Operations and Maintenance Modelling of Floating Hybrid Systems

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EXECUTIVE SUMMARY

Operations and Maintenance (O&M) accounts for a significant portion of the overall lifetime cost of an offshore renewable energy development. O&M simulation tools can help to identify critical components in the design, estimate operational expenditure to improve cost of energy calculations, and help to optimise logistical strategies. To date, most O&M simulation tools have focussed on offshore renewable energy projects with one type of device. Complexity is increased if a device is a hybrid of different electricity generating systems. This paper explores the methodology of taking an existing O&M tool centred on wave energy devices and modifying it to model a farm of floating wind-wave hybrid devices. Initial results are discussed, including quantifying the impact that the 'harbour effect' has on O&M, whereby the significant wave height behind the platform is reduced, allowing increased accessibility. The O&M tool produced as a part of this work will be made publicly available under the Ocean Energy Scale Up Alliance.

INTRODUCTION

Operations and Maintenance (O&M) of offshore wind farms is a rapidly changing landscape. In particular, the huge growth and dramatic cost reduction of offshore wind farms has driven the need for constant innovation in this field. O&M accounts for a significant portion of the overall lifetime costs of an offshore renewable energy development. Simulation models can be useful for:

1. identifying critical components which have the largest impact on performance and costs
2. estimating annual project availability, revenue and operational expenditure (OPEX), thereby refining Levelised Cost of Energy (LCOE) calculations
3. planning and optimizing O&M strategies

To date, most O&M simulation tools have focused on offshore renewable energy projects made up of one type of device. Complexity is increased if a project is formed of different devices, for example, adding floating wind turbines as an extension to an existing fixed-bottom wind farm. A similar problem exists with modelling hybrid devices. This paper explores the methodology of taking an existing O&M tool centred on wave energy devices and modifying it to model a farm of floating wind-wave hybrid devices.

OCEAN ENERGY SCALE UP ALLIANCE

The work presented in this paper has been undertaken by ORE Catapult as part of the Ocean Energy Scaleup Alliance (OESA)[1], in partnership with the European Marine Energy Centre (EMEC)[2] and Floating Power Plant (FPP)[3].

Interreg
North Sea Region
OESA
European Regional Development Fund

EUROPEAN UNION

ORE CATAPULT

ORE Catapult is the UK's flagship technology innovation and research centre for advancing wind, wave and tidal energy. ORE Catapult works closely with partners from across industry and academia, and uses its world-leading test and demonstration facilities to develop new

[1] https://northsearegion.eu/oesa/about/
[2] http://www.emec.org.uk/
[3] http://www.floatingpowerplant.com/

ways of working and prove, de-risk and develop promising new technologies. This helps to reduce the cost of offshore renewable energy, supporting business growth and delivering UK economic benefit.

FLOATING POWER PLANT

The equipment used as a case study in this paper is Floating Power Plant's (FPP) P80 wind-wave hybrid device (see Figure 1). The device consists of a floating platform, a wind turbine rated between 5MW and 10MW, and a wave power converter system rated at between 2MW to 3.6MW. The concept differs from other floating wind designs as the wave energy extraction is intended to create a 'harbour effect' behind the platform, thereby allowing Crew Transfer Vessels (CTVs) safer access in more severe seas. This aims to reduce turbine downtime by increasing the number of available weather windows for repair and inspection. As with several other floating turbine designs, it has the option to be towed back to an O&M base if required or can undergo on-site (i.e. offshore) repair and inspection.

Figure 1: Floating Power Plant's P80 design (Source: www.floatingpowerplant.com)

METHODOLOGY

O&M SIMULATION TOOL FUNCTIONALITY

All operations and maintenance simulation tools follow the same fundamental principles. Inputs consisting of failure rate data, a weather time series and maintenance parameters are provided, resulting in outputs including availability and operational expenditure. Time-domain models will step through every period provided in the weather time series and use a Monte Carlo analysis to simulate the occurrence of failures on a device. Logistical operations are simulated, such as sending technicians from an O&M base to the device with a crew transfer vessel (CTV) to undertaken repairs (i.e. unplanned or reactive maintenance) or inspections (i.e. planned or proactive maintenance). Different levels of complexity can be applied, for example, having specialist technicians for certain tasks or incorporating delivery time for spare parts. As with any kind of numerical modelling, it is imperative that the input data are as accurate and reliable as possible. A detailed flowchart of the typical functionality of O&M tools can be seen in [1].

