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WHAT ARE OPERATIONS AND MAINTENANCE SIMULATION TOOLS?

An explanation of O&M models in the offshore renewable energy sector

EXECUTIVE SUMMARY

Operational expenditure (OPEX) incurred during the Operations and Maintenance (O&M) phase accounts for between 20% and 30% of the Levelised Cost of Energy (LCOE) of an offshore renewable energy development over its lifetime. O&M simulation software tools can be used to derive OPEX estimates, along with other Key Performance Indicators (KPIs) such as asset availability. These tools are becoming increasingly common in the industry as they can also help optimise O&M strategies and improve asset management.

- How O&M simulation tools work - time-domain simulations step through the lifetime of a project, simulating the occurrence of failures and replicating the real-world decisions made in terms of undertaking repairs and inspections.

- Are these tools commercially ready? - many simulation tools are available as paid software services, whilst others are used by organisations for internal purposes only. Very few tools are open source.

- How could these tools be improved - realistic O&M simulation modelling is achieved by obtaining reliable input data, such as failure rates and maintenance parameters. These input data can be improved through industry collaboration and anonymised performance databases.

INTRODUCTION

The Operations and Maintenance (O&M) phase of offshore renewable energy (ORE) projects is a rapidly changing landscape. Innovation in this field has been driven by huge market growth, as well as the need to reduce the cost of offshore wind so that future wind farms can continue to meet Contracts for Difference (CfD) strike prices. O&M accounts for between 20% and 30% of the Levelised Cost of Energy (LCOE) of an offshore renewable energy development over its lifetime.

Reliable simulations and estimates of operational expenditure (OPEX) are becoming even more important for two main reasons. Firstly, the CfD regime has introduced intense cost-based competition in the UK offshore wind sector and reliable estimates of annual costs are required to inform an auction bid. Secondly, as the industry continues to grow apace, it is attracting many new innovations targeting the O&M phase including blade retrofits, robotics solutions and advanced software to name a few. While capital expenditure (CAPEX) is essentially fixed once a wind farm is built, the OPEX can be optimised by making informed decisions about which of these new innovations will have the largest impact on costs and production.

O&M simulation software tools can be used to derive OPEX estimates, along with other Key Performance Indicators (KPIs) such as asset availability. These tools are becoming increasingly common in the industry as they can also help optimise O&M strategies and improve asset management. This report aims to provide clarity on the topic of O&M modelling for offshore renewable energy projects.

ORE Catapult acts as an independent, centralised, forward-thinking organisation at the heart of the offshore renewable energy industry, working closely with partners across industry and academia to develop new ways of working and prove, de-risk and develop promising new technologies. This publicly available report has been compiled by ORE Catapult by gathering knowledge from a wide range of industry and academic experts, including both developers and users of O&M simulation software, as well as other key industry stakeholders.

WHAT ARE O&M SIMULATION TOOLS?

The type of O&M simulation tools discussed in this paper are for long-term logistical planning, forecasting asset availability and estimating lifetime OPEX of offshore renewable energy projects. They can be used to optimise O&M strategies based on minimising OPEX and maximising asset performance (or trading off between the two), for example by addressing uncertainties in component failure rates, vulnerability to weather conditions and access to specialised vessels. They are referred to by many different names, including (but not limited to) O&M models, decision support tools, O&M planning tools, maintenance strategy planning models, O&M optimisation models and logistical planning tools. O&M simulation tools can be a natural extension to O&M cost models, which are usually created in Microsoft Excel and aim to provide a high-level understanding of the project OPEX. The O&M simulation tools discussed in this paper should also not be confused with short-term, daily decision-support tools, designed to aid vessel operators and marine logistics managers in their day-to-day activities (i.e. by providing weather information for assessing risk or tracking live O&M programmes).

There are many different O&M simulation tools in existence. Several of these are available as commercial software products or modelling services, such as Shoreline O&M Design[i], ForeCoast Marine Gamer Mode[ii], Offshore TIMES[iii], DNVGL O2M[iv] (web-based interface under development) and ECN O&M Calculator[v] (to be phased out in favour of TNO ECN O&M Planner). Other products, such as James Fisher Mermaid[vi] can provide detailed information on scheduling of work using historical weather data, but don't go into lifetime OPEX assessment. The developers of these commercial O&M simulation tools typically provide other types of marine risk management software for purposes such as project construction or short-term decision making. The cost of purchasing a single annual licence of one of these commercial O&M simulation tools can vary significantly, depending on the user input required and level of technical support offered, but is typically in the region of £4,000-8,000 per year. Some other O&M simulation tools are developed by organisations for use on internal projects only. This is a common theme for project developers (e.g. EDF Energy ECUME[vii]), but it is also the case with some research institutions such as Strathclyde University (StrathOW-OM[viii]), the University of Exeter[ix] and SINTEF Energy Research (NOWIcob[x]).

