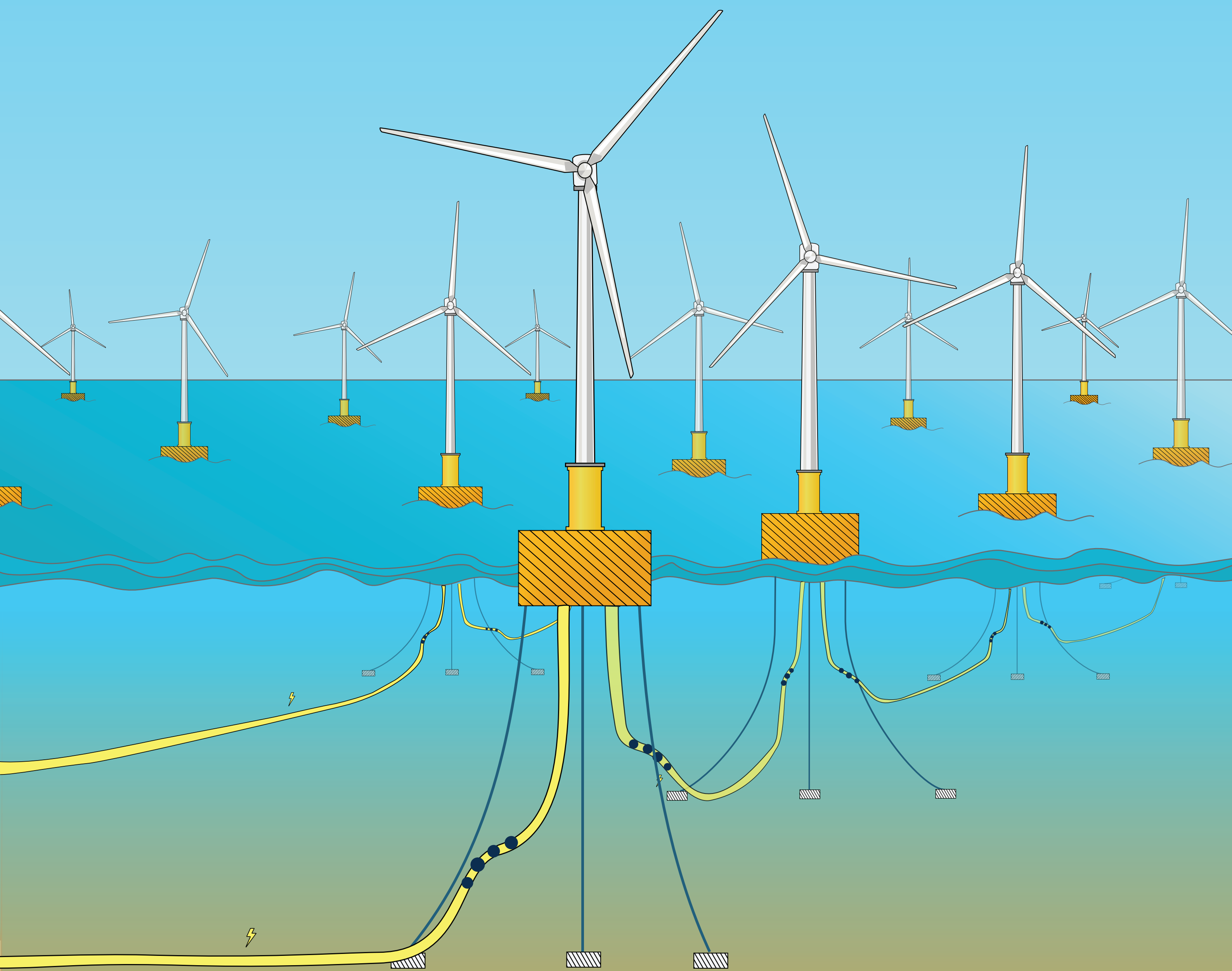
Splice Box

Floating Wind Technology Acceleration Competition

Executive summary



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1 INTRODUCTION

Before towing a Floating Wind Turbine (FWT) to shore for heavy maintenance, the dynamic array cables must be disconnected from the FWT.

