Pull and Lock Marine Quick Connection System (PALM QCS)

WES Quick Connection Systems Stage 1 Public Report

Apollo

This project has been supported by Wave Energy Scotland

1 Project Introduction

Apollo's Pull and Lock Marine quick connection system (PALM QCS) is an efficient, rugged mechanism for hooking up floating wave energy converters (WECs) with their moorings, while also controlling the mating of electrical and control connectors. Drawing on good practice and learning from other marine sectors, a robust mechanical and electrical connection path has been developed that is suitable for high energy, aerobic marine environments. The connection operation requires only winch action from an attendant vessel. No hydraulic or electrical actuation is used.

The Stage 1 project focused on the development of the initial PALM concept, adding detail while scrutinising the fitness for purpose of the device. The project set out to deal with the following challenges:

Reliability	How can the system be made robust, to cope with the fatigue-intensive duty cycles and the harsh marine environment?
Availability	How can the system be designed to improve the availability of the connection/disconnection function? How can the QCS widen the weather window in which such activities can take place?
Simplicity	Can the concept be made minimally complex and reduce the engineering, manufacture, and operating costs? Can the need for powered mechanisms within the QCS be avoided?
Performance	Can the survivability of the concept be demonstrated? And can it be shown that the concept provides the functionality required of it for the continued efficient performance of the WEC?

Significant progress was made to resolving these challenges, and in defining the various components that make up the PALM. The technical outputs, in combination with the commercial cost model, give sufficient confidence to justify an application to Stage 2 of the WES programme.

The work was completed in its entirety by the in-house engineering team at Apollo. Apollo is an Aberdeen-headquartered engineering services company and is a member of the Global Energy group of companies.

2 Description of Project Technology

The PALM connector proposes robust, reliable and repeatable connections of the WEC in a short, simple marine operation.

The PALM is based around a submerged buoy mooring with an integrated electrical riser. Tugs are used to position the WEC, engage the PALM and complete the mechanical and electrical connection.

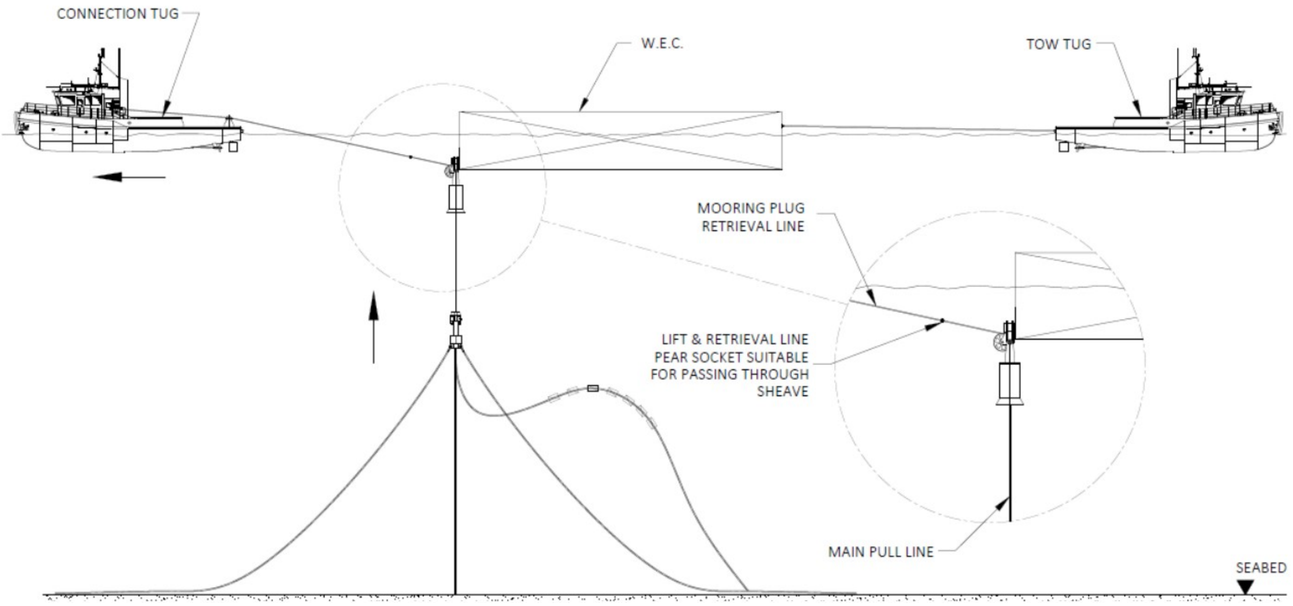

Figure 1 Connection sequence extract

The key components making up the PALM connector are shown in the image overleaf. The plug is pulled into the receptacle by a winch wire (from the assisting tug vessel) which is reeved through the sheave wheel in the fairlead. The various degrees of freedom (pitch, roll, and yaw) are achieved through hinged mechanisms.

