Floating Offshore Wind

Fabrication and Installation of OO-Star Wind Floater

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Objective and scope

The key objectives of the poster, for the **OO-Star Wind Floater**, is to describe:

- A viable and understandable execution model for floating offshore wind
- A way to reduce cost of energy
- A method with acceptable technical and commercial risk
- A model with feasible extention to future larger wind turbines
- A supply chain for floating offshore wind as an understandable long term total business model

The objective of this presentation is to describe a cost effective floating wind turbine, the **OO-Star Wind Floater**, and a viable and understandable execution model for floating offshore wind at a competitive cost of energy, and with an acceptable technical and commercial risk. It is particularly important to show an execution model which is feasible for future large wind turbines. This will help developers and large contractors to understand how a supply chain for floating offshore wind can be developed as a part of an understandable long term total business model.

Introduction

The execution model is based on a robust and cost effective floating solution, the **10 MW OO-Star Wind Floater** semi-submersible designed by **Dr.techn.Olav Olsen AS** during the first Phase of the LIFES50+ project (grant agreement No 640741) funded by the European Commission (EC). The **OO-Star Wind Floater** is very robust with regard to the following parameters:

- Wind turbine size and weight
- Environmental conditions
- Water depths available during assembly, tow, installation and operation
- Design life and durability
- Accidental scenarios
- Local industry, availability

Fabrication and Installation features:

- Fabrication onshore
- Assembly at quayside while resting on seabed
- Lifting of RNA by onshore crane
- No relative motion between crane and floater during lift and mounting
- No need for complicated ballasting operations during lifting
- Completed and tested inshore
- Towed fully assembled to the offshore site
- Connected to pre-installed mooring and power cable

Ambition

Floating wind has some significant advantages over bottom fixed. One is to extend the application of offshore wind turbines to water depths beyond bottom fixed. 70-80 percent of the worlds wind resources are in areas suitable for floating wind turbines. Enabling the use of floating sub-structures will allow for new markets to emerge in locations that does not have shallow water depths.

Competing with bottom fixed wind turbines can only be done through cost reduction, and previous studies point to manufacturing cost as the most influencing design dependent parameter on the LCOE [1].

Floating offshore wind can be standardized beyond bottom fixed offshore wind due to less dependency on water depths and soil conditions. This will in the long term help to reduce fabrication cost for floating wind and make it competitive with respect to bottom fixed solutions. Considering the large energy potential related to floating offshore wind, and the fact that many countries and areas do not have suitable shallow water sites for bottom fixed developments, the future demand for floating offshore wind is expected to be high.

Another advantage for floating solutions, like the **OO-Star Wind Floater**, is the ability to do all assembly and testing at quayside before towing to offshore site. Elimination of offshore heavy lift operations is a great benefit and can not be achieved for bottom fixed wind turbines without large additional investments to solve stability issues during temporary phases. These arguments will only be stronger in the future with larger wind turbines and no existing installation tools capable of offshore installations. Most likely there will be a split in the market between bottom fixed and floating wind with larger turbines used for floating wind than for bottom fixed. We already have a similar split between land based wind and offshore wind, where land based wind turbines are smaller than offshore turbines due to transport and handling limitations.

Conclusion

The division of construction into stages and parallel production lines allows for an industrialized fabrication process, easy to control and standardize. In addition, the construction of the different units are overlapping - for a better utilization of the resources and improved execution time. This is an efficient system for fabrication of a large number of units, where cost of establishing the construction yard is compensated with the total saving on cost and time.

Floating wind will outperform bottom fixed solutions for larger turbines (15-20 MW). EWEA acknowledge that a 20 MW turbine is possible with existing materials [2].