The Floating Wind Technology Acceleration Competition project goal was to develop a splice box that would enable the operator to disconnect the dynamic cables and splice them prior to /during the platform being towed to shore for maintenance. The splice box would protect the cables and maintain the power production from the other wind turbines of the array. The water depth for the study was agreed to be 250 m (approximately 25 bar pressure).

The project was spilt into four work packages (WP) with the following aims and objectives:

- WP1- Industrial Research – Market Evaluation
    - Aim: Identify available cable connection technologies and identify limitations related to floating equipment and subsea wet storage.
    - Objective: Summarise screening results in the study report with pros & cons and any improvement proposals
- WP2 – Splice Box Design
    - Aim: Design a splice box suited for floating wind application.
    - Objective: Define an arrangement for the splice box, including single line diagram, general arrangement drawing, mounting sequence and cost estimate for the study report.
- WP3 – Marine Operations
    - Aim: Identify installation costs.
    - Objective: Perform installation analysis, define installation procedure, define installation story bord, design installation aids and estimate installation schedule and cost for the study report.
- WP4 – Testing
    - Aim: Prove feasibility of designed solution.
    - Objective: Develop a test procedure and a test report with results for the study report.

1.1 Abbreviations

Abbreviation	Description
FWT	Floating Wind Turbine
IAC	Inter Array Cable
ID	Inner Diameter
LCV	Light Construction Vessel
OD	Outer Diameter
WP	Work Package
WTG	Wind Turbine Generator

2 EXECUTIVE SUMMARY

The following subsections gives a summary of the different WPs related to this study. With the predicted growth of the floating offshore wind market, it is important that the industry develops reliable and cost efficient solutions to connect and disconnect inter array cables. The available connect and disconnect technologies outlined in this study highlight that further design and testing is required, both at component level and at sub-assembly level. The industry should also develop common guidelines, recommendations or standards defining requirements for a connection / disconnection system.

2.1 WP1 - Industrial Research – Market Evaluation

The aim of WP1 was to identify available cable connection technologies and identify limitations related to floating equipment and subsea wet storage. From the market screening the following main cable connection technologies were identified:

- Standard (or semi-prepared cable) splice, where the cables are jointed together by overlapping the conductor core from one cable to the sheathing of the other. For disconnection the cable needs to be cut.
- Semi-prepared cable splice, similar to the standard splice, but the cable pig-tails are prepared for the splice upfront.
- Electrical connector, pre-mounted connectors that are used for plug and play for connection / disconnection.

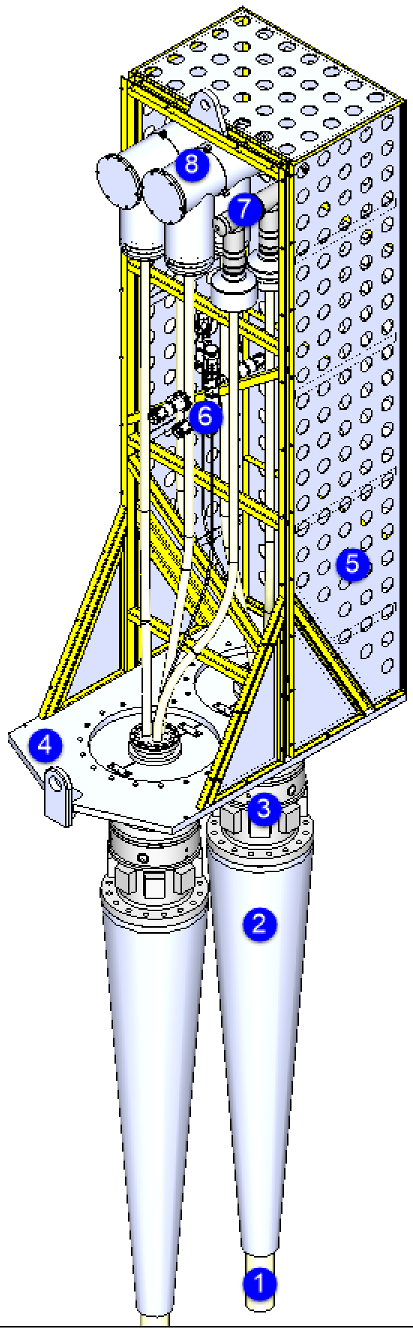
From the market screening and evaluation it was proposed to rate an electrical connector type more favorably compared to a standard or semi-prepared cable splice, even though the cable splice technology is acknowledged to be qualified for subsea use. The driver for the plug and play approach is to reduce the time spent offshore to connect the electrical cables. A standard cable splice will also require longer pig-tails if multiple connections are to be carried out.

