Edinburgh Designs Adaptive Power Take-Off (EDAPTO)

WES Power Take Off
Stage 1 Project
Public Report

Edinburgh Designs Ltd

This project has been supported by Wave Energy Scotland

1 Project Report

1.1 Project Introduction

Edinburgh Designs has designed a combined hydraulic-electric PTO suitable for a Wave energy device that has advantages over existing systems. The concept is called Edinburgh Designs Adaptive Power Take-Off (EDAPTO) and is designed to be a modular system that can be scaled according to the application's requirements.

This report briefly summarises the work performed by Edinburgh Designs (ED) under contract by Wave Energy Scotland (WES) to design and model a hydraulic Power Take Off (PTO) system suitable for a full-scale Wave Energy Converter (WEC). The contract ran from October 2nd 2015 to March 31st 2016.

1.2 Description of Project Technology

The aim of the EDAPTO project was to create a highly controllable and efficient PTO system for a WEC that also has applications outside of this key market. Edinburgh Designs set out to further understand the issues that are important for a PTO device by designing a combined hydraulic electric PTO. With this knowledge we will propose a suitable arrangement using a hydraulic gearbox at its core. The PTO will be applicable to a wide range of WECs where traditional hydraulic PTO's are currently used. The EDAPTO system can be created with commercially available components and should drive forward a step change in the levilised cost of energy.

ED began by looking at two separate topologies for the EDAPTO system. Both systems have fundamental design challenges that have an impact on the cost of energy for each system. These issues, as well as the beneficial design characteristics of each will be described briefly in this section.

The more hydraulic concept has been shelved as the quantisation steps and low speed controllability issues do not seem to be practical in this configuration. A different approach such as that being explored by Artemis IP and Quotient Ltd appears to be more suitable than the concept proposed initially by ED.

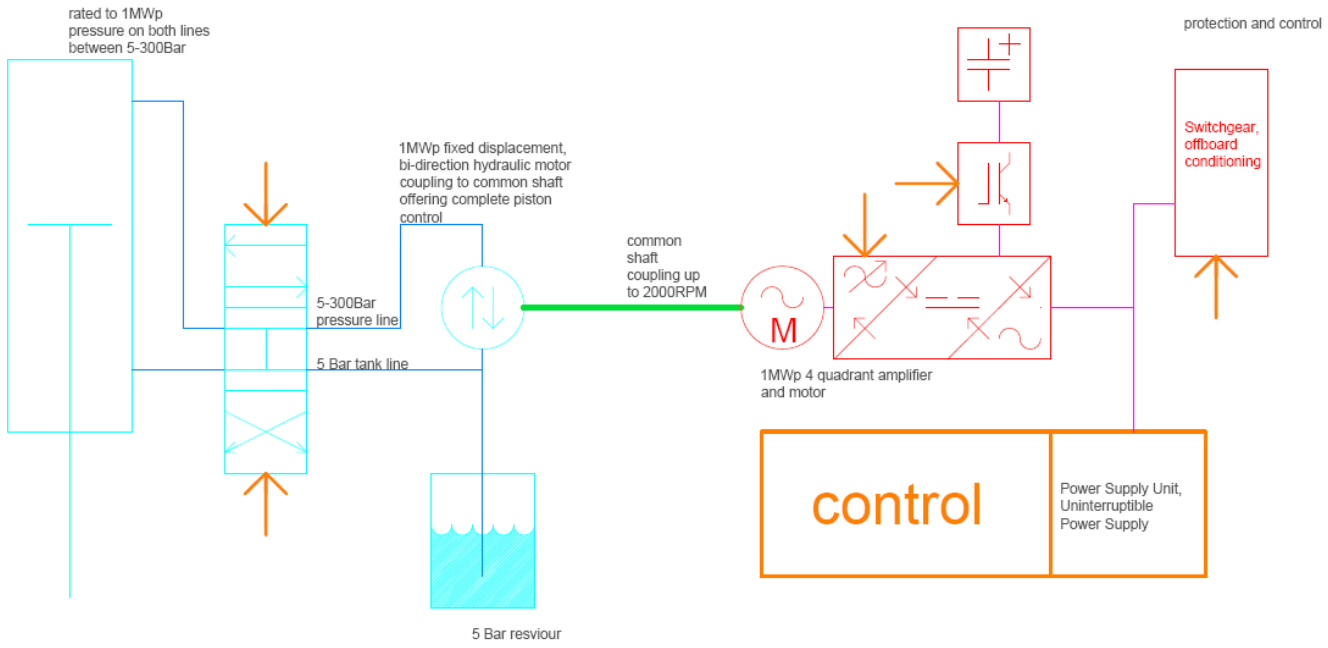

Figure 1: More Electric Schematic

1.3 Scope of Work

There are three key questions we set out to answer at the beginning of the project:

1. What is the appropriate ratio of peak to average power?
2. How much storage is required?
3. What is the benefit of full control on total power captured?