OO-Star Wind Floater - benefits:

- Favourable motion characteristics - robust and durable substructure - minimum maintenance cost - long design life/reuse
- Modular construction
- Shallow minimum draft, full assembly and testing at quayside
- Limited use of heavy lift equipment, no offshore lifts
- Step change in tower and RNA handling

Process benefits:

- Division of the pontoon in parts reduces the number of skidding lines needed to maintain the production schedule, by localizing part of the construction outside the assembly line
- Construction in stages allow for an industrialized fabrication process, easy to control and standardize
- Skidding system avoids the use of large, specialized and expensive cranes
- Construction of the units is overlapped, for a better utilization of the resources and improved execution time

Acknowledgements

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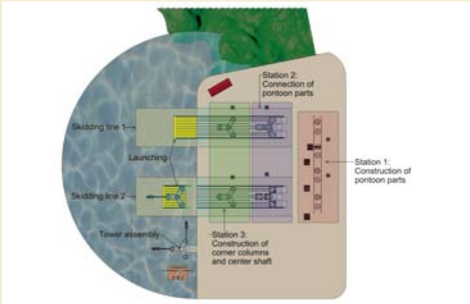
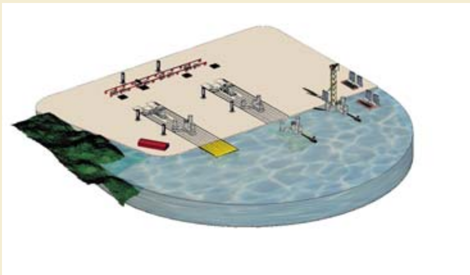
General overview

Below is a typical layout for a construction site, aiming to deliver 25 complete wind turbines each year. Based on parallel operations, and dedicated construction stations.

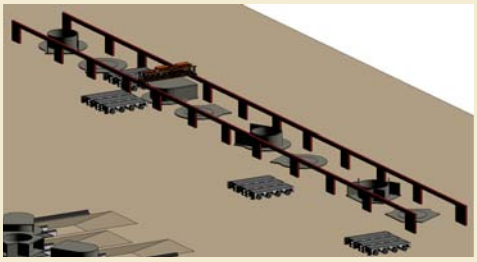


- **Station 1:** Pre-fabrication of pontoon parts (one month)
- **Station 2:** Connection and completion of pontoon parts, including post-tensioning (one month)
- **Station 3:** Slip forming of corner column and center shaft, and installation of structural steel (TP) and mechanical outfitting (one month)
- **Station 4:** Controlled launch to sea from slipway cradle or shiplift
- **Finalization:** Assembly of tower and RNA, completion and testing (two weeks)

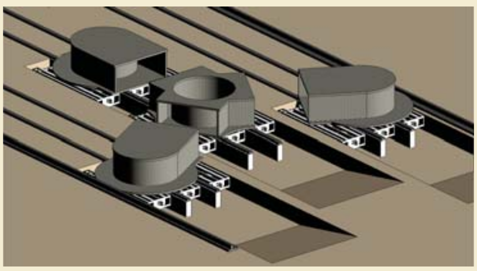


Pontoon Fabrication and Assembly

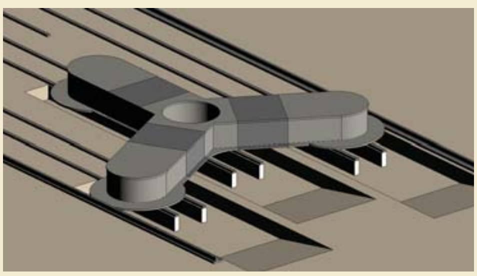
Station 1: the pontoon will be pre-fabricated, as four (4) independent pieces. Construction will be in parallel with other operations. The parts will be transported to skidding lines on multiwheelers. Skidding lines are accessible for multiwheelers from below ground access. Typical construction time is one month for four pieces.



Station 2: The pontoon parts are accurately placed with a separation between the parts. The pre-fabricated pontoon parts will have protruding rebars, and splicing rebars will fill the gap between the parts. The concrete joint surface will be cleaned and prepared for proper bonding to the fresh concrete which will be cast in-situ to fill the gaps.



