Ref. Ares(2024)2350159 - 29/03/2024

D3.2 Solutions and technologies for robotics in O&M

STEP4WIND

Training network in floating wind energy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 860737.

Document History

Revision Nr	Description	Author	Review	Date
01	D3.2 Report	Omer Khalid		28/03/2024

Index

1. Overview

This report discusses the solutions and technologies for robotics-based operations and maintenance from a techno-economic perspective. This report has been published as an open access publication in the *Wind Energy* journal under the title "*Cost-benefit assessment framework for robotics-driven inspection of floating offshore wind farms*". The reader is referred to the full publication which can be accessed through the following link: https://onlinelibrary.wiley.com/doi/full/10.1002/we.2881.

2. Abstract

O&M of floating offshore wind farms (FOWFs) poses various challenges in terms of greater distances from the shore, harsher weather conditions, and restricted mobility options. Robotic systems have the potential to automate some parts of the O&M leading to continuous feature-rich data acquisition, operational efficiency, along with health and safety improvements. There remains a gap in assessing the techno-economic feasibility of robotics in the FOWF sector. This paper investigates the costs and benefits of incorporating robotics into the O&M of a FOWF. A bottom-up cost model is used to estimate the costs for a proposed multi-robot platform (MRP). The MRP houses unmanned aerial vehicle (UAV) and remotely operated vehicle (ROV) to conduct the inspection of specific FOWF components. Emphasis is laid on the most conducive O&M activities for robotization and the associated technical and cost aspects. The simulation is conducted in Windfarm Operations and Maintenance cost-Benefit Analysis Tool (WOMBAT), where the metrics of incurred operational expenditure (OPEX) and the inspection time are calculated and compared with those of a baseline case consisting of crew transfer vessels, rope-access technicians, and divers. Results show that the MRP can reduce the inspection time incurred, but this reduction has dependency on the efficacy of the robotic system and the associated parameterization e.g., cost elements and the inspection rates. Conversely, the increased MRP day rate results in a higher annualized OPEX. Residual risk is calculated to assess the net benefit of incorporating the MRP. Furthermore, sensitivity analysis is conducted to find the key parameters influencing the OPEX and the inspection time variation. A key output of this work is a robust and realistic framework which can be used for the cost-benefit assessment of future MRP systems for specific FOWF activities.

3. Objectives

The objective of this work is to develop a cost-benefit assessment framework to estimate the cost of an MRP and assess its impact on the OPEX and key performance metrics of a FOWF. The proposed MRP consists of a commercially available UAV and ROV with the functionality of inspecting assets on the turbine and underwater, respectively. At first, the methodology for cost estimation is devised which is followed by its application to a hypothetical case study of a FOWF. The simulation is conducted in the WOMBAT cost model. Finally, sensitivity analysis is carried out and the attained results are analysed.

4. Conclusion

This study presents cost estimation for an offshore MRP and its impact on the OPEX and process time of inspecting specific components of a 1.5GW FOWF consisting of 100 turbines. The newly developed WOMBAT is employed as the O&M simulation tool. The outputs pertaining to various techno-economic performance metrics are analysed and sensitivity analysis is conducted to identify the variables that have a key effect on these metrics. The analysis shows that there is a potential for inspection time reduction by the use of MRP. This reduction has dependency on the MRP attributes, and the time taken by the UAV or ROV to conduct inspection. Considering that incurred cost, inspection time, and data acquisition are the main enablers of adoption of the MRP, further refinement of cost estimation and its validation could pave way for wide-scale adoption of robotics in the floating wind energy sector. In future, the perceived CAPEX depreciation in prices of UAV and ROV could also result in lower values of the day rates.

In comparison with CTV-based inspection, the MRP incurs a higher OPEX of 51.1% but accumulates a lower time-to-completion rate by 58.3%. The OPEX reduces by 50.6% if only one MRP is used with a relatively lower increase of 17.2% in the time-to-completion metric. This shows that initially smaller number of MRPs could be utilized which would reduce the OPEX but at an expense of increased inspection duration. Sensitivity analysis shows that the variables including the number of MRPs, day rate, and the inflation rate have the highest impact on the OPEX. On the other hand, the number of MRPs and the component inspection duration have the highest impact on the overall time-to-completion. Furthermore, correlation analysis shows that transitioning from the industrial standard of specified annual working days to fixed term O&M contracts can reduce the OPEX as well.

Such a cost-benefit framework can be used by the MRP operators or FOWF developers in order to assess and optimise the suitability of robotics-based inspections. In future, conducting sensitivity analysis of the cost estimation variables by including O&M term contracts and analysing its effect on the OPEX could result in attaining useful insights regarding the MRP use cases. The inherent flexibility of the WOMBAT tool could be leveraged to simulate a variety of FOWF scenarios and across a large parameter horizon in order to arrive at a generalized framework for the MRP cost estimation. Furthermore, extending this analysis by including major repairs, replacements, and CAPEX data resulting in a realistic value of the LCOE should make the results more resourceful, and representative of an actual FOWF.