REVIEW OF EXISTING O&M TOOLS

O&M simulation tools have been created in-house by project developers (e.g. Ørsted, EDF Energy), by private companies as commercial products (e.g. ForeCoast Marine, Shoreline), by publicly funded bodies (e.g. DTOcean, Wave Energy Scotland (WES)) as open-source software, and by research institutions (e.g. NOWITECH, ECN). The majority of existing tools are focussed on offshore wind farms. A review of selected existing O&M tools (see Table 1) has indicated that there are currently no publicly available and open source models capable of simulating activities on a hybrid wind-wave energy device.

Table 1: Selected existing operations and maintenance simulation tools (= not yet available)*

Name	Developer	Focus	Publicly Available?	Open Source?	Suitable for Hybrid Devices?
DTOcean	DTOcean	Ocean Energy	✓	✓	✗
*DTOcean+	DTOcean+	Ocean Energy	✓	✓ *(under development)*	✗
ECN O&M Tool	ECN	Offshore Wind	✗	✗	?
ECUME	EDF Energy	Offshore Wind	✗	✗	?

ForeCoast Marine	JBA Consulting	Offshore Wind	✗	✗	✗
Mermaid	James Fisher and Sons	Offshore Wind & Tidal Energy	✗	✗	?
NOWIcob	NOWITECH	Offshore Wind	✗	✗	?
Ørsted O&M Tool	Ørsted	Offshore Wind	✗	✗	?
*ROMEO O&M Tool	ROMEO	Offshore Wind	✓	✓ *(under development)*	?
Shoreline O&M	Shoreline	Offshore Wind	✗	✗	✗
WES O&M Tool	Wave Energy Scotland	Wave Energy	✓	✓	✗

MODIFICATIONS TO AN EXISTING MODEL

From the selected existing O&M tools reviewed, only two were found to be publicly available and open source; DTOcean and the WES O&M tool. The WES O&M tool was chosen for this study given its suitability for undertaking lifetime operations and maintenance simulations and relative ease of use. However, given that the WES tool is focused solely on wave energy devices, further modifications are required to make it applicable to a wind-wave hybrid device. The tool is built in Visual Basic for Applications (VBA). The WES O&M tool is described in detail in the documentation freely available on the Wave Energy Scotland website [2] and the functionality is also demonstrated in the case studies presented in [3].

The WES O&M simulation tool allows failures and maintenance to occur on either individual wave energy converters (WECs) or on the array as a whole. An example of how array maintenance can be carried out is shown in [4], where an inspection of all mooring lines in the wave farm is undertaken as one activity. For FPP's floating wind-wave hybrid device, the code needed to be altered so that any one failure or scheduled maintenance category could apply to either i) the wind turbine, ii) the system of WECs, or iii) the platform as a whole. Platform-related categories mean that both electrical generating systems are affected, for example, by a subsea electrical cable failure. When failures occur, it can cause a full or partial shutdown of the affected systems. The systems can operate independently of each other, meaning that wind turbine-related failures (and associated repairs or scheduled maintenance) will not affect the power output of the wave energy converters.

Power production is calculated from the weather conditions at each time step using a power matrix (significant wave height versus wave period) for the WECs and a power curve for the wind turbine (wind speed only). As FPP’s hybrid platform is designed to passively yaw to the direction of waves, and the turbine can actively yaw for wind direction, no adjustment is made for directional power losses. A modification also had to be made to allow scheduled maintenance to take place offshore (i.e. onsite) if required, as the WES O&M tool was originally structured to only allow inspections at an O&M base (i.e. offsite). This means that the user can now define any failure or scheduled maintenance category as requiring either onsite or offsite repair/inspection.

