Key considerations in FOW concept selection

1. Introduction

As production of offshore wind energy migrates from fixed to floating foundation structures, the energy industry faces a new series of challenges and risks, as well as opportunities. Well over 50 concepts for Floating Offshore Wind (FOW) foundations have been proposed, but very few of these have progressed beyond analytical studies to full-scale prototyping and operation offshore.

This newsletter briefly reviews the key considerations when selecting a FOW foundation structure for a specific project, including technical maturity, constructability, offshore installation, and inspection and maintenance. Selection of the most appropriate concept is a major factor in reducing project risk, developing a robust project execution plan, securing project financing, and achieving a competitive LCOE.

The considerations discussed below will be further developed in future newsletters.

2. Floating Foundation Concepts

Concepts for floating foundations can be grouped into 4 categories based on the way they achieve stability.

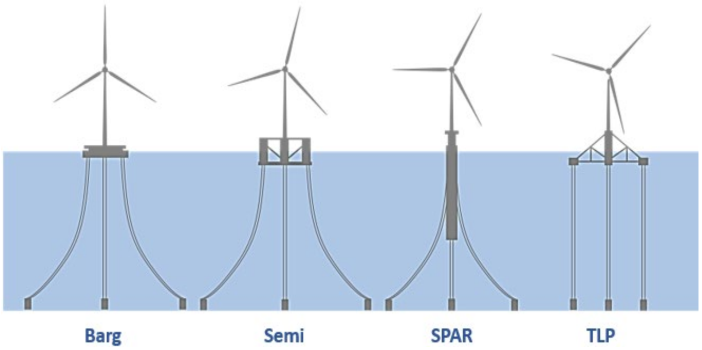

Figure 1: Foundation concepts

Barges: A barge has large plan dimensions (length and beam) compared to its draft. The distributed buoyancy, in combination with ballast, provides stability in the same manner as for a boat. Bilge keels, heave plates or other techniques may be required to achieve acceptable turbine motions.

Semi-submersibles (Semis): A semi-submersible comprises several large columns connected by braces. Semis are free-surface column stabilised structures, and their stability is dependent upon the volume of the columns and the distance between them. Buoyancy is provided by the columns and additional buoyancy may be provided by pontoons. Bilge keels, heave plates, or active ballast may be required to achieve acceptable turbine motions.

Tension Leg Platforms (TLPs): TLPs commonly have a large centre column, with a number of submerged buoyant 'arms' or buoyancy tanks connected by bracing. The stability of a TLP is provided by the high tension in its mooring tendons, which is generated by excessive hull buoyancy.

SPARs: A SPAR is traditionally a cylinder with a low waterplane area. Stability is provided by solid or water ballast which keeps the centre of gravity below the centre of buoyancy.

Most concepts are based on steel fabrication, although a number use concrete, with a small number proposed in both materials. The majority are also based on spread moorings, but a small number incorporate Single Point Moorings (SPMs), allowing the unit to rotate around the mooring under the influence of waves, wind and current.

3. Technical Maturity

The relative risks in selecting a FOW concept are heavily impacted by its technical maturity, i.e. how proven the concept is. Technology assessment based on Technology Readiness Levels (TRL) allows the technical maturity of a system to be determined and identifies the remaining steps needed to reach full operational maturity.

The TRL scale was originally developed by NASA in the 1970s, and OWRL uses a modified version specifically tailored to FOW. Our TRL scale spans from TRL 1 (a new idea) to TRL 9 (a commercial farm (at least 200MW) successfully completed 3 years operation). To date, only 5 FOW concepts have reached TRL 7, (a pre-commercial unit (Demo/pilot of at least 1MW) successfully completed 3 years operation). No concepts have yet reached TRL 8 or 9.