It is rare that an O&M simulation tool is made publicly available at no cost. One tool that will be made open access in the near future is being developed under the ROMEO project[xi]. However, only the interface of the ROMEO tool will be visible, not the source code. Two O&M simulation tools that do provide visibility of the programming code are the Wave Energy Scotland O&M tool[xii] and DTOceanPlus[xiii] (an extension of DTOcean[xiv], both of which contain elements of O&M modelling. Not available until April 2021). Whilst both of these open source tools focus on ocean (wave and/or tidal) energy, aspects of the programming code are suitable for any type of offshore renewable energy project.

HOW DO THEY WORK?

O&M simulation tools for long-term logistical planning and OPEX estimation typically adopt a time-domain approach. That means that they go through the lifetime of a project, simulating the occurrence of failures and replicating the real-world decisions made in terms of undertaking unplanned/reactive maintenance (i.e. repairs) in addition to planned/scheduled maintenance (i.e. inspection surveys). The input data required to achieve this include a time series of weather conditions, component or subsystem failure rates, maintenance parameters (e.g. parts costs, technicians required etc.), vessel details and power production parameters (e.g. power curves for offshore wind turbines). The model will assess the weather window required (i.e. subject to operational limits and duration of offshore tasks) before sending a vessel, for example, to undertake particular offshore activities. Simulation tools can also model more complex tasks, such as vessels with a continuous offshore presence, i.e. Service Operation Vessels (SOVs), scheduling of activities, and technician transfers following shift completion. Throughout the simulation, the model can record the availability and revenue of assets, as well as the ongoing OPEX. Other output parameters could include vessel usage, technician utilisation and detailed cost breakdowns. This time-domain modelling process is summarised, in its basic form, in Figure 1.

Due to the inclusion of failure rates, weather conditions and variations in operation/repair time, O&M simulation tools can be categorised as stochastic models as they contain inherent randomness. In this way, they differ from deterministic O&M cost models, usually created in Microsoft Excel, and can provide significant benefits in terms of the level of detail obtainable.