Figure 2 highlights how the O&M strategy for the case study presented in this paper assumes that the platform is only towed back to an offsite O&M base for major repairs or major scheduled maintenance tasks. The modified O&M tool also had to incorporate the ‘harbour effect’ of the floating hybrid design, where the significant wave height behind the platform is reduced by the WEC system. To achieve this, the weather window analysis method of the WES O&M tool had to be modified to increase the resolution, i.e. allowing each operation of an O&M activity to have its own weather constraints. For example, an onsite repair activity will include vessel transits to and from site which are constrained by vessel operating limits, as well as the docking operation at the platform which will be subject to the harbour effect.

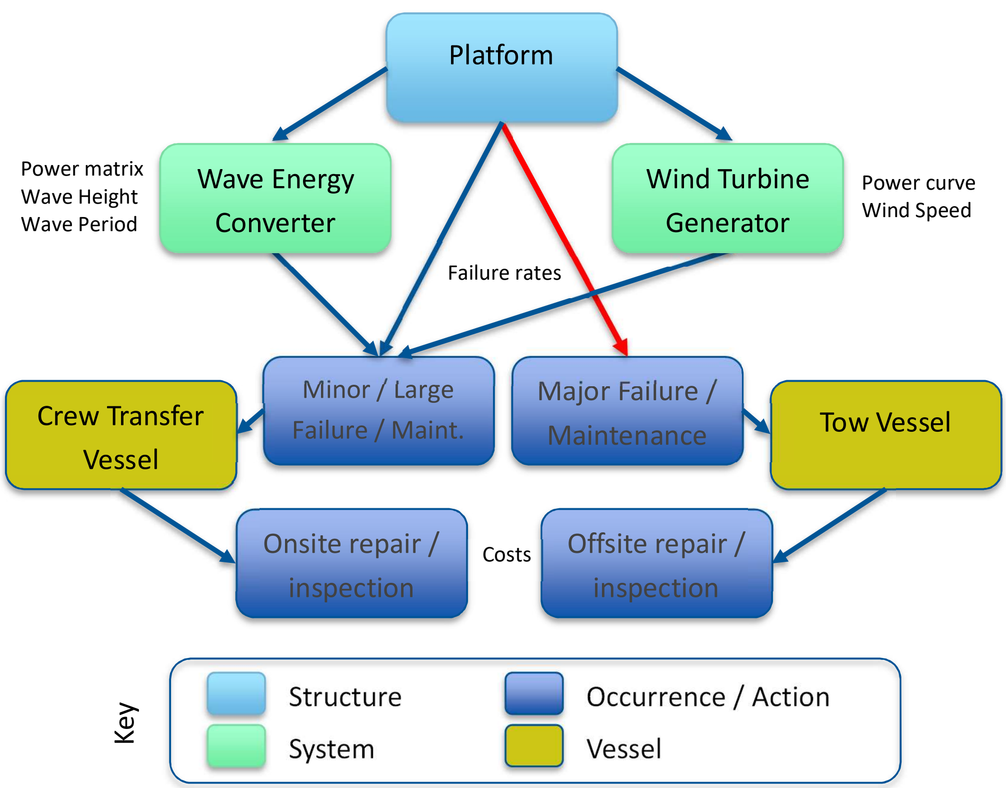

Figure 2: O&M strategy for FPP's hybrid wind-wave device, highlighting key model inputs and outputs

To achieve the required functionality for the hybrid platform, one key modification to the O&M tool code structure was the introduction of 'sub-assets' for each 'asset'. In the original WES O&M tool, an 'asset' would have meant a single wave energy converter. In the modified tool, an 'asset' refers to the floating platform itself, which can suffer failures, undergo repair or inspection, and produce power from either of its 'sub-assets' (i.e. the wind turbine or wave energy converter system). This is an important feature of the O&M tool, as it will allow the flexibility required for modelling other types of device.

