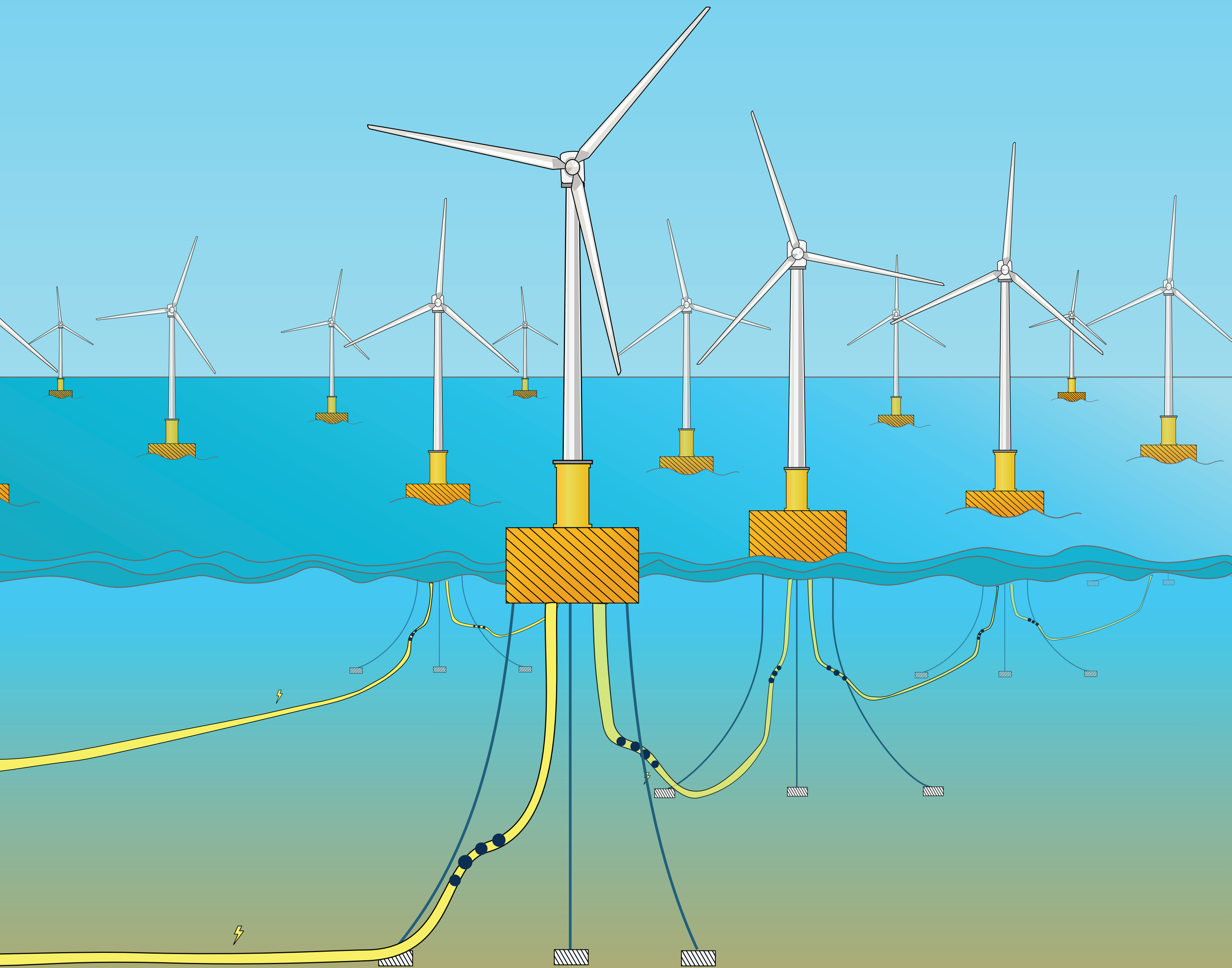
CARBON TRUST

Stevadjuster®

Floating Wind Technology Acceleration Competition

Executive summary



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Acknowledgements

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FLW JIP, formed in 2016, is a collaborative research and development initiative between the Carbon Trust, and fifteen leading international offshore wind developers: EDF Renouvelables, EnBW, Equinor, Kyuden Mirai Energy, Ocean Winds, Ørsted, Parkwind, RWE, ScottishPower Renewables, Shell, SSE Renewables, TEPCO, TotalEnergies, Vattenfall, and Wpd.