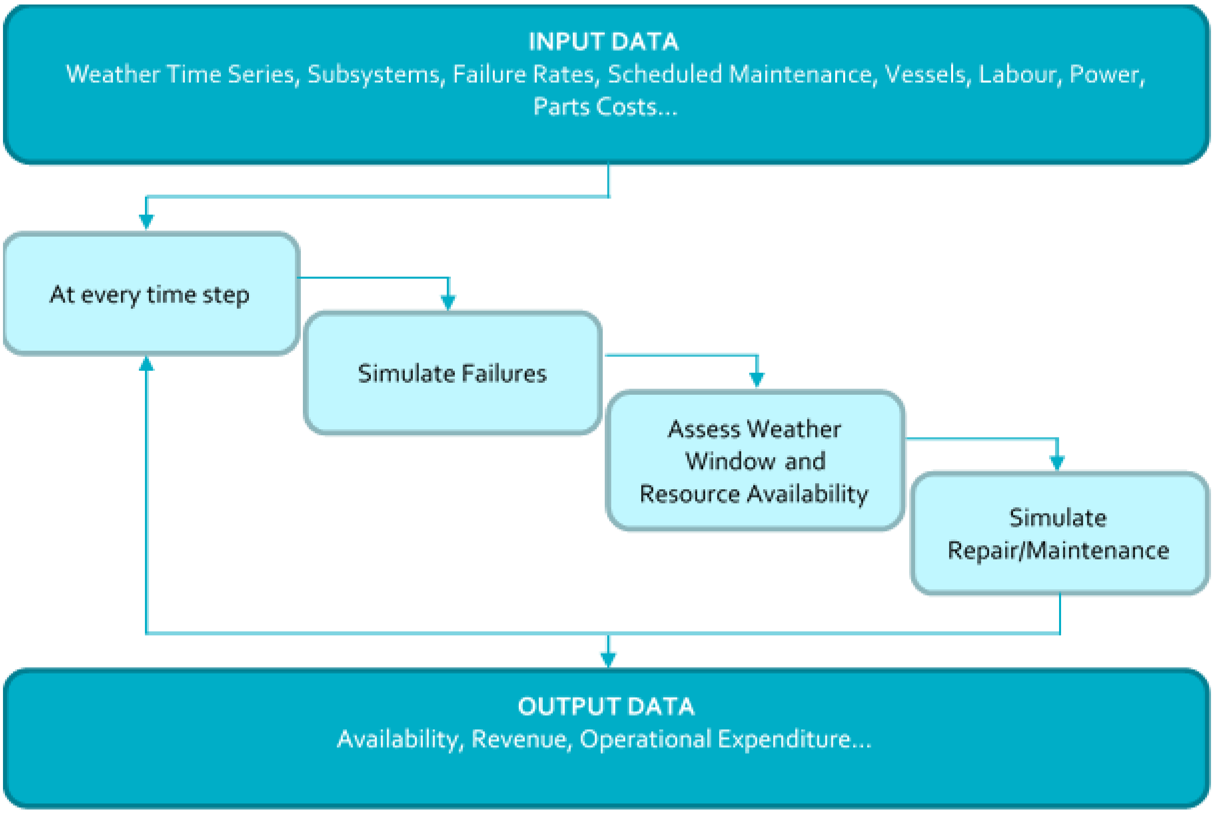

Figure 1: Summary of time-domain O&M modelling process

Due to the processing power required for these types of time-domain simulations, and the fact that these models are usually created by engineers, O&M tools are typically built in high-level programming languages, such as MATLAB and Python. MATLAB is a high-performance language which contains many in-built toolboxes for undertaking all kinds of processing. It is used widely in universities and, therefore, it is common to see MATLAB in software initially developed for academic projects. However, MATLAB is a fee-based commercial software language, resulting in many organisations being reluctant to use it which can sacrifice portability of code. Python is a high-level language designed to be easy to read and simple to implement, incorporating a wide range of in-built processing packages, with the additional benefit of being free to download and use. It is therefore rapidly becoming the programming language of choice for many engineering-based organisations. Other high-level programming languages that have been used for O&M simulation tools include C# and Java. Another language which has been used for some O&M simulation tools is Visual Basic for Applications (VBA), the background programming language within Microsoft Excel, although this is regarded as a slow and inefficient method and therefore is not recommended. The majority of existing O&M simulation tools have been created by engineers, whereas software developers would perhaps prefer to code with 'lower level' (i.e. slightly closer to machine code) languages such as C. Regardless of the programming language used, it is important that the appropriate modelling approach and program architecture is adopted, among many other software development considerations.

Some commercially available O&M simulation tools are implementing a web-based interface to make their products more user-friendly.

WHAT ARE THEY USED FOR?

O&M simulation tools are used for long-term logistical planning, forecasting asset availability and estimating lifetime OPEX of offshore renewable energy projects. These can all be achieved to some degree using a deterministic (i.e. with no element of randomness) O&M cost model, however, there are many additional benefits to creating a time-domain simulation tool. The flexibility of an O&M simulation tool means that offshore renewable energy projects can be modelled in more detail, for example, by listing the exact coordinates of each asset to get better estimates of transit times. This is becoming more important as offshore wind farms are getting larger, meaning that transit times to the turbines furthest from shore may be significantly longer than other assets. This level of detail also improves analysis of revenue losses and can provide a better understanding of weather downtime. More generally, the flexibility of an O&M simulation tool delivers the ability to model bespoke or real scenarios and provides a better understanding of interdependencies in any uncertainties. Sensitivity studies can be undertaken on those model input parameters which contain a large degree of uncertainty, such as failure rates, to understand the impact of better asset design. Undertaking many different sensitivity analyses can result in the identification of the optimal O&M strategy for a given offshore renewable energy project, thereby leading to operational efficiencies, OPEX savings, ultimately, minimising LCOE. Other examples of O&M simulation uses are described in Table 1.

Table 1: Examples of O&M simulation tool use

Use Description	Example
Understand operational costs	Provide a breakdown of OPEX so high value areas can be targeted for cost reduction
Refine LCOE estimates	Provide year-by-year estimates of OPEX and revenue to capture annual and seasonal variabilities
Long-term logistical planning and strategy optimisation	Selecting an SOV or Crew Transfer Vessel (CTV) strategy for a new wind farm. Plan optimal staffing and vessel charter arrangements etc. to minimise technical downtime and OPEX, whilst maximising revenue
Support project bids	Utilising a robust and validated O&M tool to inform a CfD bid

Support due diligence for initial investors/divestment transactions	Benchmark project costs and asset performance
Energy production assessments	Benchmarking projected asset availability
Support the business cases of SME's developing innovative solutions	Assess innovative technologies or novel operational strategies - the flexibility of O&M models means that adjusting inputs can be straightforward
Assess the impact of different operational weather conditions	Support the business case for procuring equipment of techniques that increase accessibility

WHAT ARE THE CHALLENGES TO BE SOLVED?

As with any type of numerical model, the outputs of O&M simulation tools are only as reliable as the inputs. As a result, it is vital that uncertainty in inputs is reduced as much as feasibly possible. One of the most important inputs to an O&M simulation tool is failure rate information as this allows unplanned maintenance to be modelled. It can be challenging to obtain sufficient data to provide a clear understanding of failure rates, even for project developers, given the relatively short period of time offshore wind farms have operated to date. Other challenges for developers of O&M simulation tools are shown in Table 2.