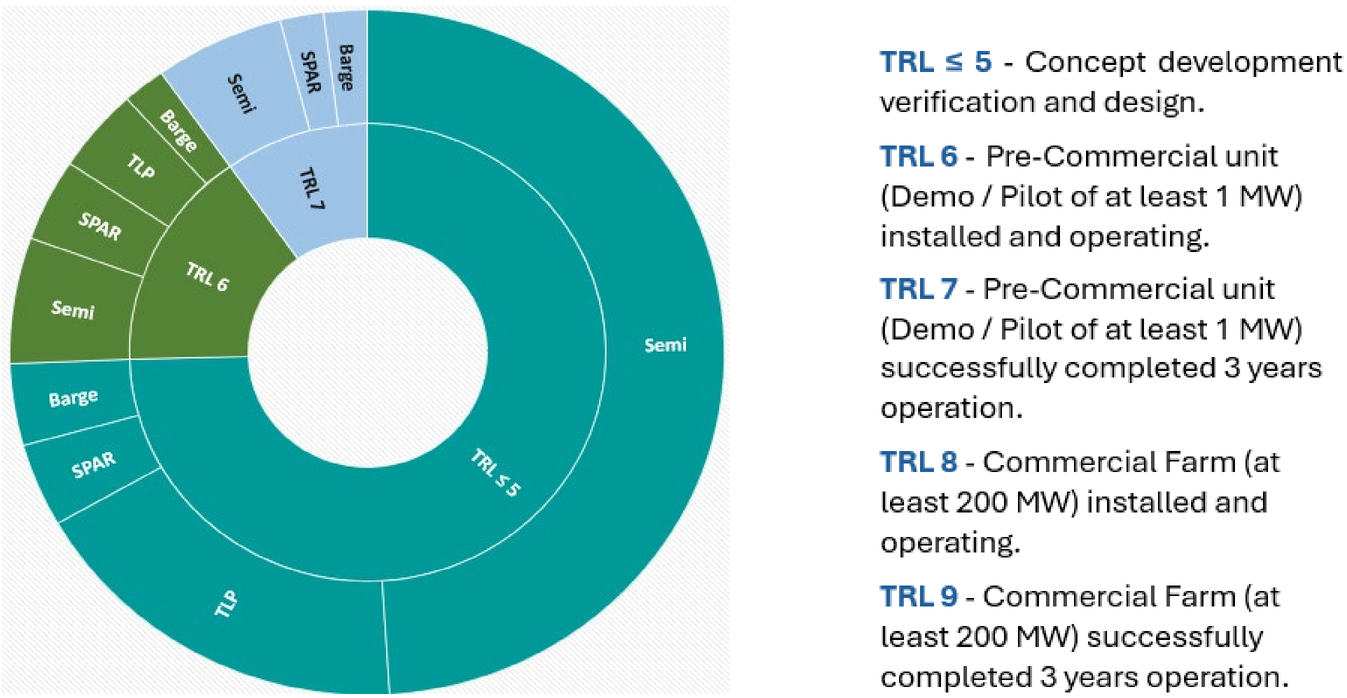

Figure 2: Concepts achieving each TRL.

4. Constructability

Commercial FOW farms will need a large number of units, leading to series building of the foundation structures. This differs from the customised approach in fabricating the floating systems traditionally used in the energy industry and will require new manufacturing strategies to be developed and incorporated.

For the mass production of many of the concepts, the structures will be built as a series of modules distributed across several fabrication yards, which will then be assembled and launched at a facility close to the site of the wind farm.

The division into modules and the transportation and assembly methodology will vary for each concept. Rapid assembly, including turbine integration, is a key consideration to minimise the storage space, size of fabrication facilities and quayside length at the assembly site.

These assembly facilities may not have been developed specifically to assemble FOW units and may lack suitable cranage and adequate water depth at quayside, requiring capital investment to remedy this.

Additionally, in the vicinity of a wind farm, high wind speeds may occur, requiring a means of providing sufficient hull stability at the quayside to avoid grounding of the hull as it pitches under wind loads on the turbine.

Alternative strategies could include the transport to site of units fully fabricated or assembled at a remote fabrication facility. For concrete structures, development of production trains in the vicinity of the wind farm could allow complete units to be constructed ready for tow to the offshore site.

Hence, the choice of concept should be closely linked to the fabrication and assembly strategy and the availability of suitable assembly yards.

5. Offshore Installation

Offshore installation comprises both the tow to site and the hook-up of the mooring system and power export cable.