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Disclaimer

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EXECUTIVE SUMMARY

Project Purpose

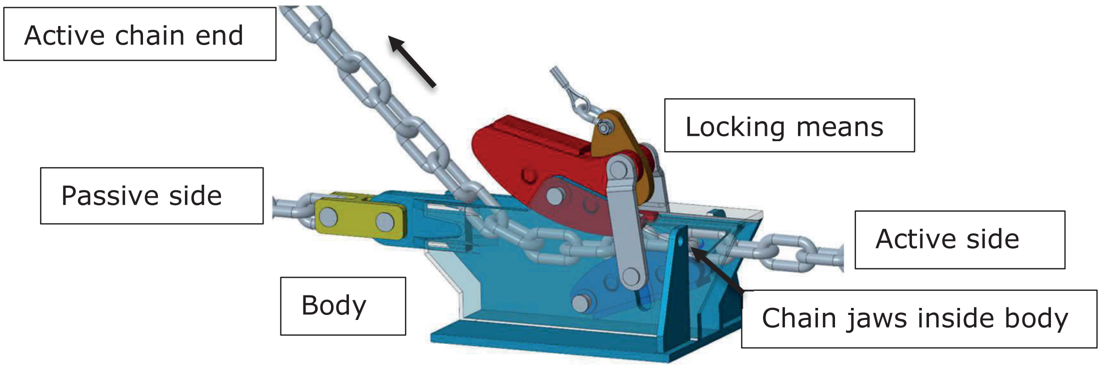
This project, funded by the Scottish Government through a grant agreement with the Carbon Trust as part of the Floating Wind Technology Acceleration Competition (FLW TAC), was undertaken by Vryhof to accelerate the development of the Stevadjuster®, a simple and cost-effective means of pre-tensioning the mooring system of a floating marine renewable energy platform such as a floating offshore wind turbine (FOWT).

For floating wind platforms, one of the key drivers is to reduce the platform equipment (and cost) to the absolute minimum, with as little additional equipment onboard as possible other than the turbine itself, its associated critical control systems, and export cable interface. Furthermore, maintenance should be reduced to a minimum and the platform should be as "lean" as possible, with the only provision for the mooring system being fixed points for mooring line attachment.

During the lifetime of the platform, it may well be necessary to adjust or re-tension the mooring system, or to release tension in order to disconnect the platform for tow-to-port maintenance. Typical project life for a FOW farm is 25 years, with heavy maintenance expected every 5 years. In a commercial farm of say 30 turbines, this represents 150 potential mooring system disconnection and reconnection operations. Clearly a cost-effective solution for carrying out this process will have cost benefits for the farm.

