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Offshore wind installation vessels – A comparative assessment for UK offshore rounds 1 and 2

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ABSTRACT

Marine operations play a pivotal role throughout all phases of a wind farm's life cycle. In particular uncertainties associated with offshore installations can extend construction schedules and increase the capital expenditure (CAPEX) required for a given project. Installation costs typically account for approximately 30% of the overall project cost. This study considers the installation modelling for UK offshore Wind Rounds 1 and 2 using probabilistic simulation tool. The tool is used to output time-domain predictions for the completion of key installation phases. By varying key wind farm characteristics such as distance to shore and the number of turbines, an assessment of vessel performance was completed for each round by reviewing recorded durations predicted by the software. The results provide a quantification of installation vessel performance and the associated deviations present a measure of installation risk. It is identified that the Round 1 vessels experience less weather downtime but higher variability and the Round 2 vessels perform more consistently but experience larger delays. The paper provides a structured method to identify and benchmark offshore wind installation risks, to support developers and project planners.

1. Introduction

1.1. Background

Offshore wind farm (OWF) development has increased steadily throughout the UK over the last decade and is predicted to maintain this momentum until at least 2020 (Offshorewind.biz, 2016; Renewable UK, 2016). The UK has more offshore wind turbines than the whole of the rest of Europe. 1.5 GW is currently under construction with a further 5 GW of projects yet to begin development (The Crown Estate, 2015). As turbine sizes, distances from shore increase, weather becomes more severe and water depths span beyond 30 m, the logistical challenge becomes ever more prominent for prospective developers.

Marine operations play a pivotal role throughout all phases of a wind farm's life cycle, yet uncertainties associated with offshore installation can extend construction schedules and increase the capital expenditure (CAPEX) required for a given project. Installation costs can account for approximately 30% of the overall project cost and it is anticipated informed engineering decisions in this area present further cost saving potential (Krohn et al., 2005). The increasing remoteness and heightened weather conditions for the UK's future OWFs, increases the complexity of the marine operations and the importance of making the correct decisions prior to development and sourcing of the correct vessels to complete the tasks.

At the beginning of the OWF development in the UK in 2001, the vessels used for construction introduced bottlenecks and delays in construction. This was caused by a lack in availability of specialised vessels as these were predominantly used in the oil and gas sector, introducing competition for their services. In some cases the vessels were oversized or not ideally suited to the operations, which were often sourced at overinflated charter rates. As OWF development increased, the industry began to manufacture purpose built offshore wind vessels that would offer more deck space, cope with more severe weather and reduce overall installation durations (Offshore-technology, 2012).

This paper considers the installation modelling for UK offshore Wind Rounds 1 and 2. The analysis is based on time-domain predictions for the completion of key installation operations under user specified exceedance probabilities, commonly used by investors to determine a project's viability and used by developers to assess their risk preferences. By varying key wind farm characteristics, an assessment on the performance of typical installation vessels adopted for

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each of the UK development rounds is investigated with the use of an OWF installation decision support software tool. A comparative analysis of the predicted durations between each of the two offshore wind rounds is completed. this analysis will help inform planning operatives when considering vessel selection in their next project and reveal if further innovation is needed to overcome delays when developing future OWFs.

The remainder of the paper is structured as follows: Section 2 presents a brief literature review of the most pertinent work in this field. In Section 3, we begin with a description of the wind farm installation software and an overview of the processes applied within the tool. We then describe in Section 3.3 the various sources of meteorological data used for each round and provide a justification for their selection. The key OWF characteristics to be varied throughout the simulations is included in Section 3.4. These are applied to resemble the range of OWF sizes and remoteness, typically experienced within each round. It is also intended that these highlight the characteristics that can significantly impact the progression of offshore installation operations and where further technological innovation can be explored. Section 3.5 describes the process used to identify the typical vessel spreads used in each offshore wind round and Section 3.6 describes the fundamental OWF installation operations and their associated environmental limits. Section 4 presents an overview of the results, which are supported with discussion in Section 5, covering the outcomes by round, value to planners and future work. Finally, a summary of our findings and relevant conclusions are presented in Section 6.

2. Literature review

The work on the modelling of logistical requirements and installation of OWFs has increased over the last five years in an attempt to reduce uncertainty associated with accessing and completing work at offshore locations. This type of modelling and analysis allows practitioners to review the installation of an OWF in advance, so that developers can prepare for certain outcomes in terms of cost or delay.

