Survival Focused
Automatic Control
(SURFMATIC)

WES Control Systems Stage 1
Public Report

Wave Venture

This project has been supported by Wave Energy Scotland

1 Project Introduction

The SURF-MATIC project targets development of a control system that is focused on device survival and achieving reduced loading and harshness in Wave Energy Conversion technology. Survival is one of the strongest cost drivers of the structure in a wave energy converter and the structural cost is a very significant overall proportion of the cost of energy produced. In addition, complications in design due to extreme loadings and harshness also increase the cost and reduce the reliability, availability and performance of subsystems such as power take off and moorings. The opportunity that we seek to address is to deliver a control system that:

- Acts to truncate the extreme tails of the structural loading probability distribution by controlling variables that alter the hydrodynamic properties of the device so that it can avoid extreme loads.
- Acts to reduce the occurrence of harshness events such as end stop impacts and tether 'snapping' by controlling variables that both alter the hydrodynamic properties and also alter the dynamic motion response of the device.
- Is generic and can work with a wide range of wave energy converters
- Comes with design tools that can systematically identify (or design in) the configurations for each WEC type that best deliver these benefits.
- Builds on state of the art ultra-high availability control systems (e.g. fly-by-wire) and adapt these to the wave energy application.

1.1 Project Partners

Wave Venture have worked to gather evidence to show that this approach is valuable and that suitable reductions in loading and harshness can be achieved for a range of wave energy conversion technologies.

Altran GB have worked to show that the proposed system can be delivered in a practical industrial control system that will achieve the ultra-high availability required for safety critical systems at the low cost required in renewable energy.

CorPower Ocean & **Mocean Energy** are developers of WEC technologies and have contributed their expert knowledge of the end use application of this system and advise on how best to apply the proposed control technology to their WEC products.

2 Description of Project Technology

The proposed control system aims to deliver improved survivability through reduced loading and harshness in Wave Energy Conversion technology. The challenges in design for survival are related to the stochastic nature of the environmental inputs. The probability distribution of the environmental loads is close to a normal distribution and the resulting structural loads and motion response are also close to a normal distribution. The long tails of these normal distributions dominate the system cost while the central values dominate the system productivity.

The proposed controller targets a truncation of the extreme tails of the structural loading distribution so that a WEC device can avoid extreme loads, and; additionally, a truncation of the extreme tails of the motion response distribution so that a WEC can avoid additional harshness events such as end-stop impacts and tether 'snapping'.

Central to the approach is the recognition that control actions can change the hydrodynamic properties of a WEC device. (For example, changing the shape, orientation or depth of a device will change the wetted surface geometry and so change the wave forces). Generally, this avenue of wave energy research is under explored, the vast mainstream of research assumes constant hydrodynamic coefficients and focuses on manipulating the PTO coefficients or PTO forces. We aim to find practical methods of exploitation of this ability to alter the hydrodynamic properties of a device to improve survivability and reduce harshness.

In practice, the proposed control system will use two different methods for protecting WEC devices from two different types of survival challenges: Firstly, manipulation of the force/torque actuated by the PTO, and additional complimentary actuators where necessary, to avoid end-stop impacts; secondly, introduction of additional actuators to allow control of transition to inherently survivable configurations. Examples of such actuators include; active mooring systems; active ballast systems; joint biasing forces; geometry modifications; and, in flexible devices, membrane pressurisation modifications. This stage one project has focused on end-stop impact avoidance and wetted surface geometry changes.

A goal is to make the controller generic so that it can work with a wide variety of WEC technologies and a wide variety of the above-mentioned manipulations. A further goal is to identify design tools that will be necessary to successfully roll out this system to multiple WEC types.

In the final implementation, the system would operate together with a separate system for energy absorption maximisation. The output from the energy absorption maximisation would be an input to the protection system. The protection system would check the demands by the maximisation system and modify them if required to protect the WEC. If the survival of the WEC is not challenged then the protection system would forward the demand without alteration. If the survival of the WEC is challenged then the protection system would modify the demand it received to eliminate this challenge. This arrangement of systems is something often used in safety-critical systems development, where a safety-protection system provides an oversight role, with an ability to step in if required to maintain safety. This approach places the burden of ensuring the safety/availability solely on the protection system, freeing the other system from the development constraints that would otherwise be placed on it and allowing it to be much more easily upgraded.

The stage 1 investigations focused on end stop impact avoidance in a generic heaving buoy device based on the CorPower device and wetted surface shape changes in a generic hinged raft device based on the Mocean device. The next sections will introduce these example systems as analysed in this project. See D2.2 for a stage 1 numerical analysis of the systems described and see D4.1 for a specification for the implementation of these systems.

3 Scope of Work

The structure of this stage 1 project is as follows:

- WP1 Project management and reporting
- WP2.1 Literature Review. This literature review focused on extreme conditions modelling, survival focused control systems, high-integrity software and technology qualification processes.
- WP2.2 Gather evidence for Impact on the WES metrics using preliminary simulations and modelling. This task applied standard modelling techniques to two examples of a heaving buoy and a hinged raft to test the scope for reducing the stresses and harshness events in WEC's. The results showed that the targeted improvements are achievable and that practical control systems based on these effects are likely to be feasible.
- WP3 Report on suitable software development environments, availability of suitable computing hardware, sensors, and actuators. The specific software development techniques that are

appropriate for high-integrity safety critical software were summarised and a recommendation for the approach to further work is make.

WP4.1 A specification of the proposed control system was developed using the REVEAL™ methodology. The requirements, specification and relevant domain knowledge were captured in a report that will form the basis for future development of the control system.

WP4.2 A review of next generation design tools focused on appropriate use of emerging CFD techniques for wave energy design. Wave energy at present has to choose between design tools based on Cummins equation and its extensions on one hand and commercial CFD on the other hand. The first of these is fast but with low fidelity while the second has high fidelity but is computationally demanding and so very slow. In reality, both tools are of limited applicability and intermediate options are needed. This task focused on exploring forthcoming research to determine if intermediate options are coming to maturity.

4 Project Achievements

The project partners achieved an effective knowledge exchange. Wave Venture gained an appreciation for the development processes in high-integrity safety critical software including the requirements elicitation techniques, programming languages and the Correctness by construction methodology. Altran gained an appreciation for the requirements of wave energy conversion technology and its modelling, simulation and control.

The modelling and simulation component of the project went very well with targeted reductions in wave loading and end stop impacts demonstrated in the chosen example WEC devices. On the evidence of the simulations and modelling done both the end stop impact avoidance and the wetted surface shape modification are both feasible and worth pursuing further.

A detailed list of sensors, and actuators was compiled and a bespoke actuator concept was initiated.

The project achieved a very thorough literature review on extreme conditions modelling.

A thorough review of next generation CFD techniques for wave energy design was completed, this will form a basis for selection of components for next generation design tools.

5 Recommendations for Further Work

The proposed SURFMATIC control system should be pursued and further developed.

The novel actuator proposed for the wetted surface shape modification control should be investigated.

New design tools based on flow solvers that are intermediate to Cummins equation on one hand and commercial RANS type CFD on the other hand should be pursued.

6 Communications and Publicity Activity

A poster was presented at the Wave Energy Scotland conference.

A joint Wave Venture Altran press release is in preparation and will be available shortly.

7 Useful References and Additional Data

[1] www.wave-venture.com

[2] www.altran.com

[3] www.moceanenergy.com

[4] www.corpowerocean.com