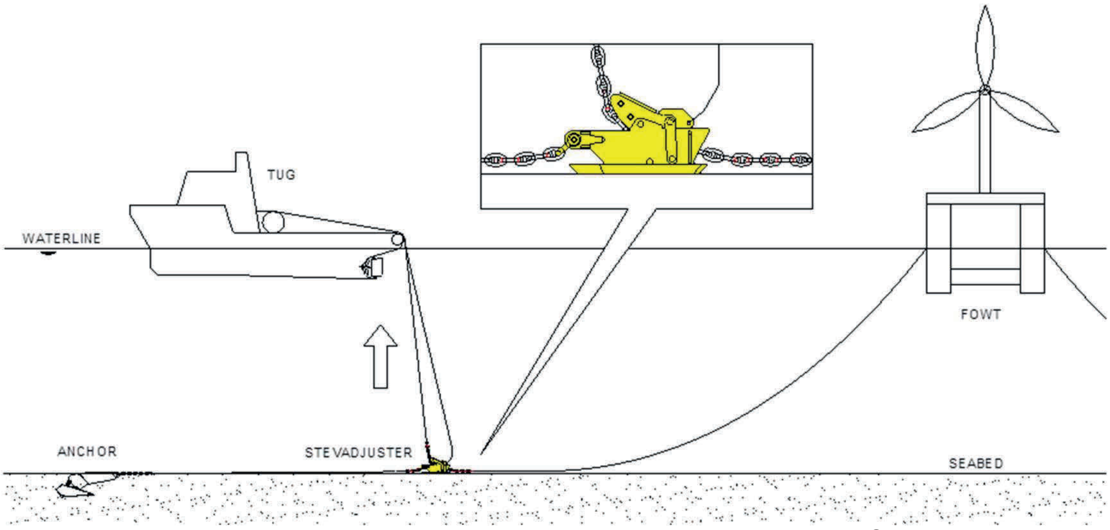
Background

The Stevadjuster® uses simple mechanical principles to enable the length of a mooring line to be adjusted, thus altering the tension in the line. It operates on a chain by locking onto it at the required length/tension. This chain remains locked in place until either the system requires re-tensioning or relaxing, whereupon the chain can be released and is able to be further shortened or lengthened as required. In the particular case considered in this project, the Stevadjuster® is designed to be positioned in the lower portion of a mooring line, typically in the grounded chain normally resting on the seabed, with one side attached to the Stevadjuster® (termed the passive side), and the other side (active chain) passes through the device.



Stevadjuster® Mk2 principal features

The motive force required to adjust the chain length is applied by an installation vessel from the sea surface, pulling roughly in a vertical direction on the active chain end. This pulls the active chain through the Stevadjuster® until the tension increases to the required level and the chain can be locked in the device against fixed chain jaws inside the body. The locking process in this case is activated by a simple cam that when rotated causes a moveable chain guide to direct the chain into alignment with the fixed jaws. Once engaged in the jaws, the chain will not fall out of engagement provided it is under tension. The cam and moveable guide act as a secondary security means, preventing the chain from leaving the fixed jaws even when slack.



Typical mooring arrangement with Stevadjuster®

Previously chain adjusters had been used in the offshore oil and gas industry, from which the present embodiment had been developed. Prior to project commencement, the latest design had been validated at model scale in the laboratory and tested as a small scale working prototype in a real environment (wet testing of 19mm chain diameter size in a harbour location).


Prototype 19mm chain size Stevadjuster® scale model testing

In order to bring this technology and product to the floating renewables market, it required development to full scale size (>76mm chain diameter), with proof of its structural adequacy, operability, reliability and longevity (specifically its fatigue performance). The Carbon Trust grant agreement, funded by the Scottish Government, provided the platform from which to accelerate this development process.

Research questions

The development of the Stevadjuster® to a state of market readiness for FOW projects required several key "research questions" to be asked and answered, encompassing theoretical, practical, and commercial aspects.

(i) Could the geometry and construction of the 19mm prototype be successfully scaled up to chain sizes 4-8 times larger without loss of functionality and still have adequate structural strength?

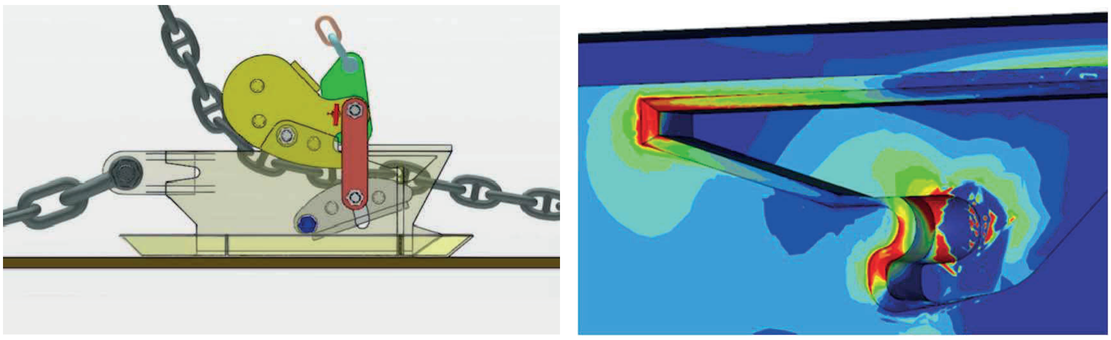
(ii) Would such a device have the required life expectancy for long term mooring (e.g. 25 years) with minimal inspection and maintenance whilst still retaining its reliability/operability?