Many authors focus on the modelling of the construction operations and subsequent weather risk analyses. Irawan et al. (2015) look to address the scheduling issues surrounding offshore wind construction by means of an integer linear programming method to identify the optimal installation with lowest costs and shortest schedules, combining weather data and vessel availability. Their investigation in the use of metaheuristic approaches such as Variable Neighbourhood Search (VNS) and Simulated Annealing (SA) was found to offer reasonable results with low computation time. Their approach is compared against a linear programming optimiser known as CPLEX, which is found to identify the optimum solution but takes longer to reveal the answer.

Others have considered the specific modelling of the logistics surrounding the installation steps, where Barlow et al. (2015) review what vessels and operations are most susceptible to weather constraints during the installation campaign. Their study aims to assess the impact of operational and vessel improvements over recent times, indicating that a non-linear relationship exists between vessel limits and the duration of the installation. It is also concluded that load out operations appear most susceptible in adverse weather conditions.

Logistics are again the topic in the paper presented by Vis and Ursavas (2016) where their modelling approach reveals that the key activities impacting performance are the vessel loads, distance to shore and the pre-assembly strategy adopted for the main wind turbine components. They recommend that a pre-assembly strategy should be employed that presents the optimum choice between the lowest number of lifts possible and the maximum number of turbines that can fit on a vessel. This reflects that the optimum will differ in each offshore wind project but careful consideration of these two parameters should help reveal the best solution for a given project.

Scholz-Reiter et al. (2011) point out that bad weather conditions are the main cause for delays in the logistics and installation of an offshore wind farm. They apply their mixed integer linear programming (MILP) model to identify the optimal installation schedule for different weather conditions and the loading operations. Their study considers the installation of 12 turbines across three synthetically produced weather scenarios, each representing either good, medium or bad weather and the tool is used to identify optimal installation schedules for the vessels. They acknowledge the stochastic nature of weather conditions and express an interest in developing their tool and assess the impact of weather uncertainty beyond these initial three categories.

Ait-Alla et al. (2013) developed a MILP model to minimise the installation costs by considering vessel utilisation and fixed costs that span the length of the installation period. Their approach considers the weather in a deterministic manner and reviews the outcome of two installation scenarios.

Muhabie et al. (2015) consider the use of discrete event simulation by considering weather restrictions, distances, vessel capabilities and assembly scenarios. They consider the use of real historical weather data and generated data sets adopting a probabilistic approach. The results demonstrate a good level of agreement between the two approaches when considering the average mean lead-time and reference future work to optimise the fleet sizes, capacities and overall installation strategies.

This paper evaluates the installation durations and subsequent vessel performance during the construction of an OWF. A probabilistic function to simulate the weather is enclosed within the adopted tool, which is capable of producing a range of results under user specified exceedance probability quantiles. The user defined exceedance quantiles provides an assessment of installation risk at different confidence levels. This presents a key benefit over the tools reviewed in this section as it offers the adaptability to planners and investors as required. The tool can simulate the full installation of an OWF, handled in phases and considers the environmental constraints of the operations and vessels across the predicted weather outcomes.

3. Methodology

This paper employs an offshore wind installation software simulation tool to determine the installation duration of an Offshore Wind Farm (OWF) in advance. Moreover, a focus on the predicted performance of vessel technology, synonymous of typical vessel spreads used throughout the first two UK offshore wind rounds, are analysed to identify the variation in installation durations and weather downtime.

3.1. Wind farm installation software

The software tool relies on Monte Carlo methods to simulate multiple independent scenarios of the defined installation strategy for an offshore wind farm. The tool considers risk as delays to the installation, imposed by adverse weather conditions. A HMM model (Rabiner and Juang, 1986) has been used to generate each meteorological scenario informed historical weather data, which begins with the evaluation of a transition matrix A for the Markov chain. This matrix represents the evolution of the weather parameters: wind speed (V_t), wave height (H_t) and speed of the sea current (P_t). In this study, the wind speed and wave height are the only weather conditions evaluated. Meteorological parameters are intrinsically stochastic but also exhibit some continuity over time. Therefore, at any one time, if the sea is in a certain state, it is more likely that the next time (one hour, for example), the sea remains in a similar state. The main characteristic of a Markov chain is that the next state depends only on the state at the current point in time, which is described by Fig. 3.1. If the probability of moving from one state to another are known, then it is possible to generate meteorological parameters and thus to obtain a new weather scenario.