The choice to employ a wet tow or dry tow to the offshore site will depend primarily on the distance involved. When the distance is short, a wet-tow will be the lower-cost option – all demonstrators and pilot farms installed to date have employed a wet-tow. Most concepts claim they can be towed to site, with the turbine integrated, by standard tugs. However, for the SPAR concepts this usually first requires turbine integration in a sheltered deepwater location before the tow to site.

An additional consideration for a wet tow is that the unit may not be at its final in-service draft and may consequently have reduced stability. This will reduce the allowable metocean conditions during tow, which in turn may reduce the available weather windows for both the tow and the hook-up operation.

Costs for the hook-up phase of installation are a significant element of the CAPEX for FOW, with estimates of approximately 10% of farm development costs, depending upon the floater design, the water depth, and the geographical region.

Several factors affect the installation costs and safety during tow and hook-up.

- To minimize installation costs, units should be suitable for tow and installation with common means rather than specialized installation vessels.
- Hook-up time can be minimised by pre-installation and abandonment of mooring legs and the power export cable.
- Mooring leg connection should preferably be made on a portion of the mooring leg, using external means, to achieve a storm-safe condition without the need for access onboard.
- Pre-connection of mooring legs and export cable to a buoy for plug-and-play connection of a Single Point Mooring (SPM) to the floating unit can reduce hook-up (and disconnection) time.

6. In-service Inspection and Maintenance

Versions of many of the hull forms used for FOW have a long history in the oil and gas industry. The majority of these have followed the classification society 5-year marine survey cycle for hulls and mooring systems.

However, there are key differences in the fabrication and operation of these hull forms for FOW applications:

- Units for floating offshore wind will be a series of nominally identical hulls, though there will be some difference in mooring legs if there is a variation in water depth across large wind farms.
- Series production has the potential to improve fabrication standards compared to the single bespoke units generally employed in the oil and gas industry.
- The units will normally be unmanned, with no crew on-board for routine inspection and maintenance. Additionally, wind farms may occupy several hundreds of square kilometres, creating logistic challenges for inspection. Consequently, designs that reduce the need for inspection and maintenance, for example by avoidance of active systems or having a high tolerance to marine growth, should have an advantage in extending inspection intervals.

Alternatives to the marine survey cycle, combining remote monitoring with risk-based inspections, are likely to be a more cost-effective option, but the industry must demonstrate that this can provide the required level of reliability.

When integrity issues are identified, but repairs cannot be carried out offshore, the units may need to be disconnected from their mooring and returned to a quayside. The simplicity of disconnection and the limiting weather conditions vary between concepts, and this should be a consideration during concept selection.

7. In-Service Performance

Energy production and turbine reliability are both influenced by the motions of the turbine, so minimising motions at the turbine nacelle should be a key objective of the foundation design.

Different foundation concepts each have different motion characteristics, not only in their response to wave and current loading, but also due to a different response to the complex interaction between the floater motion and the turbine thrust. Additionally, the motions of a given concept will vary under different environmental conditions, with some concepts having an advantage for certain conditions. Consequently, the correlation between floater motion and the Capacity Factor, under the specific site conditions, should be considered in project LCOE calculations before the concept selection is finalised.

8. Summary of Considerations

There are many factors to be considered when selecting the optimum concept for a FOW project, accounting for site-specific offshore conditions and the local infrastructure available for fabrication and assembly. This newsletter has briefly described some of the key considerations, and future newsletters will provide a more detailed review of concept in-service performance, fabrication and assembly requirements, reliability considerations, concept scalability, installation methods, mooring system design, supply chain impacts, regulatory regime, decommissioning, and the influence of concept design on OPEX.

Based on the above considerations, and using tools and techniques developed in-house, OWRL provides independent project assessment services to help clients identify the optimum solution for each project.

9. Glossary

CAPEX	Capital Expenditure
FOW	Floating Offshore Wind
LCOE	Levelized Cost of Electricity
OPEX	Operational Expenditure
OWRL	OpenWater Renewables Ltd
SPM	Single Point Mooring
TLP	Tension Leg Platform
TRL	Technology Readiness Level