Critical Review of Floating Support Structures for Offshore Wind Farm Deployment

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Abstract

Current situation: - numerous deep water sites with promising wind potential → floating structures possible, bottom-fixed systems not;
- large diversity in floater concepts → fast achievement of high technology readiness levels (TRLs) inhibited.

Thus, different floating support structures are assessed with respect to their suitability for offshore wind farm deployment. Based on a survey, a multi-criteria decision analysis (MCDA) is conducted, using the technique for order preference by similarity to ideal solution (TOPSIS). With the individual scores of ten floater categories, considering the weighting of ten specified criteria, suitable concepts are identified and potential hybrid designs, combining advantages of different solutions, are suggested.

Methodology

Set of alternatives

I.	spar - standard	common spar floater type
II.	spar - advanced	improved spar (horizontal transport, short draft, vacillation fins, delta configuration)
III.	semi-sub - standard	common semi-sub floater type
IV.	semi-sub - advanced	improved semi-sub (braceless, active ballast, wave-cancelling, inclined columns)
V.	barge floater	common barge floater type
VI.	TLP - standard	common TLP floater type
VII.	TLP - advanced	improved TLP (redundant mooring lines, gravity anchors)
VIII.	hybrid floater	mixed spar, semi-sub, TLP floater types
IX.	multi-turbine floater	floater supporting more than one wind turbine
X.	mixed-energy floater	floater for wind & wave/tidal/current/ photovoltaic utilisation

Set of criteria

1.	(-)	LCOE	rate of return, power density, mooring footprint, dimensions, turbine spacing
2.	(+)	volume production	ease to manufacture, fabrication time, onshore fabrication, modular structure
3.	(+)	ease of handling	weight, assembly, transport, installation, decommissioning, equipment, dimensions
4.	(+)	durability	redundancy, corrosion resistance, fatigue resistance, aging
5.	(+)	flexibility	site, water depth, soil, environment
6.	(+)	certification	time & ease to achieve, TRL
7.	(+)	performance	deflections, displacements, nacelle acceleration, dynamic response
8.	(-)	maintenance	frequency, redundancy, costs, downtime
9.	(+)	time-efficiency	assembly, transport, installation, maintenance, decommissioning
10.	(-)	mooring requirements	number & length of lines, need of flexible cables (motions), anchor system costs

Results

Survey: - scores (1: least applicable - 5: most applicable) assigned for each criterion to each alternative;
- weights (1: not important - 5: important) represent importance of each criterion with respect to offshore wind farm deployment.

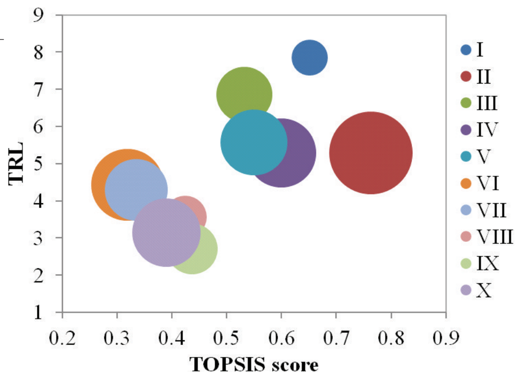
Analysis using TOPSIS: - scores yield a decision matrix, which is - after normalisation - multiplied with the weight vector;
- final ranking of alternatives based on their closeness/distance to the positive/negative ideal solution (table 1);
- comparison of TRL wrt to potential to scale up to mass production for multi-MW wind farm deployment (figure 1).

Table 1: Weights, scores, ranks

	Weight		Score	Rank
1.	**4.26**	I.	0.651	2
2.	3.43	**II.**	**0.763**	**1**
3.	2.91	III.	0.532	5
4.	3.24	IV.	0.600	3
5.	2.33	V.	0.549	4
6.	3.40	VI.	0.319	10
7.	3.38	VII.	0.335	9
8.	3.59	VIII.	0.425	7
9.	3.02	IX.	0.436	6
10.	3.10	X.	0.390	8

Figure 1: TRLs wrt potential to scale up to mass production for multi-MW wind farm deployment

TRL	Description (based on Horizon 2020 https://ec.europa.eu/)
(0	idea for an unproven concept)
1	basic principles observed
2	technology concept formulated
3	experimental proof of concept
4	validation in lab
5	validation in relevant environment
6	demonstration in relevant environment
7	demonstration in operational environment
8	system complete and qualified
9	proven in operational environment



* the bubble size represents the standard deviation of the TRL

Conclusions

- Assessment of ten floating wind turbine support structures wrt ten criteria focusing on wind farm deployment;
- MCDA based on survey results and TOPSIS method;
- Costs are still most important and advanced spars have the highest potential to develop for multi-MW wind farm deployment.

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