

Redefining rugged: next generation mooring connectors for challenges offshore

Mooring hook up and tensioning is a critical factor for the success of all Floating Offshore Wind (FOW) projects. For commercial-scale projects to meet delivery goals, developers will need to install floating foundations offshore as quickly, and as safely, as possible. In some instances, the aim is to install one wind turbine every week, or even more. This is much more challenging than what has been done in the oil and gas industry, where typically only one or two assets make up the whole project. The question for the new floating offshore wind industry is how to connect so many mooring lines in short order to stay ahead of the production schedule.

The challenge is made even more difficult because wind farms are purposefully located in waters that have high wind resource potential. That creates metocean conditions that are difficult for offshore operations with high winds and waves. A typical sea state for an offshore wind farm may be a 2 m average wave height (Hs) and 15 m/s wind speed. These conditions are much harder to accommodate compared to typical operating conditions for offshore oil and gas mooring.

If offshore operations are stopped due to bad weather or because the mooring strategy is difficult and prone to problems, the entire project is jeopardised. These projects will be relying on the offshore team to install platforms at sea quickly to keep the production line in the port running smoothly.

If there is a hold up offshore, there is only so much wet storage for the floating foundations to be stored at the port. Along with wet storage, components in the ports, both construction and tower integration, need to be considered. If all the storage space is allowed to be consumed, the project will come to a screeching halt and project costs will accumulate at an exponential scale.

For these reasons, as well as reducing Levelised Cost of Energy (LCoE), projects are looking for ways to reduce risk, time, effort, and cost for mooring hook up and tensioning. Many projects are in need of a simple plug-in connector to connect mooring lines to the floating foundations.

One primary challenge facing the industry is how to connect these mooring lines quickly, safely, and efficiently at low cost and low risk.

Collaboration and ingenuity save the day

Based on proven technology and decades of experience in offshore mooring, Bardex has developed a new type of mooring connector that is lower cost and a simple, reliable way to ensure no problems during installation offshore in deep or shallow waters.

The new connector was originally conceived to solve a different problem that one of our repeat clients came to us with. They needed a ship-to-ship mooring connector to join a Floating Liquefied Natural Gas facility (FLNG) to a Floating Storage Unit (FSU). The two vessels were to be permanently tied together and spread moored in shallow water of 50 m. The design included 17 external mooring lines leading out to anchors on the sea floor, four on each corner, and one corner has five lines, and 20 Ship-to-Ship



Connectors (STSCs) which permanently tie the two vessels together. There were no existing mooring connectors on the market that could do this quickly and efficiently.

Bardex sat down with the client to define the design parameters that needed to be met. Each problem was solved together by a team of Bardex engineers working with the client's installation team, naval architects, and structural engineers.

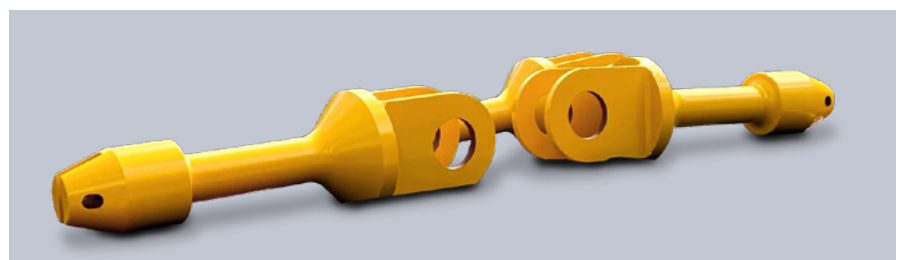
We often face challenges like this and thrive on collaborative problem-solving that brings new products to the market. In this case, the solution was a combination of a new type of quick connector coupled with a conventional uni-joint connector to make up each STSC.

