due to excessive torque resistance associated with the indirect drive approach.

1.2 Description of Project Technology

Key features: This project investigates the feasibility of technology transfer from the automotive industry to the wave energy sector. In recent years, great advances have been made in the development of highly reliable, efficient and low cost drive train technology for the rapidly growing electric vehicle market. NEAPED will use the latest mass produced electric vehicle technology as the basis for a wave energy PTO.

Anticipated advantages: The project objective is to transfer 'best in class' automotive performance, efficiency and reliability to deliver a step change reduction in the levelised cost of energy (LCOE) of wave energy converters.

1.3 Scope of Work

The work undertaken: Work Package 1: Concept Generation - WP1 included research, idea generation and concept evaluation activities to deliver a short-list of potential solutions. A stop/go decision was made at the Concept Generation Review meeting at the end of the WP. Tasks included requirements capture; automotive component research; knowledge transfer from MSP and wave industry experts. Deliverables included Functional requirements specification; Design brief; Brainstorm review video; and a report including concepts.

Work Package 2: Concept Engineering - WP2 involved preliminary engineering & design of the selected concept(s) against the requirements specification. Tasks included Component identification; Layout; Integration design; Modularisation & scaling; Systems engineering analysis. Deliverables included Concept design drawings; Technology Development Plan (including functional decomposition & technology risk assessment); Specification for Stage 1 prototyping & testing and a report.

Work Package 3: Simulation - WP3 developed a techno-economic model to help expose and understand design trade-offs and guide further concept engineering. Model outputs will include estimates of the extractable energy and LCOE. Tasks included Theoretical modelling; Sub-system simulation; integrated system simulation; Review & reporting.

Work Package 4: Prototyping & Testing - WP4 involved basic prototyping and testing of critical component integrations to validate high-level assumptions, and included the construction of a demonstrator model test rig, review & reporting.

Work Package 5: Market - WP5 undertook a route to market study, involving industry experts, and feeding into the Commercialisation Roadmap. Tasks included Market assessment; Engagement with WEC device developers; Review & reporting.

Work Package 6: Stage 2 Preparation - WP6 included Engineering scoping; Commercialisation scoping; Project planning & costing.

Work Package 7: Dissemination & Exploitation - WP7 synthesised and reported on outputs from all other WPs including Consolidation reporting and Presentation of results.

Work Package 8: Project Management - WP8 covered project management.

Reasoning for Key Activities: WP1 was designed to deliver a short-list of potential solutions. WP2 delivered Concept design drawings; Technology Development Plan (including functional decomposition & technology risk assessment); Specification for Stage 1 prototyping & testing and a report.

WP3 produced a Techno-economic model, and the output from WP4 was the model demonstrating both direct and indirect drive approaches, with WP5 producing a market report.

The Specification of POC model; Stage 2 Project Plan & Costing and a Commercialisation Roadmap were produced in WP6. The formal non-confidential and confidential reports were produced in WP7. WP8 concerned the project management system used throughout the project.

1.4 Project Achievements

What went well: The study confirmed the long-term strategic potential of wave energy globally, and that there are WEC developers supported by WES who believe that NEAPED may be suitable to pair with their devices. In addition a number of potentially interesting technological developments around the rapidly evolving electric vehicle supply chain with potential for incorporation in the NEAPED concept were identified for future consideration. Some of these remain at the R&D stage and therefore do not yet fit into the definition of COTS. However such game-changing technology, should it reach the commercial market, will have the potential to increase the attractiveness of the NEAPED approach by facilitating further improvements in efficiency and operatability, thus reducing LCOE even further.

Challenges encountered: included the failure of bearings in the indirect drive-train of the demonstrator model. This has highlighted the importance of accommodating the significant torque forces generated in transferring and converting reciprocating linear motion into continuous circular motion, and will form an important aspect of future phases of the development of NEAPED.

