C-DART

WES Quick Connection Systems Stage 2 Public Report

Blackfish Engineering Design Ltd

This project has been supported by Wave Energy Scotland

1 Project Introduction

The aim of the WES Quick Connection Systems programme to reduce the duration, cost and risk of offshore operations for prototype wave energy converters by supporting projects to design and develop a quick connection and disconnection system between a device and its moorings and/or electrical system.

The C-DART concept, developed by Blackfish Engineering Design Ltd, is a novel system that provides an electrical and mooring connection to floating devices, such as Wave Energy Converters (WEC), Tidal Energy Converters (TEC) and Offshore Wind support infrastructure, collectively referred to a "devices" in this report.

The main requirements for the concept have been:

- To increase the weather window for marine operations, by eliminating all ROV and diver operations.
- To improve HSE and minimise risks to vessels and personnel, and to eliminate high risk deck operations.
- To improve availability of the floating device and reliability of the connection.
- To eliminate any adverse performance effects on the device due to the connection.
- To eliminate and changes required to the device design that would not be present anyway (e.g. mooring padeyes and electrical cable).

As a result, the C-DART system provides some significant benefits over incumbent mooring solutions, whilst allowing developers to create an optimum energy capture device without compromising the performance.

The project Team comprised of the following members:

- Blackfish Engineering: Project lead and management, mechanical design, numerical analysis, cost modelling
- Skua Marine Ltd: Marine operations, cost modelling
- Morek Ltd: Numerical analysis and mooring design using Orcaflex
- ETA Ltd: Electrical cable and connector design

The technology is novel and Blackfish are in the process of applying for a patent to protect certain elements of the design. As a result, this report does not discuss details which may compromise this application.

2 Description of Project Technology

The C-DART system is a novel technology development that enables a remote mechanical and electrical connection of a towable, floating device to pre-installed floating sparbuoys. The configuration of these buoys is determined by the nature of the floating device and the metocean data (e.g. free yawing wave energy converter, bi-directional floating tidal energy converter)

The C-DART system works in the following way:

- The floating device is installed with a hawser and / or a hawser and electrical jumper cable assembly. This is used for towing and will be used to moor the device to the spar buoys.

- At the end of each of the hawser(s) is an installation dart and beyond that a catcher line. At site, the vessel manoeuvres so that the catcher line is aligned with the specifically shaped feature on the spar buoy. Once the rope is caught, the dart can be pulled into the sparbuoy using the vessel and the connection can be made courtesy of the internal geometry.
- Recovery is achieved in a similar way, using a second dart that is engaged into the spar buoy using a towed line from a vessel. The main dart is then released and the device can then be towed back to port.

The headline benefits of the project are:

- A novel system has been developed encompassing both electrical and mooring connections.
- Significant improvements in HSE as diver operations, ROV operations, high risk deck operations and vessel close working at sea have all been eliminated.
- Operations can be completed in Hs up to 2m and are not restricted to daylight hours, opening the operation window to improve device availability.
- A reliable system that does not have any actuators, power sources or hydraulics, complex mechanisms, active stored energy systems (such as springs, accumulators, batteries, rubber elements) or active control systems.
- A quick connection system that provides mooring only, electrical only or mooring and electrical connection.
- Minimal impact on the device performance and no complex system integration required by the developer. The C-DART system uses only the mooring padeyes and dynamic electrical cable that would have been present on the device anyway so no further alterations or device design work is required by the developer.

3 Scope of Work

The scope of work completed for Stage 2 is summarised below:

- 3-D printed scale models of the connection system were used to assess geometry and provide initial feedback for improvements to the concept.
- A test case using a large scale floating tidal energy converter as a baseline. Activities included mooring and cables design and analysis using Orcaflex, concept and detailed CAD modelling, Finite Element Analysis of key components, loads assessment, systems engineering, corrosion and biofouling design, and instrumentation design. In addition, detailed risk assessments were completed.
- A test case scenario using a small prototype WEC as a baseline. Building on the design work completed for the tidal device, the mooring design was modified to allow a free yawing and self-referencing WEC to function as intended. Detailed CAD design, Orcaflex moorings analysis, Finite Element Analysis of key components, cable fatigue assessment, risk assessment and systems engineering were completed.
- For both these test cases cases, a detailed package of work examining all aspects of marine operations was undertaken. This included marine operations reviews, story boards of installation and recovery, risk

assessments, contingency assessments, durations assessments, baseline assessments and proof of feasibility.