The draw back with the electrical connectors currently available, is that they are not rated for subsea use. There are however solutions in the market for protecting the electrical connectors from seawater ingress for subsea use, but these solutions are typically used for joining a dynamic cable to a static cable. It would be possible to utilise such solutions for connecting inter-array cables, however it is highly likely that the marine operation time would be significant.

The main driver for exploring the development of a splice box with electrical connectors is cost reduction. However, for this solution to be viable, the water tightness of the connectors must be demonstrated. This was considered in subsequent work packages in the report.

2.2 WP2 - Splice Box Design

The aim of WP2 was to design a splice box suited for floating wind application. The illustration below shows the splice box system when two inter array cables (IAC) are connected.



Component description
1. Inter-Array Cable
2. Bend stiffener
3. Bend stiffener connectors
4. Base plate with lifting structure
5. Protection Cover
6. Fibre Optical connector
7. Electrical Connectors
8. Watertight cannister (around electrical connectors)

Illustration - Splice box system

Before the two IACs can be connected they need to be pulled out of the FWT I/J-tubes with the use of a pull head integrated to the IAC termination ends. The IACs are then transferred to a vessel and docked to a balcony attached to an installation vessel (see 2.3 for vessel equipment) before they are connected as shown in the illustration above. Aker Solutions has delivered similar solutions for joining electrical cables offshore and permanently storing these subsea. However this has been based on a standard splice technology and at lower voltage. In this study a proposed way to build a watertight barrier around the electrical connectors is detailed. The design which was tested is relevant for the pull out (and pull in) operation with respect to the sealing / watertight cap around the electrical connector, however a similar approach can be adapted to the cross-over of two electrical connectors used in the splice box.

As all identified electrical connectors have a larger envelope compared to the outer diameter (OD) of the uniphase electrical cables, a proposal to increase the OD of the electrical cable is made by adding an object around the cable itself. By doing this, the inner diameter (ID) of the object needs to be greater than the OD of the electrical cable. To close and make the gap between the ID and OD watertight, a self-amalgamating, insulating mastic tape was proposed to be tested as sealing material.

To be able to verify the cable/object sealing, a cap was designed which interfaced to the object around the cable. The cap has a cavity inside making it possible to apply external pressure to the parts and still having ambient pressure inside. Standard radial sealing (O-rings) between the cap and the object was used. See 2.4 for further details related to the testing of this technology.

The cavity in the cap needs to be sufficient for the electrical connector to fit inside, but as small as possible. The size of the cap / electrical connectors is the main driver for the size of the FWT I/J-tube design. From this, it is highly recommended that a close dialogue between the cable and the I/J-tube supplier is established early in a floating wind development project. The size of the splice box is of less importance with respect to available space at the installation vessel, but in general, the larger the equipment needed to manufacture and handle the splice box, the higher the cost.

2.3 WP3 - Marine Operations

The marine operation work package developed a methodology and equipment list for installing and recovering the splice-box . In addition, the work package developed an approximate installation schedule and costs estimates for vessel and installation equipment hire.

On the vessel, a hang-off balcony receiving the inter-array cables is proposed. The balcony will also be used as working area for the splice box system assembly. The below illustration shows a proposed hang-off balcony for the inter-array cables. The following main steps are to be carried out for deploying the splice box for subsea storage:

1. Installation vessel is in close proximity of the FWT
2. FWT to lower IAC #1
3. Vessel to deploy deck winch #1
4. Transfer cable load from FWT winch to Vessel winch
5. Recover IAC #1 onboard and keep the load on the winch.
6. Recover IAC #2 (same steps as 2-5)
7. Install temporary hang-off plates
8. Transfer cable load from deck winches to hang-of plates
9. Install the splice box.
10. Remove balcony’s beams with winches lifting points
11. Connect Vessel crane to splice box rigging
12. Lay both cables simultaneously by lowering the splice box
13. Activate crane heave-compensation (if needed) and land splice box on the seabed