These questions are fundamental to the overall efficiency of different approaches and the cost of implementing them. To carry out this work representative models of a WEC device and PTO had to be built. WEC-Sim provided a good method of modelling the device within the Simulink environment. The PTO was also modelled in Simulink and made to work as a standalone simulation, or as an integrated part of the WEC-Sim model.

The EDAPTO project consisted of three working projects being carried out concurrently. Each project was designed to explore different areas of the PTO and its wider context within the WEC marketplace.

WP1. EDAPTO Modelling - The main EDAPTO study built up models in Simulink that facilitated the creation of a design suitable for further investigation as a scale or full-scale prototype. In the first third of the project, ED developed two models in Simulink. In the second section of the project, the "more electric" variant was focussed upon and developed thoroughly.. Later in the project, the "more electric" model was developed heavily. This modelling include farm modelling with time series inputs from ED's wave synthesiser software

WP2. WEC Data Mining - ED planned to study the data from the Pelamis devices during sea trials to gain a more detailed insight into the requirements of a WEC PTO and the input conditions they face on a daily basis. As the project progressed, it became clear that although interesting, the Pelamis data provides a limited view of one WEC and that a generic modelling tool would be much more useful in determining the requirements of a PTO. As a result, ED reallocated WP2 resources towards studying WEC-Sim, an open source WEC modelling tool developed by the National Renewable Energy Laboratory, NREL.

WP3. Commercialisation - The commercial aspects of the project will include the assessment of key performance criteria that influence LCOE, evaluation of critical component supply and communication with key suppliers and device developers to determine the potential position of EDAPTO in the marketplace. Energy storage investigation with ES Select.

1.4 Project Achievements

The EDAPTO design is based on a heavily developed version of the "More Electric" concept. As will be discussed shortly, the majority of hydraulic components are only available up to 250kW$_{peak}$. Therefore a topology comprised of modular branches was conceptualised. Modularity provides redundancy, easy scaling and the applicability to many different devices. Figure 2 shows how a schematic of a 1MW$_{peak}$ EDAPTO system.