(iii) Could full size units be approved by a third party certifying authority for use in actual mooring systems for long term mooring?
(iv) Would manufacture of these large steel fabrications be practical, both in terms of materials availability, construction methods, and welding technology? Furthermore, what would be the economics of building them?
(v) How could the Stevadjuster® be tested to demonstrate its fitness for purpose?
(vi) Would deployment and operation be possible using conventional installation methods, vessels and equipment?
(vii) What level of performance could be expected from the Stevadjuster®?
(viii) What could be the potential market for the technology?
(ix) What cost benefits could the Stevadjuster® bring to commercial FOW farms?

Research undertaken

To answer the questions posed above, a series of four work packages were planned and executed. These followed a natural sequence of design and analysis, approval, manufacture and testing, installation planning, supply to real project, and assessment of commercial potential.

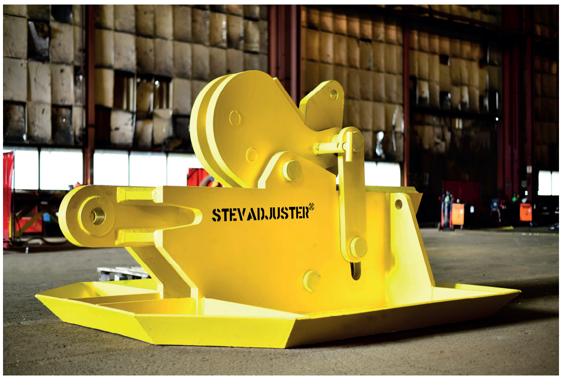
Work package WP1 covered the process of taking the existing prototype design to full size, using numerical modelling to validate the design in both computer simulation and 3D printed models. Finite element analysis (FEA) was used to ensure the structural integrity of the design, to be stronger than the chain on which it would be working. Industry standard practice was applied using the FEA results (maximum principal stresses) to assess the fatigue life of the design, to demonstrate it had longer life expectancy than the chain and thus not be the weak link in the mooring system. A parametric model was created to enable scaling of the generic design to any selected chain size within the range of interest (typically 76mm to 170mm diameter), from which an automated routine created working drawings to use for production. The deliverables from WP1 were 3D models, simulations, structural and fatigue assessment reports, plus working drawings of 76mm and 107mm sizes.



Example 3D modelling simulation and finite element analysis output

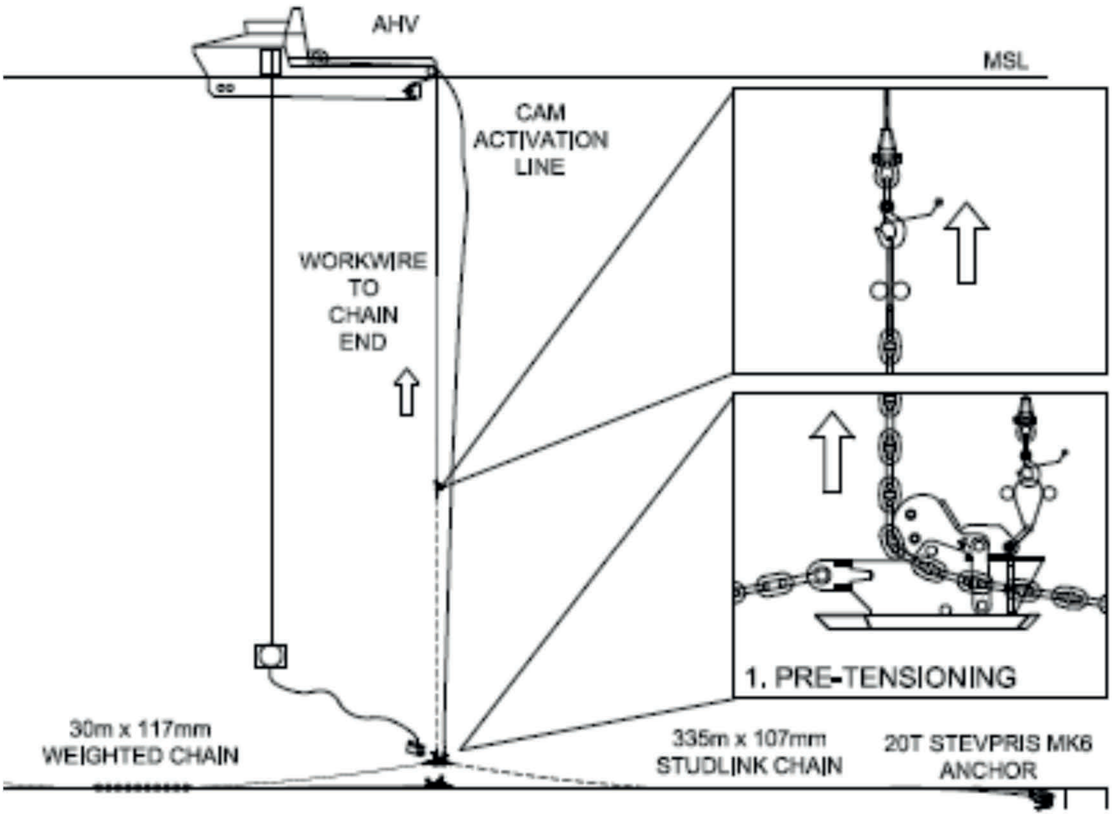
Work package WP2 took the output from WP1 and submitted it to a third party certifying authority (TPCA) for design review and approval. Norwegian classification society Det Norske Veritas (DNV) was selected for this process and the deliverables were the resulting approval letters for the Stevadjuster®.

