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Recommendations for risk and cost reductions of FOWT farms

[Version 1.0]

STEP4WIND

Training network in floating wind energy

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Document History

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1	First draft	Matteo Baudino Bessone Academic supervision: TU Delft Industrial supervision: OREC		March 26th 2024
2	Review	Oana Trifan (TU Delft)		28.03.204

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1. Overview

This report presents an assessment of the relevance of the life-cycle trade-offs involved in the selection of spar buoy or semi-submersible support structure for a floating wind farm. This document only contains the executive summary of the research carried out, while the extended methodology and results are included in the accompanying research paper **‘Relevance of life-cycle trade-offs in substructure concepts selection for floating wind farms’’.** As this paper has not yet been published, no reference to the repository can be done yet. This will be done in the Technical Report at the end of the project.

2. Abstract

Various floating substructures concepts have been developed to support floating wind turbines in deep waters. These concepts have strengths and weaknesses in different phases of the life-cycle of the wind farm. Thus, the selection of one or another concept affects a significant portion of the Levelised Cost of Energy (LCoE) of a floating wind power plant. In this work, we assessed the relevance of the trade-offs between different life-cycle phases of a floating wind farm embedded in the selection of spar buoys or semi-submersibles. Multidisciplinary Design Analysis and Optimisation (MDAO) has been adopted to optimally size the substructures, while accounting for material, manufacturing, installation and major wind-turbine-components replacement costs. For each substructure concept, onsite and tow-in maintenance strategies have been evaluated. We accounted for the variation of eight external design drivers affecting the relevance of the trade-offs. The results showed that the trade-offs involved in selecting the floating substructure concept are significant and should be accounted for in the planning phase of floating wind farms. Both spar buoys and semi-submersibles can be the most cost-effective concept depending on the wind farm project boundary conditions.

3. Objectives

Floating wind allows deploying wind farms in waters deeper than 60m, opening up new markets where conventional bottom-fixed wind farms are currently too expensive to be installed. Access to the deeper sites is enabled by adopting floating substructures, usually subdivided into spar buoy, semi-submersible, barge, or tension-leg platforms (TLP). Different substructure concepts have relative benefits and weaknesses related to the various lifecycle phases of a floating wind farm [1] [2] [3] [4]. External design drivers can further enhance or dampen the strengths and weaknesses related to different floater concepts. As the selection of the floating substructure can affect costs related to different phases of the life-cycle of a wind farm, it is arguably important to assess the relevance of the life-cycle trade-offs related to the floating substructure concept selection.

This work sheds light on the importance of the trade-offs involved in selecting spar buoy and semi-submersible substructures, showing that both the substructure concepts can become the cost-optimal option for different combinations of design drivers. We account for production, installation and replacement costs of major wind-turbine components as key elements affected by the substructure concept selection. We consider eight design drivers that can enhance or attenuate the strengths or weaknesses related to different floating substructure concepts. These are site-specific weather conditions, distance between the wind farm site and the marshalling port, steel price, manufacturing cost, vessel and port rates, discount rate, price of electricity, and major component replacement rates. We adopt the same methodology based on design optimisation to size both substructure concepts, allowing for a fair assessment of the trade-offs. Spar buoys and semi-submersibles are selected as representative concepts, having strengths and weaknesses in different stages of the life-cycle of a wind farm. These substructure concepts are parametrised with the MDAO workflow according to the design variables reported in Figure 1 and Table 1.

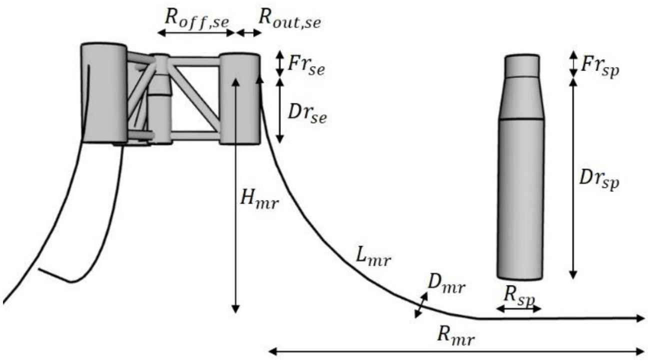

Figure 1: Design variables for the parametrised spar buoy and semi-submersible substructures supporting the wind turbine. The mooring system design variables are the same for both floating substructure concepts and are only represented for the semi-submersible for clarity. The figure is not to scale.

Table 1: Design variables of the spar buoy and semi-submersible substructures.