Connection is achieved as the plug is pulled up into the receptacle. A series of initially coarse, and increasingly fine, guides orientate and direct the plug into its locked position. The mooring node at the bottom of the plug connects the plug to the moorings. Electrical connection is achieved through wet-mate stabs between the plug and receptacle.

Key to the PALM's design philosophy is its simplicity and robustness. Proven marine engineering solutions are applied in a novel configuration. The central innovation in the design is the passive locking mechanism that provides the connection and load transfer between the WEC and its moorings. This function is purely mechanical and requires only the input of a suitable deck winch on the installation vessel, i.e. there are no remotely controlled hydraulic or electric actuators in the system. This simplicity overcomes the key challenges of reliability and availability, whilst also reducing engineering and manufacturing costs.

Figure 2 PALM concept

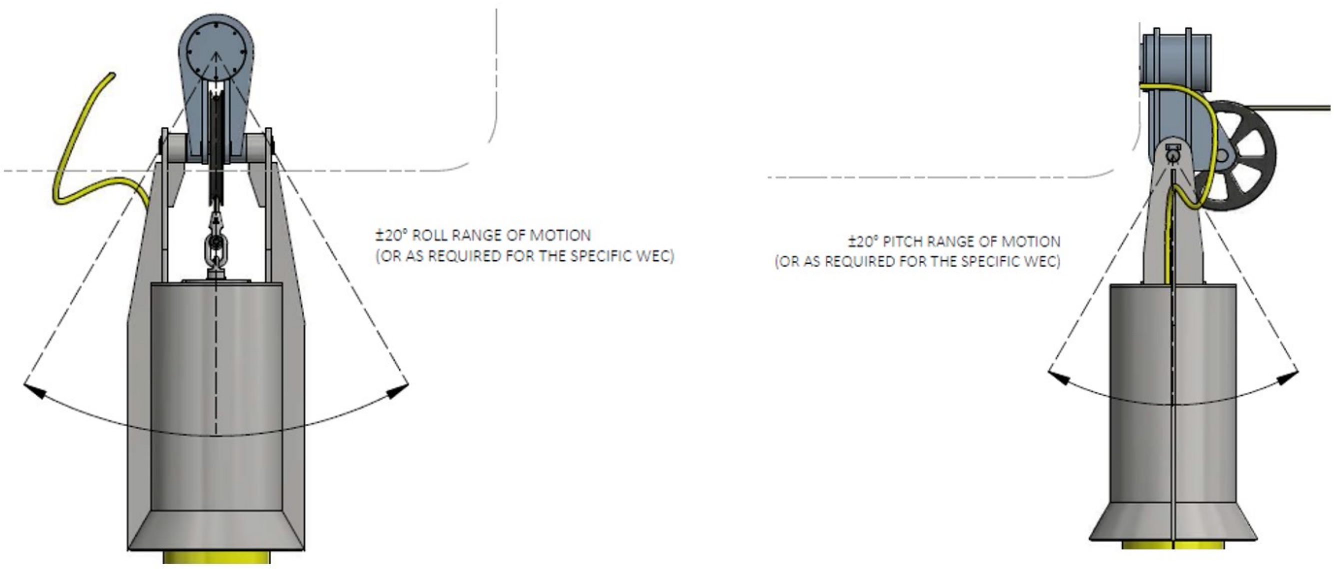

Figure 3 PALM degrees of freedom

3 Scope of Work

This project focused on the development of the PALM concept, and on proving it against generic requirements of a notional floating, forward-moored WEC. Central to this was the creation of a 3D model of the connector, attached to the WEC. This model set out the geometry for each of the components. The 3D model was supported by engineering calculations to prove the components are suitable for the design loads.

The concept development phase was aided by consultation with a WEC developer, to better understand the likely requirements of the QCS. The design philosophy took into consideration the learnings from the Pelamis P2 project, formulating a set of design constraints and key drivers (simplicity, durability, reliability, etc.). The information was formalised in a Basis of Assessment (BoA) document.

An operational storyboard was compiled which set out the proposed order of operations for the PALM's connection and disconnection sequences. A Hazard Identification and Risk Assessment (HIRA) was then carried out, drawing out key operational risks and proposed mitigations for development in the Stage 2 project.

In a similar fashion to the HIRA, a design risk register was compiled to identify key risks and mitigations associated with the design at a component level. This will be used to inform areas of focus and investigation in a Stage 2 project.

A detailed cost model was developed based on the Stage 1 3D model and engineering work. CAPEX and OPEX estimates were made, and opportunities for targeted optimisation in Stage 2 identified.