We provided the uni-joint mooring connectors, BarLinks, and the new pull-through quick connector we named the BarMoor™ Quick Connector for the project. The primary challenges were the very fast delivery needed and the close proximity between the STSCs. This meant that we had to design all of the components to not clash with each other as the ship-to-ship lines were being installed and tensioned.

From challenge to change in offshore wind

These design challenges led to a very simple, lightweight mooring connector that can be used to install mooring lines quickly and release quickly in case disconnection is needed in the future. These points are very important to the Floating Offshore Wind Turbine (FOWT) market because they meet the primary needs of the new industry.

These include industrialised scale of production for mooring connectors, with fast delivery including approval by classification societies such as Bureau Veritas (BV). Cost was kept low too, with a simple, lightweight design compared to other connectors that have high precision machined components and many moving parts.





It features a simple and fast way to hook up mooring lines and also disconnect to tow the FOWT back to port in case of major turbine maintenance; pull in to latch the connector in place, pull in again to open latches for disconnect.

The arrangement of the BarMoor™ Quick Connector and design of the foundation structure can be modified to suit any hull configuration. The size of the components may also be scaled to accommodate larger loads, various water depths, or extended system design life.

The component parts are simple, can be produced in mass quantity, and do not have highly precision machined parts making them more reliable and less prone to fabrication defects or assembly errors.

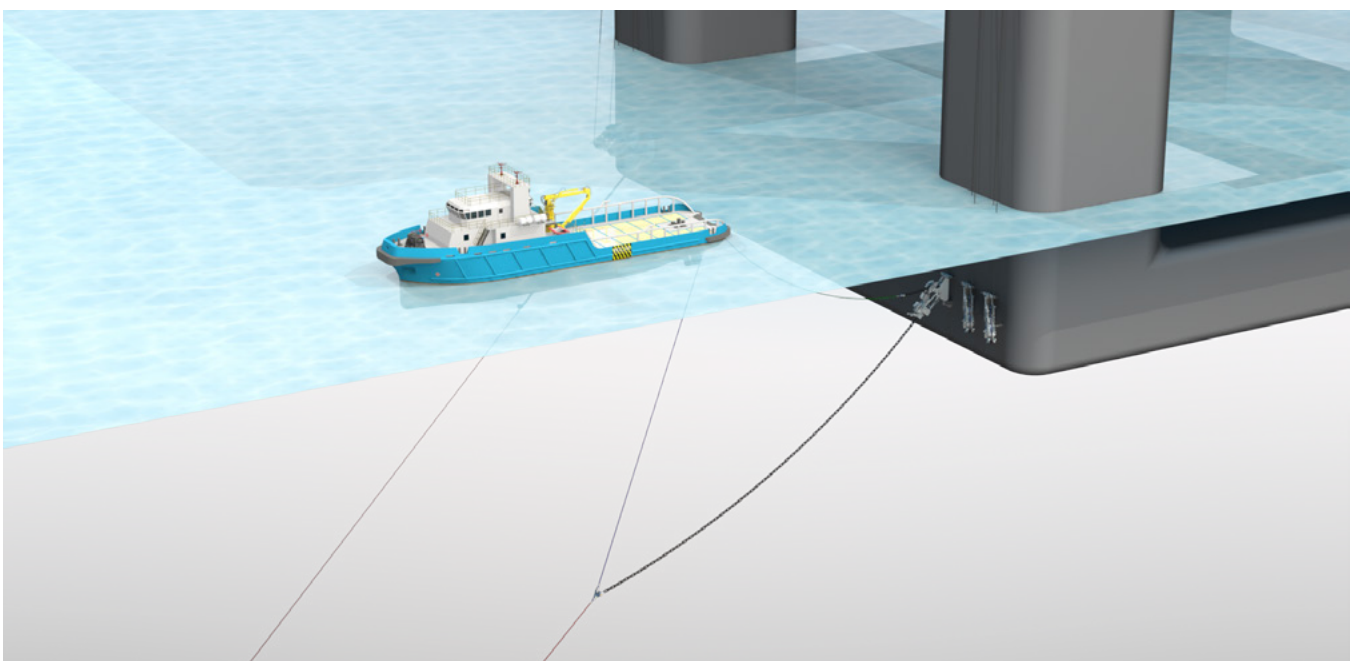
Finally, the BarMoor™ Quick Connectors can be used to reduce offshore risks and shorten the time necessary to install mooring lines.