Design variables	Substructure	Symbol
Draft	Spar buoy	Dr_{sp}
Freeboard	Spar buoy	Fr_{sp}
Radius at the keel	Spar buoy	R_{sp}
Draft	Semi-submersible	Dr_{se}
Freeboard	Semi-submersible	Fr_{se}
Radius outer columns	Semi-submersible	$R_{out,se}$
Radial position outer columns	Semi-submersible	$R_{off,se}$
Nominal diameter moorings	Both	D_{mr}
Radial anchors position	Both	R_{mr}
Fairlead height	Both	H_{mr}
Length mooring lines	Both	L_{mr}

4. Conclusions

Overall, the results showed that the trade-offs involved in selecting floating substructures are significant and should be accounted for in the development phase of floating wind farms. This is because different floating substructures become the cost-preferred option depending on the boundary conditions of the project. Within the ranges considered in this study, wind-turbine reliability, manufacturing cost, vessel and port rates, site weather conditions, and distance from the marshalling port showed the highest potential to affect the trade-offs. Semi-submersibles combined with a tow-to-port major replacement strategy and spar buoys with an onsite major replacement approach were identified as the most cost-effective solutions, as can be noticed in Figure 2. The semisubmersibles with tow-to-port maintenance strategy resulted as the most cost-effective option for a vast number of scenarios. In these cases, primarily low operational and secondarily low installation costs due to the relatively inexpensive spread of installation and maintenance equipment determined the life-cycle cost advantage. However, spar buoys with an onsite maintenance strategy became a more economically appealing alternative for combinations of high reliability, high manufacturing cost, low vessel and port rates, benign weather conditions, and further distance from the marshalling port. In these conditions, the lower major replacement and installation costs for the semisubmersible were no longer enough to offset its higher production cost. The spar buoy combined with the tow-in maintenance strategy and the semi-submersible combined with an onsite major repair approach did not appear to be a cost-effective solution for a floating wind farm.

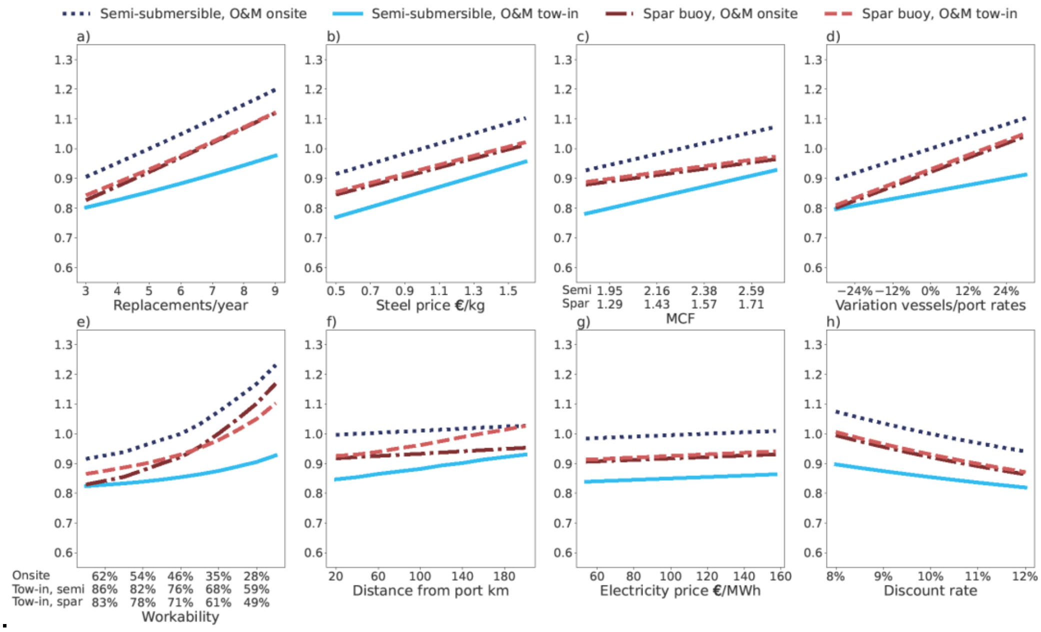

Figure 2: Nondimensional discounted cost at the variation of the design drivers. The nondimensionalisation factor is the maximum discounted cost among the four different combinations of floating substructures and maintenance strategies, when all the design drivers are at baseline. In e) the workability is defined as the ratio between the theoretical time required to carry out the major replacement campaign, and the actual time accounting for waiting on weather.

5. References

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