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Investigating key decision problems to optimize the operation and maintenance strategy of offshore wind farms

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Abstract

This paper investigates three decision problems with potential to optimize operation and maintenance and logistics strategies for offshore wind farms: the timing of pre-determined jack-up vessel campaigns; selection of crew transfer vessel fleet; and timing of annual services. These problems are compared both in terms of potential cost reduction and the stochastic variability and associated uncertainty of the outcome. Pre-determined jack-up vessel campaigns appear to have a high cost reduction potential but also a higher stochastic variability than the other decision problems. The paper also demonstrates the benefits and difficulties of considering problems together rather than solving them in isolation.

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1. Introduction

There is still a great need for the offshore wind industry to reduce costs. An objective of the EU FP7 project LEANWIND [1] is to provide cost reductions across the offshore wind farm lifecycle by identifying potential areas for optimization in all relevant processes. The operation and maintenance (O&M) phase of an offshore wind farm is subject to a vast range of decisions and, therefore, opportunities to improve efficiency. Optimizing the O&M strategy involves finding solutions to these decision problems. Based on work completed in LEANWIND, this paper applies a decision support tool to investigate three decision problems with potential to optimize O&M and logistics

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strategies for offshore wind farms. Decision support tools have been applied to O&M optimization since the early days of the offshore wind industry and [2] provides a recent review of the literature on relevant decision problems. This paper is concerned with strategic decisions, particularly the selection and utilization of vessels, and considers a selection of problems for corrective and preventive maintenance: 1) If chartering jack-up vessels for predetermined heavy maintenance campaigns, what is the optimal composition of annual campaign periods? 2) What is the optimal number and composition of crew transfer vessels (CTVs) to service the wind farm for smaller corrective and preventive maintenance tasks? 3) What is the optimal start month for annual preventive maintenance services? The following paragraphs briefly review the existing literature on these topics and summarize how this paper contributes.

The use of jack-up vessels for heavy maintenance (major replacements) is the biggest contributor to O&M cost [3]. Therefore, it is interesting to investigate how costs can be minimized by optimizing their use. A number of different strategies are considered in the literature including "Fix-on-failure" (FoF), namely short-term on-the-spot charters [3–6]. In the other extreme, long-term charters (for a number of years) or purchasing of jack-up vessels is also considered by a number of sources [3–6]. However, this strategy only appears to be viable for very large wind farms [3]. Waiting until a number of failures have occurred before chartering a vessel is often referred to as a batch repair strategy [4,5]. Short-term annual charters are also considered in [3–6], while the Crown Estate has investigated sharing strategies to optimize the use of jack-up vessels for O&M [7].

For the majority of maintenance tasks, the only vessel needed is a crew transfer vessel (CTV) to allow technicians to access the wind turbines. The problem of selecting the best fleet of crew transfer vessel has already been studied using simulation models [8,9], and a mathematical optimization model has also been developed [10]. A comparison of different models applied to this problem is presented in [11]. Whereas corrective tasks are usually performed throughout the year as required, the majority of preventive maintenance tasks are undertaken in annual service campaigns during spring and summer. The impact of when this campaign is scheduled is in [6,12].

To summarize the objectives and main contributions, this paper a) seeks to identify viable and robust jack-up vessel charter strategies, focusing on predetermined heavy maintenance campaigns, which is a strategy that has so far not been considered in the literature; b) compares the decision problems in terms of cost saving potential and the uncertainties in results, specifically demonstrating higher potential savings but larger stochastic variability for the jack-up vessel decision problem; c) investigates the potential benefit of considering multiple decision problems simultaneously, as solving each problem in isolation and neglecting possible interactions could result in a sub-optimal O&M strategy. In particular, the paper identifies the importance of considering the timing of annual service campaigns with the selection of the CTV fleet. The paper is organized as follows. The general method of approaching the decision problems is described in Sec. 2. Sections 3.1, 3.2 and 3.3 present results for each decision problem, after which they are compared in Sec. 3.4 and combined in Sec. 3.5. Section 4 summarizes the main findings and suggests areas for further investigations.

2. Methodology

The NOWIcob O&M simulation model [13,14] developed by SINTEF Energy Research was used to undertake this study. This strategic decision support model is a discrete-event simulation model for the O&M phase of offshore wind farms, which has been developed further and applied as an O&M strategy model within the LEANWIND project. Using a Monte Carlo approach, it captures the stochasticity of weather, times of turbine failure etc. A 10 year simulation period was chosen.

A set of offshore wind farm scenarios has been defined in LEANWIND and provides the reference for this paper. The base case wind farm scenario comprises 125 turbines set at 30 km from shore. The turbine is the LEANWIND 8 MW reference wind turbine [15], and metocean data correspond to the location of West Gabbard [16]. To produce representative metocean conditions at the site, 100 synthetic metocean time series were generated by a multi-parameter Markov chain weather model based on the metocean data. When comparing different strategies, the difference in results between two strategy solutions is calculated for each metocean time series to reduce the variance. The standard error of the differences is used as a measure of uncertainty for the results that are reported, which are averages over results for all the 100 Monte Carlo iterations.

To model the decision problems, a set of promising strategy solutions were defined and ranked according to the *total O&M cost,* which is defined here as the sum of direct O&M costs and lost revenue due to downtime for a given