Integrated Marine Point Absorber Control Tool (IMPACT)

WES Control Systems Stage 1 Public Report

SgurrControl

This project has been supported by Wave Energy Scotland

1 Project Introduction

The IMPACT project aims to develop a control tool for point absorber Wave Energy Converters (WECs) to enable more advanced controllers than those currently commonly used to be designed and implemented quickly and easily. The tool aims to be as generic as possible to allow the wave energy industry as a whole to benefit.

The project team consists of SgurrControl, part of Wood PLC (formally known as Wood Group) as the lead contractor and Cruz Atcheson Consulting Engineers as a project partner. SgurrControl have many years of experience developing controllers for the renewable energy sector, including development of the SgurrControlBox, a control tool for designing and implementing wind and tidal turbine controllers. Cruz Atcheson is an independent engineering consultancy, specialising in wave, tidal and floating offshore wind energy applications. Their three key areas of work are: concept design, due diligence support and project development support.

2 Description of Project Technology

A high-level outline of the structure of IMPACT is shown in Figure 2-1.

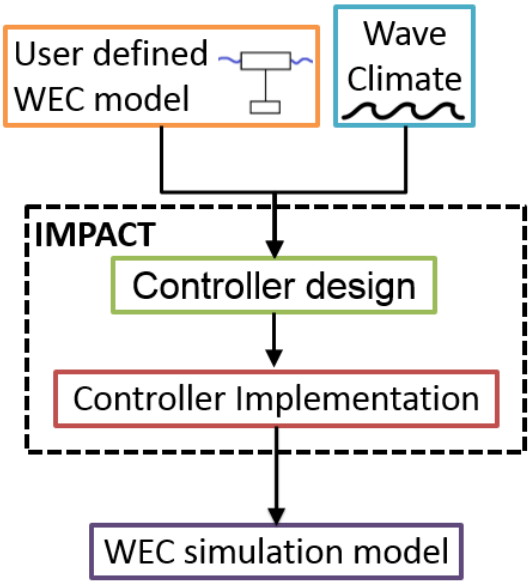

Figure 2-1: Structure of IMPACT

The user is required to define their WEC and PTO (Power Take-Off) according to a set of defined parameters. These parameters are used to construct a linearised model of the system. The user should also define the wave climate that the WEC is to be designed for.

Using these inputs, IMPACT provides the user with an easy to use graphical interface for designing their controller. This includes quick and simple to use plotting of key controller performance indicators.

With the controller designed, IMPACT will link together with simulation software for easy implementation of the designed controllers. This includes a generic controller structure that the tool will populate, which links to the WEC-Sim simulation package.

As part of the project, suitable generic point absorber simulation models will also be created. As such, all the necessary components for designing and simulating point absorber WECs with advanced controllers will be created within the project.

As IMPACT is designed to be generic, a wide range of point absorber WECs can make use of it to aid their controller design. Making controller design easier and providing a generic architecture for the controller, allows WEC and PTO developers to more easily integrate controller design into their WEC/PTO design process. As IMPACT offers more advanced control than the linear damping methods typically used by point absorber developers at the moment, the performance of WECs can be improved substantially through the use of IMPACT. The increased ease of design and improved performance combined, offer the potential to massively reduce the LCOE (Levelised Cost of Energy) for point absorbers, and, as IMPACT is generic, this potential improvement in LCOE is to the benefit of the whole industry rather than a single manufacturer.

3 Scope of Work

Table 3-1, shows the document number, full title and deliverable number for each of the deliverables presented in stage 1 of the IMPACT project (not including stage 2 application documents). For convenience, the deliverable number will be used when referring to these works with the suffix "D" and a bold font will be used e.g. **D1**.

Table 3-1: Deliverable documents for reference

Document Number	Full Title	Deliverable number
6.17.11061.SCL.R.003	IMPACT Surveys Summary Report	**D1**
1056-TN-01	Database of Point Absorber WEC models	**D2**
1056-TN-02	Database of Power Take-Off Models	**D3**
6.17.11061.SCL.R.001	IMPACT Methodology Review	**D4**
6.17.11061.SCL.R.002	IMPACT Specification Document	**D5**
6.17.11061.SCL.R.004	IMPACT Hardware Review	**D6**
6.17.11061.SCL.R.006	IMPACT Feasibility Study Report	**D7**

A key part of IMPACT at stage 1 was to identify where control technology for point absorbers is currently at, where the potential areas to advance forward are, and to identify how IMPACT can be designed to enable point absorber WEC manufacturers to move their controller technology forward.

As such, **D1** and **D6** were focussed predominantly on the current situation. **D1** allowed the IMPACT team to engage with developers to identify what their requirements are for improved controllers, and to identify the technologies currently used in the industry. **D6** looked at the hardware that is available, particularly in terms of sensors, for providing inputs to controllers.

With the current control landscape mapped via **D1** and **D6**, **D4** was undertaken to identify the direction in which controllers for point absorber WECs could be advanced. An overview of the academic literature gave a clear view of the possible methodologies that could be used as part of IMPACT.