4 Project Achievements

The project successfully developed a simple and robust mechanical and electrical quick connection system concept.

The Stage 1 proposal had presented a very high-level outline of an idea for a connection system. Subsequent activities addressed the main challenges associated with that concept, took on board bid evaluation feedback and eliminated known weaknesses.

One concern was the initial requirement to transfer personnel onto the WEC when completing the connection sequence. In Stage 1 the entire connection and disconnection sequence was amended to eliminate that hazardous and operationally-limiting activity. Only one mechanical link to the facilitating installation vessel is now used (i.e. via the vessel's winch wire). This was achieved through close consideration of the marine operational sequences and by simplifying the lock-off mechanism.

Initial discussions considered remotely operated actuators (or a second winch line) to articulate a locking device during connection/disconnection. This however would add design and operational complexity, making the overall PALM system a less attractive proposition. Significant design effort was directed towards a mechanism wherein the plug/mooring node assembly could be pulled up into the receptacle, locked off, and disconnected, all with the single winch wire interface. The resulting design achieves this, representing a significant step forwards.

The initial proposal concept omitted the roll and yaw rotational degrees of freedom which are very likely to be required between the WEC and its moorings. These have been successfully incorporated into the design. Leveraging of the team's experience in marine engineering and deck machinery design, a repurposed, field-proven mooring swivel-head fairlead concept was adopted. This provides an elegant and economical method of allowing the necessary degrees of freedom to be achieved, whilst withstanding the mooring load duty cycle and the marine environment.

In its current form the PALM is considered to offer marginal capital cost improvements over the system that was deployed on the P2 Pelamis device, but with significant life-cycle cost benefit. The device is expected to perform better in long term operations due to its improved integrity and operational features. Capital cost savings of the order of 20% those for P2 are predicted, but this figure does not tell the whole story. Crucially, it doesn't illustrate the marked improvement in availability and reliability that the PALM will offer over the life of the WEC. Additionally, further development of the design should reveal greater capital cost benefits. Note that the PALM will be suitable for operations in seastates up to Hs = 2.5m, with the connection and disconnection operations each taking less than 90 minutes.

5 Recommendations for further work

At this stage of the PALM development, a device has been conceived which solves many of the technical challenges of WEC quick connection. The project team believe that it can now be optimised, reducing weight to bring down fabrication costs and to avoid any yield impact on the WEC. There are potential applications in alternative mooring configurations such as a mid-line device for spread moorings. Also, it would be useful to explore a lower cost permutation where only the mooring connection is required i.e. no electrical or control wet mate connectors.

To move forwards on all these ideas, the team are keen to work more closely with developers of specific WECs and to demonstrate how the PALM will generate value to their projects. Thus the stage 2 project will include the below work scopes, with reference to specific WEC designs.

Advanced engineering analysis	Mooring analyses. These will be used to establish suitable limiting sea states for the connection and disconnection sequences.
	Finite element analysis of the structural components (operating, survival, impact, and fatigue cases).
Engineering studies	Materials investigation.
	Continuation of design risk analysis and FMECA.
	Operational sequence review and HIRA.
	Scalability investigation to determine the suitability of the PALM for WECs operating on different orders of magnitude of electrical and mechanical loadings.
Conceptual design (mechanical)	Progression of the 3D model. Optimisation of geometry based on refined requirements and results of engineering analyses.
Electrical design	Develop the electrical design in collaboration with a specialist.
WEC developer engagement	To inform the progression of the design, and to aid in the creation of a refined set of requirements for the QCS.
Commercial	Refined CAPEX estimates based on revised engineering and design work.
	Refined OPEX estimates based on revised operational methodologies.
Test design	Design of a potential scaled test set up. This would form the basis of the testing activities that would be conducted in Stage 3.

6 Communications and Publicity Activity

Generally, Apollo have avoided widespread publicity of the concept while it goes through a critical phase of technical development. The team are currently in discussions with Intellectual Property advisers concerning the innovative connecting and locking mechanism that has been developed.

Some reference has been included in Company social media releases, and the project was discussed in the Aberdeen Renewable Energy Group bi-annual newsletter issued this month.

Discussion of the potential for the PALM to support Floating Offshore Wind devices has been proposed for a paper in the forthcoming Foundation Ex 2020 conference in Bristol, run by Empire Engineering.

7 Useful References and Additional Data

D04 Basis of assessment

D05 3D model

D06 Engineering report

D07 System specification

D08 Design risk register

D09 Installation methodology

D10 HIRA report

D11 Feasibility study report

Publicity Material

Filename	Media Type	Description
PALM images	.pptx	Various images of PALM conceptual model