1.5 Applicability to WEC Device Types

NEAPED has the potential to operate with the following families of WEC devices:-

Attenuator	Discussions have taken place with two developers so far. One is pursuing their own PTO development internally but the other believes that NEAPED may be an appropriate option.
Point Absorber	NEAPED has been introduced to a developer of a Point Absorber device who is also pursuing developmental support overseas.
Oscillating Wave Surge Converter	One WEC developer is very keen to work with the NEAPED concept, to the extent of even adapting the demonstrator model for use in their scaled test tank modelling

Oscillating Water Column	Although the NEAPED PTO is not directly applicable to OWC where the movement is in the form of air, it could be used where the OWC has physical moving parts. Initial interest has been indicated by a WEC developer as an alternative PTO system.
Submerged Pressure Differential	The NEAPED team is working closely with a WEC developer toward the US Department of Energy Wave Energy Prize (separately from WES)

1.6 Summary of Performance against Target Outcome Metrics

Affordability: CAPEX at £10K to £20k for a 60kW system. The Indicative wave energy device CAPEX breakdown for a mature PTO is around £55k for a 60kW System. NEAPED is therefore looking conservatively at a CAPEX reduction between 64% and 82%. OPEX relating to the PTO is not considered significant in a mature system due to the inherent high reliability of the technology underpinning NEAPED.

Performance: NEAPED is a system based on a motor/generator capable of achieving 60kW continuous regeneration with a possibility of capturing peak loads of up to 135 kW. Early simulation work from the simplified model indicated mechanical to electrical efficiencies ranging from average values of 70% to peak values of 90+%.

Availability: In terms of reliability a range of quality assured COTS components suitable for incorporation into NEAPED has been identified. All major COTS components identified come with individual maintenance instructions

Survivability: The NEAPED concept, as developed thus far, has adopted a simple approach to overcoming end-stop issues. If at later stages of development this simple approach does not prove to be sufficient a more complicated concept will be developed.

1.7 Communications and Publicity Activity

Presentations of the NEAPED concept have been made at two WES workshop sessions in November 2015 and March 2016. A poster was produced, referenced below.

1.8 Recommendations for Further Work

The NEAPED PTO system makes use of COTS components and potential components and suppliers have already been identified. The suppliers, such as MSP Technologies (motor/generator) and others (variable ratio gearbox, KERS) have been able to assist with the specification of components and have provided data on performance, efficiency and other aspects of their components. They have shown a willingness to assist in the construction of the PTO system and to help integrate their own components.

The aim for Stage 2 (Concept Optimisation - Simulation and Model Scale Testing) is to achieve TRL4. At this level the technology has had components and/or sub-systems validated in a laboratory environment. The key challenges to address at this stage are the specification and integration of components into a working system,

and the testing both physically and numerically of the operation of the system. However, the demonstrator model has already proved, to some extent, that the components can be formed into a working system.

Whilst the desk-top demonstrator model provided a clear indication of the potential of the NEAPED concept from an oscillating prime motion source, it also highlighted some of the difficulties which may arise in a scaled-up version due to excessive torque resistance associated with the "indirect" drive approach. Indeed this excessive torque caused early bearings failure with the "indirect" drive option.

Testing of the two options together would provide a balanced perspective and also develop a greater understanding of any potential weaknesses to the "indirect" drive option as a result of excessive torque reaction.

The small scale test programme and engineering studies have confirmed the high level assumptions underpinning the NEAPED concept as well as confirming its potential, justifying progress on to Stage 2. However, as we have carried out the majority of our test programme and have good results from the other work packages; we believe this does not present unacceptable risk to continuing with the Stage 2 programme.

During the next stage it is intended to re-equip the demonstrator with heavier duty bearings which will withstand the torque applied and complete our planned test programme. Additionally, if a small scale variable ratio gearbox can be found or constructed, this would reduce the torque requirements of the one-way bearings. Completion of the test programme will enable us to make a fully detailed comparison of the direct and indirect drive approaches.