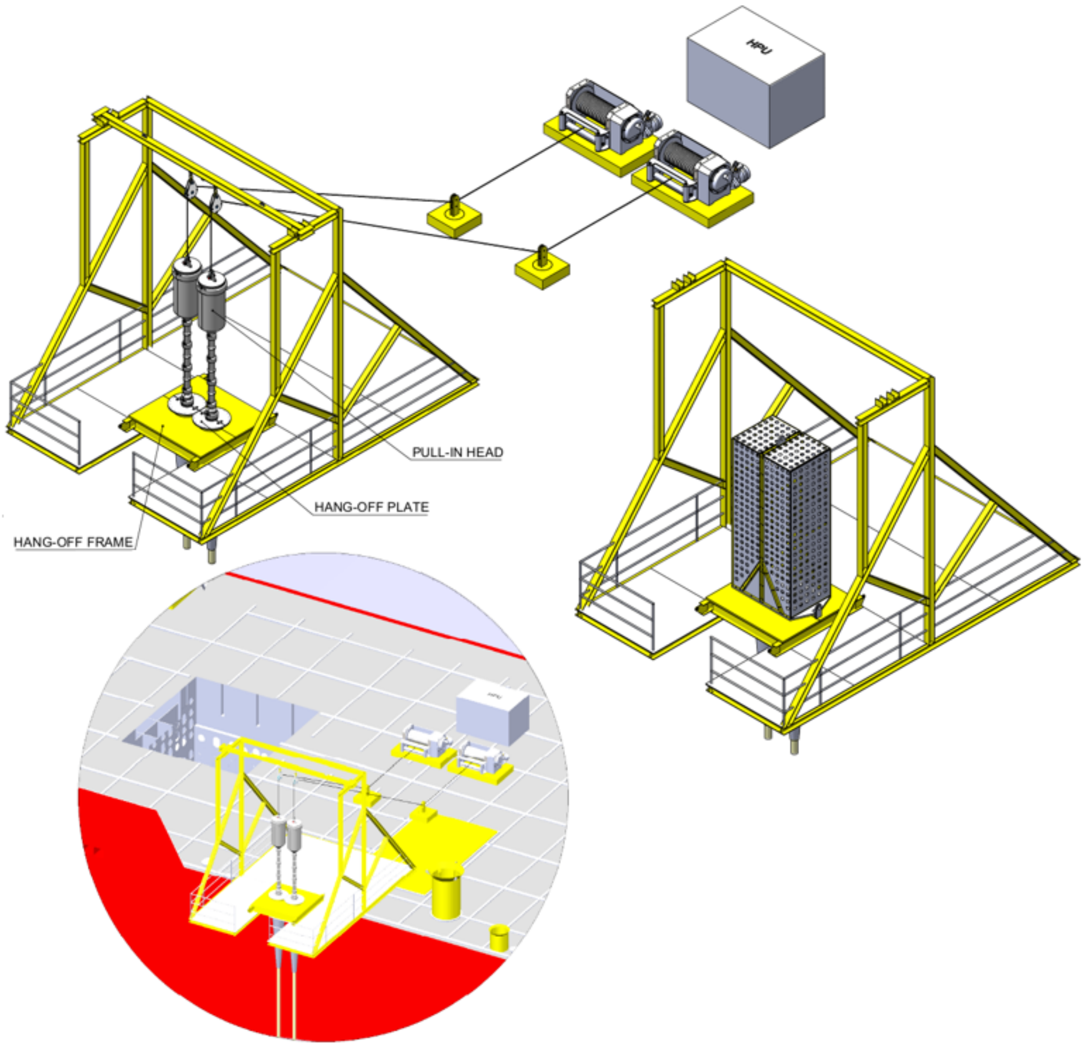


Illustration: Hang-off balcony

From the preliminary installation analysis the following steps were checked:

- Cables transfer from the FWT to the vessel for installation of the Splice box
  - ✓ Maximum top tension when cables are hung-off on Vessel
  - ✓ Clashes between cables and vessel hull
- Landing of the splice box on the seabed
  - ✓ Cable overbending
  - ✓ Bending moment in interface between splice box and cable

The models were run with 5m of max wave height, which conservatively translates operational limitations at 2.5m Hs.
The response amplitude operator used in the Orcaflex model are representative of a light contraction vessel.