Leaning on Bardex's experience in subsea mooring installations, the BarMoor™ Quick Connectors have been designed to provide engineering proficiency and improved operational interfaces to extend the life of the system and the mooring lines.

The system was also classed by BV. Bardex is very familiar with all the marine classification societies. We were able to bring that experience to the table and quickly get approval.

Under the hood: four simple components driving the industry forward

The BarMoor™ Quick Connector consists of the following main components: main body swiveling on a vertical axis; receptacle arm swiveling on a horizontal axis; bullet



Typical Off Vessel Tensioning requiring no people on board

connector stabs into receptacle to make the mooring connection; and a diverter wheel used to redirect pulling rigging to tensioning device above or on anchor handling vessel.

Versatility to meet the needs of any project

The FLNG-FSU project decided to tension the ship-to-ship tendons by using the small moveable chain jacks originally provided for future replacement of the tendons. However, other means could have been devised, e.g. winches or crane with diverter sheaves. Off vessel tensioning (OVT) could be used in applications where the connectors are used to hook up mooring lines to anchors. This method doesn't require any tensioning equipment on board. The tensioning source comes from the Anchor Handling Vessel (AHV), meaning we can install the mooring lines without the need for people on board the floating foundation.

Moving people on and off floating wind foundations at sea during mooring operations is dangerous, time consuming, and requires special heave compensating equipment. All this adds money, time, and risk to the project. Being able to hook up and tension the mooring lines without having any people on board provides opportunities to improve schedule, mitigate risk, and reduce cost.

This project is a prime example of Bardex's capabilities as an international engineering and manufacturing company providing in-house design and fabrication services on an incredibly expedited schedule. We developed the tailored concept in partnership with our clients before executing the design, fabrication, and installation of 20 BarMoor™ Quick Connector assemblies within a one-year timeline. This scale of engineering and fabrication effort could not have been met without the experience we carry in offshore mooring and our fabrication proficiency.

The latching mechanism can be manipulated by personnel if accessible, as in the case of the ship-to-ship connectors, or automatically spring latch closed similar to a traditional fairlead stopper ratcheting mechanism.

In the case of the ratcheting latch mechanism, an automatic locking mechanism can be added to lock the latches open for paying out mooring line should quick disconnection be required. In this case, the larger portion of the bullet is pulled through the latches to open them beyond their normal operating range until an automatic locking mechanism holds them in the wide-open position. The line can then be quickly paid out.

Beyond innovation: envisioning the future of offshore mooring

Mooring decisions should not be left until after other decisions are made. They



BarMoor™ Quick Connectors with Moveable Chain Jack Installation

should be a critical part of the development process early in the project since the knock-on effects of a poor mooring strategy can affect cost, schedule, and financial success of the project.

The hook up and tensioning methodology selected have a direct effect on the vessel spread required, project risk, and cost to support mooring operations. The BarMoor™ Quick Connector is one tool in the tool kit that can have a significant positive impact on offshore operations and by extension, on the entirety of the project.

Customisation for each project is a normal part of the design process for Bardex,

with the goal of standardisation for the large production runs that are required for commercial scale wind farms. Mooring connectors can become the bright, shiny, albeit important, focus of a mooring project, but they are not the only piece of the puzzle leading to a successful hookup and tensioning experience.

A well thought out plan, an experienced crew, teamwork, and transparent communication with stakeholders are all key components. The future of offshore mooring is auspicious: all those components come standard with the BarMoor™ Quick Connector.

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