Logistic Efficiencies and Naval architecture for Wind Installations with Novel Developments

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Optimisation Algorithms for Dynamic Scheduling of Preventive and Corrective O&M

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Executive Summary

This report presents mathematical optimisation models and solution algorithms for dynamic routing and scheduling of operation and maintenance (O&M) activities at offshore wind farms. It reports on work carried out within WP4 "Operation and Maintenance strategies" of the LEANWIND project on the optimisation of maintenance logistics. Whereas previously reported work in LEANWIND and WP4 in particular has considered decision support for strategic maintenance logistics problems, the present report is primarily concerned with operational decision problems.

The offshore wind logistics challenges addressed in this report are related to the scheduling of maintenance activities and the routing of crew transfer vessels (CTVs) for carrying out these maintenance activities. These maintenance activities include both corrective and preventive maintenance. That routing and scheduling decision problem is dynamic relates to evolution over time of the information that is available to the decision maker: Turbine failures prompting new corrective maintenance tasks or unexpected changes in weather conditions, e.g., may render the assumed optimal solutions sub-optimal.

To address these challenges, three optimization models or frameworks are proposed together with an approach for solving them:

1) An optimisation model for routing and scheduling of preventive maintenance for multiple offshore wind farms and multiple O&M bases.
2) A framework for dynamic routing and scheduling of preventive and corrective maintenance integrating a tactical scheduling model and an operational routing and scheduling model.
3) A stochastic vessel routing optimisation model for corrective and preventive maintenance.

These models and solution algorithms form the theoretical foundation for the development of advanced decision support tools for operational decision problems within offshore wind maintenance logistics. Ultimately, such tools can be used e.g. by an offshore wind farm operators to decide which technicians and vessels should visit which turbines the following day. Currently, no advanced operational decision support tools are available for routing and scheduling of O&M activities at offshore wind farms. Developing decision support tools based on the optimization methods presented here would contribute to reducing the levelized cost of energy compared to the current practice for routing and scheduling. However, more work is needed to fully take into account the uncertainties in weather conditions, to validate the methods, and to ensure that they can provide robust decision support for real-world decision problems.

The first model that is presented is a mathematical model for selecting the optimum route configuration developed to minimise the total cost comprising travel costs and technician costs. The total cost also includes fictive penalty costs that are introduced to incentivize completing maintenance in a timely manner and to allow for prioritization of the different maintenance activities. The model finds the optimal schedule for maintaining the turbines and the optimal routes for the crew transfer vessels to service the turbines along with the number of technicians required for each vessel. The model takes into account multiple

vessels, multiple O&M bases, and multiple wind farms, but considers only preventive maintenance. It is intended for operational decision support and considers a 3–7 day planning horizon. The routes have to consider several constraints such as weather conditions, the availability of vessels, and the number of technicians available at the O&M base. A solution method for the model based on the Dantzig-Wolfe decomposition method is also presented. The computational experiments on the existing dataset show that the proposed approach outperforms the method proposed previously in the literature.

Secondly, a framework for the integration of tactical and operational optimisation models for the dynamic maintenance scheduling and routing at an offshore wind farm is presented. First, a tactical model is solved to find the optimal schedule for preventive maintenance over a medium-term planning horizon of around one month that minimises travel costs, downtime costs and penalty costs. This schedule is produced assuming a weather forecast for the entire planning horizon, which in practice will be very uncertain. However, for each day, an operational maintenance routing model is then solved to obtain optimal vessel routes with a planning horizon of one day, assuming updated weather forecast for that day. In this operational routing model, both preventive and corrective maintenance is considered: The turbines that are scheduled for preventive maintenance are being provided by the tactical scheduling model, whereas the turbines requiring corrective maintenance are assumed to be provided by information updated on a daily basis. The vessel routing model also considers the number of technicians required for each vessel. In case that in the solution generated by the routing model there are some turbines that cannot be maintained due to weather conditions or lack of resources, the monthly maintenance activities are rescheduled by solving the tactical scheduling model considering the delayed activities. This approach is dynamic in the sense that the previous schedules are repaired based on the updated information. Two alternative solution methods for the routing problem are also proposed: One based on the Dantzig-Wolfe decomposition method and one matheuristic approach. The computational analysis reveals that the proposed solution methods produce competitive solutions compared to the exact method.

The two models described above are deterministic models, and uncertainties in e.g. weather conditions are not taken into account. However, a stochastic model for the maintenance routing problem (MRM) is also presented in this report where uncertainties in the following parameters are taken into account: The travel time of each vessel, the active maintenance time at the turbines, the transfer time for technicians and equipment to a turbine, and the weather (time) windows when it is possible to access the turbines safely. Input data for these uncertain parameters can be based on information about the uncertainties in the weather forecast. This is an operational optimisation model considering a planning horizon of one day and including both corrective and preventive maintenance. It is dynamic in the sense that it provides proactive plans designed to be robust to uncertain conditions rather than reactive repair plans. A simulation-based optimisation algorithm is proposed for solving this problem where Monte Carlo simulation and an exact method (Dantzig-Wolfe decomposition) are used in order to deal with the stochastic behaviour of the problem.