As IMPACT aims to allow controller design and implementation, it is key that "Software in the Loop" (SiL) simulations are possible and that the dynamics of a variety of WEC and PTO methods are well known. To this end, **D2** and **D3** were conducted to build a comprehensive set of generic WEC and PTO models.

In **D5**, the outputs from the prior mentioned deliverables was used to specify at a high level what IMPACT will and will not include as development continues, in other words writing a specification for IMPACT.

Finally, **D7**, a feasibility study report, was written to summarise the outputs of the project thus far.

Each deliverable has aided the IMPACT project in preparing for stage 2 of the WES control systems call. The requirements from industry and current state of control has been assessed, the methodology for an advanced control system has been identified, the control tool has had a specification prepared, and models of point absorber WECs required to develop the control tool have been developed.

4 Project Achievements

The short stage 1 project has successfully shown the feasibility of the approach – identifying a desire for more advanced controllers that can be easily applied to a wide range of point absorber WECs, identifying control methodologies that can potentially improve performance for point absorber WECs, identifying the potential WECs that can benefit from a point absorber control toolbox, and providing generic models of point absorber WECs which can be used both as a basis for development of the control tool and as useful simulation tools themselves.

The following lessons have been learned from the IMPACT project:

1. There is a clear desire from industry to move towards more advanced control methods
2. Advanced methods identified within the academic literature are suitable for developing further, from their academic application into industrial application
3. No expensive additional hardware is required for the methodology chosen.
4. There are a wide range of point absorber types with no clear convergence of design. As such, a generic approach is of clear benefit to the industry as a whole
5. It is feasible to create a useful and usable control design tool within the 9-month time frame of the stage 2 projects, which would be applicable to a wide range of WEC and PTO types.
6. The desire for more advanced control strategies within the industry makes a future partnership with one or more manufacturers for a stage 3 project to demonstrate the controller via hardware tests an achievable ambition.

5 Recommendations for Further Work

The specification document **D5** sets out the key requirements for IMPACT, presented again here:

1. IMPACT will consist of a MATLAB application with a user friendly graphical interface that allows WEC developers to design a controller for point absorber WECs.
2. IMPACT will provide a generic controller structure (that can be auto-populated with the parameters set by the designer) for implementing the controller in the WEC-Sim simulation package.
3. IMPACT will be applicable for point absorber WECs with translational inputs to their PTOs that can provide four-quadrant control. If deemed feasible during stage 2 this may be expanded to include WECs with rotational inputs to the PTO too.
4. IMPACT will use an ACC/AVT (Approximate Complex Conjugate Control / Approximate Optimal Velocity Tracking) control methodology

5. IMPACT will allow wave/excitation force prediction to be modelled either as a user provided input or via an internal estimator.
6. IMPACT will be designed for ease of SiL (software in the loop) and HiL (hardware in the loop) testing.

Development of the control tool to meet the above requirements would be the focus of the stage 2 project. This would include testing of the controllers via SiL simulations.

In stage 3, it is recommended that the control tool be used to design and implement a controller for either a full or model scale WEC, to validate the performance against real world measurement. To achieve this is it anticipated that a further partner will be added to the project at stage 3 in the form of a WEC developer.

The end goal of a generic tool for complete controller design and implementation for point absorber WECs is eminently achievable within the WES control systems call.

6 Communications and Publicity Activity

As stage 1 was a short (3 month) feasibility study phase there was limited scope for publicity. Despite this, the wider industry was actively involved in the project during stage 1 via surveys of WEC and PTO developers to help inform the direction the project should take for stages 2 and 3. The project team also participated in the WES annual conference and a poster was provided for the event to help communicate IMPACT to the wider industry. The poster is available via Wave Energy Scotland, details in the "Publicity Material" section.

7 Useful References and Additional Data

As part of the project sets of WEC-Sim models of generic WECs and PTOs were compiled. These may be accessed via for example the WES knowledge library. The models comprise WECs of the types shown in Figure 7-1 and the following PTO types:

- Direct–drive linear generators
- Rack and pinion (or equivalent) mechanical systems
- Hydraulic power conversion chains

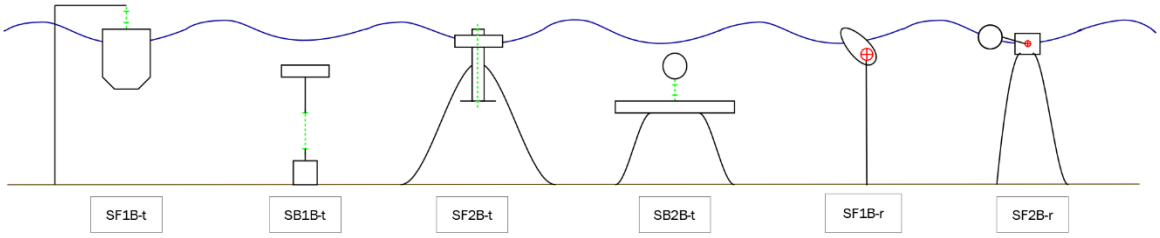

Figure 7-1: Categories of point absorber
(SF=surface, SB=submerged, 1B=1 Body, 2B=2 Bodies, t=translational, r=rotational)