EUROPEAN CASE STUDY

The European case study selected for this work is the Katanes Floating Energy Park, off the north coast of Scotland, currently in development by FPP and DP Energy (see Figure 3). Hindcast wind and wave conditions from 2004 to 2018 were obtained using DHI's Metocean On Demand service. The metocean data has a resolution of 1 hour, which is therefore the temporal resolution of the modified O&M tool. Two of the key inputs to the O&M tool are fault categories (and associated parameters such as time and cost to repair, number of technicians required, impact on power output etc.) and weather data. Several other parameters have been defined in order to simulate this European case study, including; the number of platforms, distance from O&M base, labour availability and cost, vessel availability and cost, and project lifetime. Thorough testing and visualization of results will ensure the simulations replicate what may happen at a farm of floating wind-wave hybrid devices as realistically as possible.

Figure 3: Location of Katanes Floating Energy Park in Scotland (Source: www.floatingpowerplant.com)

INITIAL SIMULATION RESULTS

The full definitions of case study inputs are not presented in this paper, nor are the simulated results, as this is an ongoing Ocean Energy Scale Up Alliance project. However, normalised results of initial simulations are presented in Figure 4, showing the mean time to repair each failure. Figure 5 and Figure 6 show the percentage of annual revenue gained from each generating system and the breakdown of operational expenditure causes, respectively. These graphs provide an indication of the outputs achievable with an O&M simulation tool.

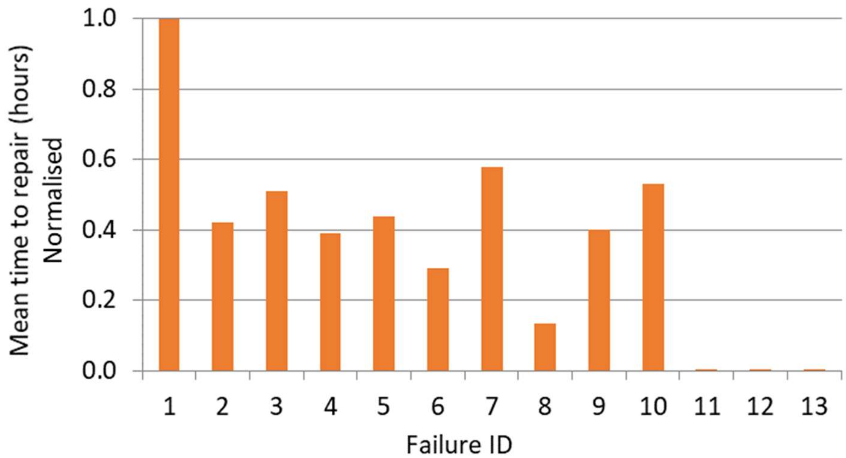

Figure 4: Mean time to repair each failure (indicative results, normalised)

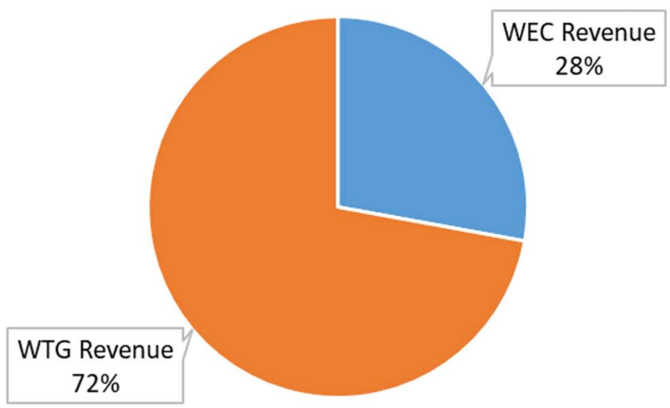

Figure 5: Percentage of annual revenue generated by each system (indicative results)