- A preliminary design was completed for a number of test rigs and demonstrations was completed. These rigs will be used in the QCS Stage 3 project to validate and verify the requirements and mitigate risks. The planned tests specifically mitigate the key technology risks in three areas of numerical modelling validation, proof of geometry and proof of marine operations. Hardware has been designed, with detailed test plans and costs obtained.

- Assessment of how the C-DART concept will be certified and adhere to all relevant codes and standards, as well as highlighting where there are gaps in capability or understanding to being able to obtain this compliance.

- A detailed business case assessing all aspects including CAPEX, OPEX (assessments were made using the WES O&M tool), the business model, identifying customers and projects, market assessment, IP assessment and the plan to progress the Technology Readiness Level (TRL) and Commercial Readiness Level (CRL).

4 Project Achievements

Stage 2 project achievements include:

- Printing 3D scale models of the connection system proved to be invaluable for the understanding of the geometry and proving feasibility.

- Support from WEC and TEC developers was very productive and highly relevant information was used to support the work.

- Design of the test rigs highlighted some key factors in the design of the system. Design, cost and functionality improvements to the concept were also identified during this phase.

- Development of storyboards was an effective means for assessing all stages of marine operations in a number of ways and visualising the operations. It enabled a more thorough approach to risk mitigation and contingency planning.

- The original concept was proved to be sound as no significant deviations were necessary throughout the course of the design and analysis. The original objective of achieving a remote connection without the use of divers, ROVs or deck operations has been achieved, whilst the connection system does not rely on actuators, backup power, active stored energy systems, complex mechanisms or control systems.

Difficulties encountered during Stage 2 include:

- Validation of numerical modelling was considered vital, but especially for the WEC test case this took longer than planned due to the complex dynamics involved.

- The initial mooring design for the WEC proved to have issues for the WEC performance. A second mooring design was therefore developed. However, this was significantly better and therefore proved that the C-DART concept was able to be easily adapted to various configurations and scales.

- Selecting and using suitable comparison baselines was challenging as direct comparisons were not possible, as similar technology is not available.

5 Recommendations for Further Work

It is acknowledged that the C-DART concept is still at a low Technology Readiness Level of 3, as the concept was entirely new at the start of this programme. As a result, there is significant work ahead to demonstrate and realise the benefits of this system.

Testing during Stage 3 of this project is clearly a necessary step to continue development. This is proposed to include wave tank testing, mechanical test rig and scale marine operations testing. Further development of compliance, business case, IP protection and deeper iterations on design are all also necessary. Discussions on partnering with a developer is well underway in order to develop the technology and business case in the right direction. A detailed TRL and CRL development plan for later stages gives a clear path to commercialisation.

6 Communications and Publicity Activity

During this project the team has been focussed on the techcial aspects of the work. Accordingly communications and publications has been limited.

Due to the nature of protecting the IP, further public release of project specific information has not been possible.

7 Useful References and Additional Data

There is no additional published data on this technology, as it is confidential. However, Blackfish would be very interested to share relevant information with bona-fide interested parties under NDA and subject to agreement of WES.

Publicity Material

[Please supply WES with any logos, images and video files that are non-confidential and available for WES to use to promote WES supported projects. Files should be uploaded to the Objective Connect milestone folder. Use the table below to summarise the publicity material.]

Filename	Media Type	Description
Blackfish Logo Square	JPG	Blackfish Logo
Skua Marine sg3 final	PNG	Skua Logo