Table 2: Challenges for developers of O&M simulation tools

Challenge	Why is it an issue?	How might it be solved?
Validating models against other tools or real projects	Validation is necessary to add confidence to outputs. However, validation against real life scenarios is difficult without long-term access and tracking of real projects.	Collaboration with project owners and between tool developers.
Obtaining reliable weather data for specific sites	Measured data are accurate but expensive to obtain and limited in duration. Hindcast data need to be reliably validated and can be expensive to procure. Tools often require multiple data points for a single site due to size and location of projects.	Weather data access portals such as Metocean on Demand[xv] or Copernicus ERA5[xvi] are increasing in reliability and popularity, but can suffer from poor spatial resolution, especially for complex coastal sites.
Obtaining accurate maintenance parameters	E.g. servicing times, number of technicians etc.) and cost estimates – this problem is complicated further by fluctuating market prices dependent on demand.	Collaboration with project owners. Tracking market price fluctuations. Modelling fluctuations over project lifetime.

Challenge	Why is it an issue?	How might it be solved?
Fully understanding uncertainty	Uncertainty impacts on decisions made at all stages of a project. Different inputs contain different degrees of uncertainty and types of fluctuation.	Ongoing benchmarking against real projects and further advancements in processing power.
Incorporating crew/technician fatigue and contractor lead times	O&M simulation tools need to replicate real-life logistics in order to obtain reliable cost estimates. Personnel factors are not modelled in detail at present.	Collaboration with staffing providers to enhance personnel details in O&M simulation tools.
Modelling novel approaches with new technologies	E.g. towing floating wind to port. Limited real-world experience means validating models is challenging.	Collaboration with industry - ongoing tracking of industry developments and updating of O&M simulation tools.
Modelling the marine environment more realistically	E.g. wave effects of floating platforms. Can be computationally expensive.	Advancements in processing power.
Balancing the desire to meet wider industry needs with the reliability of a site-specific model	Site-specific models can be validated to some extent but lack confidence for other sites if not fully tested.	Clearly defined programming structure and input database.
Creating a generic O&M tool for all forms of ORE device	Different types of ORE device have different O&M requirements. E.g. some tidal energy devices may require narrow weather windows due to slack tide.	Collaboration between tool developers and industry - ongoing tracking of industry developments and understanding of requirements.

WHERE ARE THE SOLUTIONS?

As outlined in Table 2, collaboration between tool developers and industry users is key. Maintaining an up to date understanding of industry requirements is critical to ensuring simulation tools remain relevant and value-adding. This collaboration can be targeted at the development of a specific tool; or a wider industry initiative could provide a forum for sharing of best practice and foresighting of requirements.

Anonymised performance databases (such as SPARTA[xvii] and WEBS[xviii]) are important as they remove issues surrounding commercial sensitivity, but they need to be combined with collating ongoing operational data from a rapidly growing industry. This will allow O&M simulation tools to capture the probabilistic nature of failures with a greater degree of confidence, including the typical 'bathtub curve' where there are a high number of failures in the component's early life, reducing to a steady rate throughout the lifetime, but increasing again towards the end of life as degradation occurs. An increased amount of available data will also lead to a better understanding of how failures differ between assets depending on location and type, as well as an increased knowledge of the knock-on effects of certain failures within a system.

ORE Catapult is sponsoring an Engineering Doctorate (EngD) student as part of the Industrial Doctoral Centre for Offshore Renewable Energy (IDCORE[xix]). The three-year research project will involve making enhancements to ORE Catapult's internal O&M simulation tools, as well as looking at ways to capture and build upon the vast amount of industry knowledge gained through collaborative projects. The academic outputs of this research will add value to the field of O&M modelling and help to solve some of the challenges outlined in this report.

KEY FINDINGS

- O&M simulation tools are stochastic, time-domain models that analyse the operational phase of offshore renewable energy projects.
- O&M simulation tools are used for long-term logistical planning, forecasting asset availability, estimating lifetime OPEX.
- O&M simulation tools have many benefits over traditional, deterministic, Excel-based O&M cost modelling, including higher flexibility, increased realism of scenarios and increased confidence in outputs.
- There are many O&M simulation tools in existence, some of which are offered as commercial products, but a small number are available as open source software models.
- One of the biggest challenges for O&M simulation tools is obtaining reliable failure rate data to model unplanned maintenance.
- Some of these challenges can be addressed through industry collaboration and use of anonymised performance databases.

ACKNOWLEDGEMENTS

This report has been compiled by gathering input and feedback from a wide range of industry and academic experts, including both developers and users of O&M simulation software, as well as other key industry stakeholders. Their contribution is greatly appreciated.

Appendices

RECOMMENDED READING

The following references are recommended for anyone wanting to find out more about the field of O&M modelling for offshore renewable energy projects:

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AUTHOR PROFILE

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