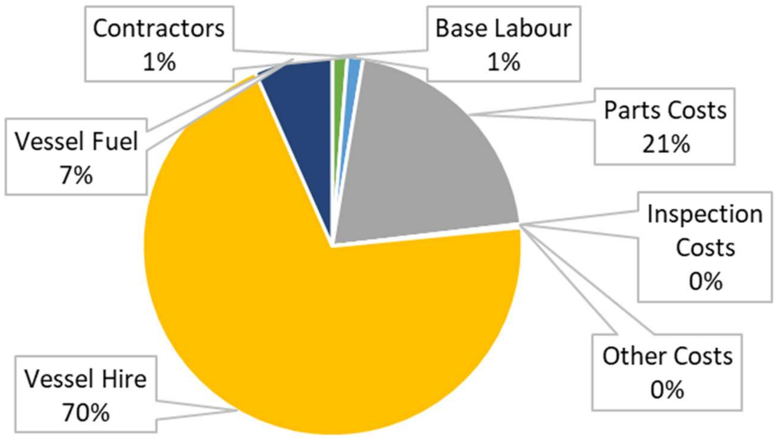

Figure 6: Percentage breakdown of annual operational expenditure (indicative results)

CONCLUSIONS AND FURTHER WORK

Operations and maintenance (O&M) of offshore renewable energy projects is a rapidly changing landscape, with a steady stream of new technologies and innovative ways of working. O&M simulation tools can be used for device design, project strategy planning and lifetime cost estimation. Many of the existing O&M tools have focussed on offshore wind turbines, but very few are available as open-source models in the public domain. No existing, open-source and publicly available O&M simulation tools can model farms of floating wind-wave hybrid devices. Therefore, to analyse the O&M lifecycle of the floating hybrid device being developed by Floating Power Plant (FPP), an existing, open-source tool in the public domain, but focussed on wave energy devices, had to be modified.

This paper has highlighted the key modifications needed and has presented some indicative results. The code structure modifications have attempted to create a flexible model, meaning that the tool should, with only small programming changes, still be able to model farms of wave energy converters, as well as these hybrid devices, whilst also now being able to model fixed-bottom or floating wind farms. When ready for public release, the modified tool will be made open source through the Ocean Energy Scale up Alliance.

The modified model is by no means a comprehensive tool for analysing offshore O&M strategies. More complex modelling would be needed to incorporate wave and wind direction power losses, and possible effects on access, as well as platform stability. The O&M tool also fails to account for the fact that many repairs or inspection activities will require technicians who are specialists with those particular components. Nor does it incorporate delivery times for spare parts. Many of the existing O&M tools are subject to ongoing development, therefore, it is possible that these models will incorporate the ideas presented in this paper for simulating multiple electricity generating systems (either with farms of different types of device, or farms of hybrid platforms), should these approaches become commercialised.

As with any type of numerical modelling, it is imperative that the input data are as accurate and reliable as possible. An increased confidence in the input data will yield increased confidence in the model outputs, which can contribute to the de-risking process of a technology. One of the key inputs to an O&M simulation tool is failure rate data, which often contain a significant degree of uncertainty. This is particularly true of a nascent technology such as wave energy converters. Compiling shared data such as failure rates into databases (e.g. SPARTA for offshore wind farms [5]) can hugely benefit the industry as a whole.

REFERENCES

[1] Kolios, A (2018). D8.1: Review of existing cost and O&M models, and development of a high-fidelity cost/revenue model for impact assessment. ROMEO Project. Available from: https://www.romeoproject.eu/wp-content/uploads/2018/12/D8.1_ROMEO_Report-reviewing-exsiting-cost-and-OM-support-models.pdf.

[2] WES (2019). Online Library, Other Activities, O&M Simulation Tool. Available from: https://library.waveenergyscotland.co.uk/.

[3] Gray, A. (2017). Modelling Operations and Maintenance Strategies for Wave Energy Arrays. EngD Thesis, University of Exeter. Available from: https://ore.exeter.ac.uk/repository/handle/10871/27909.

[4] Gray, A., Findlay, D. & Johanning, L. (2016). Operations and maintenance planning for community-scale, off-grid wave energy devices. Taylor & Francis Group. Available from: https://ore.exeter.ac.uk/repository/handle/10871/24049.

[5] System Performance, Availability and Reliability Trend Analysis – SPARTA (2019). Portfolio Review 2018/19. Available from: https://ore.catapult.org.uk/stories/sparta/.