With approval secured, the Stevadjuster® was able to be manufactured, which was part of work package WP3. Certified materials were sourced and fabricated into the required form using approved subcontractors and processes. Rigorous inspection of all welds was carried out. The units were subjected to physical proof load test. Factory acceptance testing (FAT) was successfully completed, including trial fit of chain, operation of the locking cam system and securing pin. The finished units were painted and made ready for supply. The evidence for all activities were combined in the deliverables for WP3, being the manufacturing record book from the production.



Stevadjuster® factory testing & painting ready for delivery

Work package WP4 concentrated on the actual delivery of the Stevadjuster® to the market. A thorough research of the FOW landscape was conducted, with industry leaders and key players engaged in focussed meetings, webinars and presentations, in order to assess the potential uptake of the developed technology/product. Installation procedures were developed using scale models as well as computer simulations to ensure the Stevadjuster® could be deployed, operated and recovered using conventional methods, available vessels and equipment. The produced units were supplied to real projects for inclusion in full size moorings, one of which was successfully installed in late 2020 while the other is ready to install in Spring 2021. In addition a first-order cost benefit assessment was made, to evaluate the potential savings that could be realised by using Stevadjuster® rather than alternative methods, over the lifetime of a FOW platform.



Example extract from operating procedure storyboard development

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Key findings

The Stevadjuster® Mk2 prototype design was able to be successfully scaled to full size whilst maintaining its functionality, structural integrity and adequate fatigue life. A parametric 3D model was created that enabled semi-automated creation of working drawings for any selected chain size within the expected range applicable to FOW.

Third party approval for two different sizes of Stevadjuster® Mk2 was obtained, certifying the design as suitable for use in long term moorings.

Two sizes of Stevadjuster® Mk2 were manufactured, tested and supplied to different marine renewable energy projects, 76mm size for use with a wave energy converter, and 107mm size for a 3.6MW FOWT project.

Installation procedures were developed for the deployment and operation of the Stevadjuster® Mk2 as part of full size mooring systems, using conventional methods and readily available vessels.

Market potential for the technology was assessed by considering future projections for floating wind developments worldwide, showing a 10% uptake over the next 10 years would require 150 units, representing an estimated revenue of US$ 50M.

Cost benefit analysis of using Stevadjuster® compared to having a winch on the FOW platform, or using large tugs to pull the platform over to connect it, showed potential savings of more than 80% compared to the winch option and over 20% compared to using large tugs.

The project was completed on schedule and under budget.

Vryhof acknowledges the support provided by the Scottish Government, Carbon Trust and Floating Wind Joint Industry Project (FLW JIP) partners through the Floating Wind Technology Acceleration Competition.

For further information regarding Stevadjuster®, please follow the link below:

https://vryhof.com/products/connectors/stevadjuster/