Prior to cast prestressing ducts in the existing pieces will also be properly connected and prepared for the post-tensioning process. The cables will be tensioned and grouted when the concrete in the pontoon joints has reached sufficient compressive strength, typically 1-2 weeks after casting. The tendons in the base slab will be tensioned when pontoon walls are cast. The top slab tendons will be tensioned after slip forming of the first part of the central shaft and corner columns.

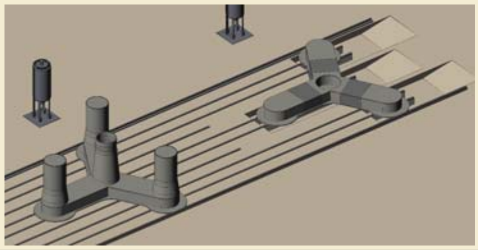


Estimated time for completing the star pontoon at Station 2, including enough curing time before skidding, is typically 1 month.

Station 3: Corner columns and central shaft

Key features of Station 3:

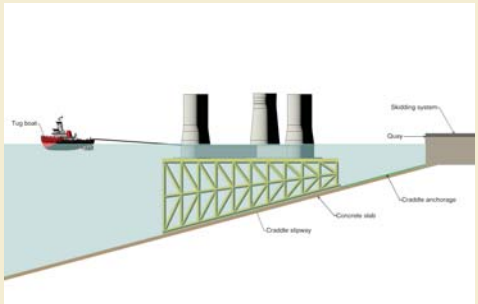
- Last fabrication station
- Slip forming of corner columns and central shaft
- Adjustable formwork adapting to the changing geometry
- Parallel fabrication for each corner cell and center shaft
- Post-tensioning possible without the use of dead-end anchors



Launching

The following procedure is planned for launching:

- Assembly lines with continuity onto slipway cradle (or shiplift)
- Transfer to the cradle by skidding system used for Station 2 and Station 3
- Cradle has a trapezoidal shape with top surface always horizontal, supporting the concrete substructure
- Decent performed through a set of steel cables pulled by jacks
- The cradle is lowered along the inclined plane until the concrete substructure disconnect from the cradle and a tug boat intervenes



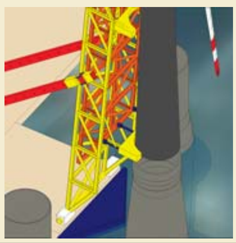
Tower and RNA operations

Two possible ways of installing tower and RNA is proposed:

1. Assembly of tower and RNA is crucial for a robust and cost effective execution model. Our concept eliminates offshore heavy lifts, and use of floating crane vessels in general. An efficient and purpose built pier will facilitate the assembly operations. The seabed outside the pier will be leveled and the substructure will be grounded in exact position relative to the pier. Land based crane solutions may be used for the assembly operations.
2. For future large floating wind turbines the tower and RNA may be assembled onto a long steel cradle, resting on multiwheelers. The cradle, with completely assembled turbine, can be moved and skidded into a support frame with a pivot point close to the quayside.

The substructure is towed into position, and grounded (by ballasting) onto supports to eliminate the typical challenge of relative motion between substructure and lifting arrangement.

A set of climbing beams makes it possible to tilt the support frame with the cradle, with tower and nacelle secured and fixed, to a vertical position. When tower and RNA is positioned over the substructure, the cradle can slide inside the support frame, and the tower and RNA can be landed onto the central shaft. The complete floating WTG is then ready for testing and subsequent tow to site and installation into pre-installed mooring system.



There is no need for specialized vessels with long reach cranes. This makes the method very robust wrt. future large WTGs.

The "telescopic ladder" system described is based on a patent owned by **Dr.techn.Olav Olsen AS**. The method will require that turbine manufacturers modify their design and allow for horizontal assembly. Until this is in place the land-crane method will be used.

References

[1] LIFES50+ Deliverable D7.6
[2] UpWind - Design limits and solutions for very large wind turbines [EWEA]