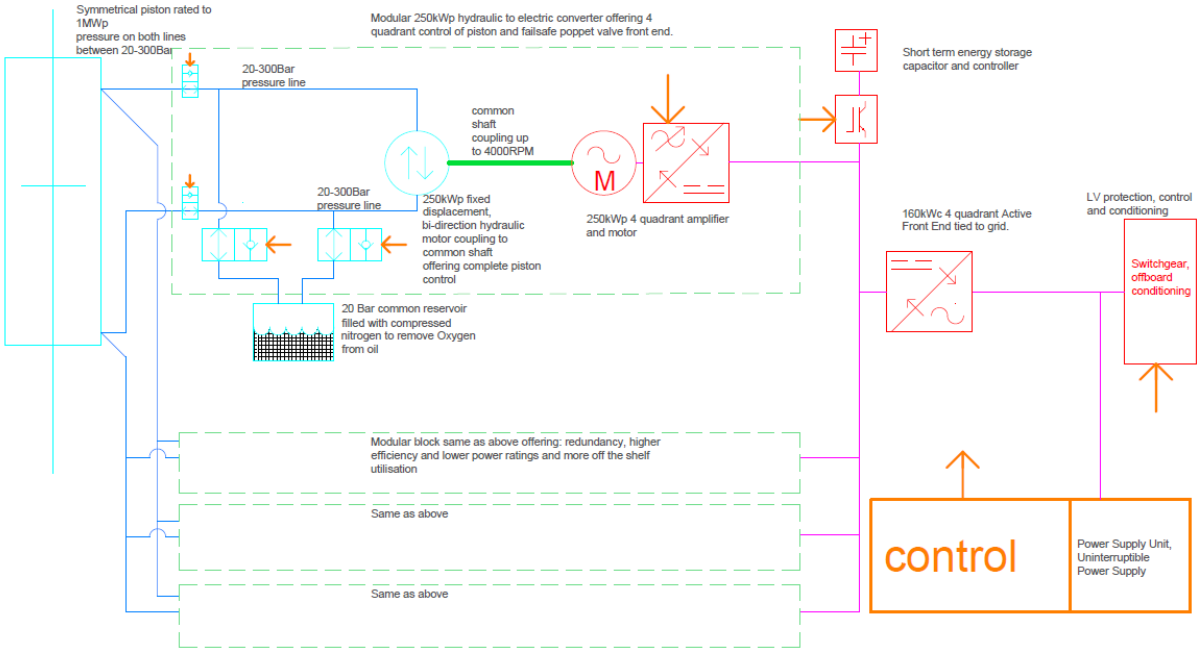

Figure 2: Top level overview of a 1MW$_{peak}$ EDAPTO PTO

1.5 Applicability to WEC Device Types

It is not possible to design a versatile PTO suitable for all WEC designs, and a clear definition of the requirements from each WEC developer is required to aid the PTO design process. Simulation of the combined system will then aid in understanding the potential to exploit the strengths of each approach and help complete the optimisation process for the two components.

The requirements for the PTO will vary between WECs, but will always be driven by two key requirements. The first is to ensure the survivability of the WEC as a power capture device. The seconds is to maximise the total power delivered to the grid for the lowest cost. To do this the WEC and PTO must be integrated together and designed to complement each other's capabilities.

1.6 Summary of Performance against Target Outcome Metrics

The EDAPTO concept appears to show a step change in performance in comparison to existing PTO devices. While there are issues that require further research before a full scale prototype is built, ED believes that the concept shows enough potential to merit further investigation.

The LCOE figures suggest that the EDAPTO system is more affordable than the Pelamis P2 PTO, with modelling results suggesting an decrease in cost of 7%. The increased controllability gained by the design is likely to make further gains. EDAPTO has been designed to reduce operating costs over the lifetime of the WEC by using modular and redundant components.

EDAPTO is designed to be highly suited to adaptive control algorithms to optimise power absorption and wave capture width in different sea states. These factors will be dependent upon WEC design itself and the arrangement of PTO systems.

The PTO should also be as reliable as possible as this may impact on overall WEC availability if unreliable components cause system shutdown or failure. Where it is not possible to achieve a high mean time between

failure of components the system should be designed to be fault tolerant (eg through redundancy). It should be developed with a strategy to tackle situations when a) transducers may give erroneous information from failure or calibration drift or b) if communications are compromised - either between nodes within the machine or to a manned control centre (with analogies to the 'limp-home' mode seen in car engine management systems). Aside from the reliability of the PTO system itself, the system may impact on longer term system reliability by alerting to the need for preventative maintenance (eg vibration and noise indicating bearing wear). This could prevent failures from occurring which could have a more severe consequence on system integrity and/or power production. This will minimise the time to repair the fault and hence increase machine availability.

As a purely paper based study it is difficult to assess the reliability of the system, although EDAPTO has been designed with maintainability and redundancy in mind. Intuitively the electrical nature of the energy storage system offers the potential to reduce O&M downtime versus mechanical hydraulic-gas systems; a long term test would confirm this.

1.7 Communications and Publicity Activity

Edinburgh Designs are in discussion with a number of parties about PTO development or modelling projects. It is likely that ED will be involved in wave energy research in the near future but have been unable to carry on with the WES PTO programme due to other commitments. ED endeavour to stay within the WES community so that we can contribute for the advancement of wave power technology.

1.8 Recommendations for Further Work

The EDAPTO project has shown that a combined hydraulic electric approach could be applied to a WEC to provide a cost effective and efficient method of power capture. As a paper study, parameters such as survivability and reliability can only be speculated upon and require further investigation before a full prototype should be built.

One particular component that requires further research is supercapacitors. Accelerated lifetime test rigs with various power management strategies should be studied to determine how lifetime can be increased. This research would be most suited to a supercapacitor manufacturer with guidance from a PTO developer. As discussed previously, this research could benefit a large range of WES participants.

Storage is a problem that must be tackled by all of the PTO systems proposed by developers in the WES program. For the more electric approaches such as the direct drive linear generator, supercapacitor technologies are a prerequisite for commercial deployment. Therefore, supercapacitor lifetime is an area that ED believes needs to be targeted by future WES research.