The most critical finding from the installation analysis was identified as bending in the cable at touch down. This finding can be resolved either by utilising vessel heave compensation or shift the centre of gravity of the splice box/bend stiffener relative to the lifting points on the splice box base plate.

2.4 WP4 - Testing

From work package 2 it was proposed to verify if a watertight seal could be formed between the cable outer sheathing and the surrounding object. The testing was carried out at Aker Solutions manufacturing plant in Moss during December 2020.

Four tests were carried out with the following applied pressure:

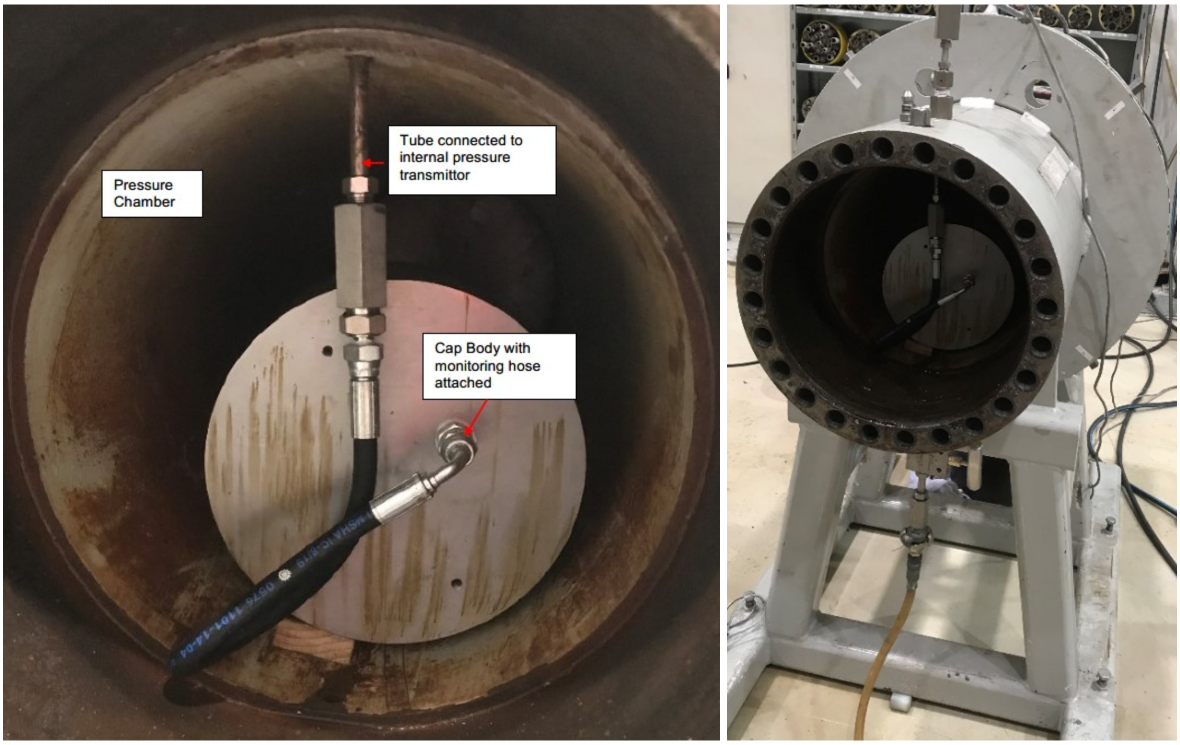
- 12,5 bar (approximately 15 min duration)
- 25 bar (approximately 15 min duration)
- 37,5 bar (approximately 15 min duration)
- 37,5 bar (approximately 1 week duration)

The acceptance criteria was set to be no visual leakage in the cavity inside the cap. All tests were approved. The main objective was to verify a watertight sealing between the electrical cable and the belly (surrounding object). Picture 1 below shows the pressurised test equipment. Picture 2 below shows the pressure chamber with the test equipment installed. Both the pressure in the pressure chamber and inside the cap cavity were measured.

Overall the project has met it's objectives with respect to the defined tasks and deliverables as identified in the scope of work.


Electrical Cable
Heat Shrink Tube covering the Mastic Tape
Belly
Cap Body
Electrical Cable
Belly (surrounding object)
Cap

Picture 1


Pressure Chamber
Tube connected to internal pressure transmittor
Cap Body with monitoring hose attached

Picture 2