Suitability of Monopile and Jacket foundations for Contemporary Offshore Wind Turbines

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Abstract

The increasing popularity of offshore wind turbines (OWTs) as a source of renewable energy has attracted a lot of interests from governments, researchers and industry. The construction of these facilities offshore are even more challenging in terms of designing/choosing suitable foundations to support them. Different foundation types have been specified for different conditions, including various water depth ranges and turbine ratings. This paper presents a global trend of existing OWTs supported on monopile and jacket foundations in relation to these two factors. This trend is properly defined in order to serve as a guide in selecting the appropriate foundation type for a particular OWT.

Introduction

The use of wind for electrical energy production requires the construction of wind turbines, which harness this resource and converts it into electrical energy. While it seems easier to place these facilities onshore, certain circumstances make this less attractive, e.g. limited location of suitable plains onshore (Mieloszyk and Ostachowicz, 2017), the fact that wind speeds on oceans are steadier and almost double their amounts on land, (Archer, 2005). Therefore, offshore wind turbines (OWTs) become more popular.

The cost of OWT foundation is normally between 25-34% of the total cost of the wind farm (Bhattacharya, 2017). The choice of support foundation depends on such factors as site conditions (wind, wave, current, sea bed condition, ground profile, water depth etc.), installation, operation and maintenance, decommissioning laws, economics and size/capacity of turbine (Bhattacharya *et al.*, 2012). For the same ground conditions across the sea bed, water depth and turbine size play the most important part in selecting foundation type for an offshore structure (Shi *et al.*, 2014), possible reasons are: the deeper the foundation, the higher the wave loading (Bhattacharya *et al.*, 2012); also, the cost of foundation increases with increase in water depth (Oh *et al.*, 2018), therefore, the decision on choice of foundation depends on the one which can safely support the super structure under prevailing loads and at the minimum cost, hence determining the viability of the wind farm. Water depths can be categorised into three: shallow (0-30m), transitional (30-60m) and deep (60-200m) (Bhattacharya, 2017). In terms of turbine sizes (usually ranging between 0.1 - 9 MW), they also determine the choice of OWT foundation (Eea, 2009), the reason is: with an increase in the size of rotor-nacelle-assembly (RNA) in order to capture more wind, an equally bigger tower size is required to support the RNA, and the reverse is true; this in effect, will also require a foundation capable of safely transmitting the loads to the ground, and on this basis, a choice is made.

Methodology

Based on the above review, the water depths and turbine sizes have been considered vis-à-vis the types of foundations that have been adopted to support the OWTs at their locations. This study undertakes a global survey of existing wind farms housing monopile and jacket supported OWTs constructed between the years 2000 and 2018 to identify the prevailing factors to choose the foundation types for OWTs. These data are obtained from http://www.4coffshore.com/windfarms/. Since the water depths of different OWTs are in a range instead of a single value, the average water depth has been used. Using these data, a graphical plot of turbine sizes against water

depths has been made, with the foundation type indicated at their intersection points.

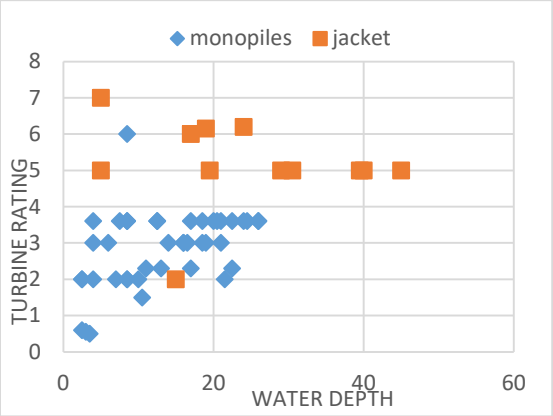

Figure 1. Graphical plot of turbine ratings (in MW) against water depths (in m) for OWTs supported on monopole and jacket foundations between years 2000 and 2018.

Results and Discussion

From Fig. 1, the majority of monopile foundations currently in use, support OWTs at a water depth between 4-26m which agrees with the range specified by (Bhattacharya *et al.*, 2012; Oh *et al.*, 2018); these have a power rating range of 2-3.6 MW. It is also seen from the plot that the jacket foundations supporting OWTs currently in use, are utilised in majority of cases at water depths of 17-45m. This lower limit falls short of (Oh *et al.*, 2018)'s limit by 3m with the upper limit falling well within the limit specified by (Bhattacharya *et al.*, 2012; Oh *et al.*, 2018).; Existing OWTs supported on jacket foundations have a power rating range of 5-7 MW. From the foregoing, it is clear that turbine rating has more influence on the choice of a foundation to support an OWT than the water depth at its location. This is obvious from the figure, as OWTs having power ratings of 5 MW and above are all supported on jacket foundations except one (which is an outlier) while turbine ratings below 5 MW are supported on monopiles except one (another outlier). On the other hand, OWTs located at average water depths exceeding 26m are all supported on jacket foundations while those below are supported on monopiles in majority of the cases. This loss of generality in the case of water depth as a factor in the selection of foundation type would place the turbine rating above it in this regard.

Conclusions and Future Work

A graph of existing OWTs supported on monopile and jacket foundations with relation to turbine ratings and average water depths has been plotted. This has led to the emergence of a trend/ranges for basing decisions regarding choices between the two foundation types. First, the choice of foundation types for the OWTs with 5 MW or higher ratings was overwhelmingly jacket, while for those with 4 MW or lower ratings, monopiles were selected. Second, all the OWTs with the monopiles are within the shallow water zone, while those with jackets cover both shallow and transitional water zones.

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References

Archer, C. L. (2005) 'Evaluation of global wind power', *Journal of Geophysical Research*, 110(D12), p. D12110..

Bhattacharya, S. *et al.* (2012) 'Soil–Structure Interactions for Offshore Wind Turbines', *Engineering & Technology Reference*, 1(1), pp. 1–16.

Bhattacharya, S. (2017) *Civil Engineering Aspects of a Wind Farm and Wind Turbine Structures*, *Wind Energy Engineering*. Elsevier Inc.

Damgaard, M. *et al.* (2013) 'Cross-wind modal properties of offshore wind turbines identified by full scale testing', *Journal of Wind Engineering and Industrial Aerodynamics*. Elsevier, 116, pp. 94–108.

Eea (2009) *Europe's onshore and offshore wind energy potential*, *EEA Technical report*. doi: 10.2800/11373.

Mieloszyk, M. and Ostachowicz, W. (2017) 'An application of Structural Health Monitoring system based on FBG sensors to offshore wind turbine support structure model', *Marine Structures*, 51, pp. 65–86.

Oh, K. Y. *et al.* (2018) 'A review of foundations of offshore wind energy convertors: Current status and future perspectives', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, 88(May), pp. 16–36.

Shi, W. *et al.* (2014) 'Feasibility study of offshore wind turbine substructures for southwest offshore wind farm project in Korea', *Renewable Energy*. Elsevier Ltd, 74(2015), pp. 406–413.

Wymore, M. L. *et al.* (2015) 'A survey of health monitoring systems for wind turbines', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, 52(1069283)

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