Operation & Maintenance Cost Estimator (OMCE)

Estimate future O&M cost for offshore wind farms

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Operation & Maintenance Cost Estimator (OMCE)- Estimate future O&M cost for offshore wind farms

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Summary

The operation and maintenance (O&M) costs of offshore wind farms contribute significantly to the energy generation costs. Reliable estimates of these costs are required during planning and operation of the wind farm at several stages. Such estimates however have a large spread and are uncertain. ECN is developing the O&M Cost Estimator (OMCE) with which owners and operators of offshore wind farms are able to better estimate and control the future O&M costs for the next coming 1 to 5 years. The OMCE uses data and experience generated by the wind farm under consideration. The generated wind farm data, such as O&M data, data from SCADA systems, or data from (load) measurements and condition monitoring is suggested to be structured such that a so-called "Event list" can be extracted. The OMCE consists of so called "OMCE Building Blocks" in which structured data according to the event list format is processed into useful information for stand-alone analysis of the wind farm operational status and as input for the "OMCE-Calculator". The OMCE-Calculator is the core of the OMCE, which uses the output of the building blocks to make cost estimates for the next 1, 2, or 5 years.

Keywords: Operation and Maintenance, Offshore Wind Energy, Cost Estimation, OMCE

1 Introduction

Governments in several countries have defined targets to increase the installed capacity of offshore wind power significantly the coming decennia. To be able to control and subsequently to optimize the future O&M costs of these new wind farms, it is necessary to accurately estimate the O&M costs for the next coming period of e.g. 1, 2 or 5 years, taking into account the operational experiences available at that moment. Several reasons are present for making accurate cost estimates of future O&M of (offshore) wind farms:

- Deciding on new O&M contracts after the expiration of the warrantee period.
- Making reservations for future O&M costs.
- Quantifying the impact if operational experiences indicate that the O&M strategy needs to be adjusted;
- Selling a wind farm to another investor.

Presently, ECN is developing the Operation and Maintenance Cost Estimator (OMCE) as partner in the Dutch Offshore Wind Energy Services (DOWES) project. Within the DOWES project an integrated asset management system is being developed, in which the OMCE will be integrated. The OMCE consists of two parts: (1) the OMCE Building Blocks to process the operational data, and (2) the OMCE Calculator to assess the future costs.

1) The OMCE requires feedback of operational data of a specific wind farm under consideration, such as O&M data, data from measurement campaigns, and data from condition monitoring programs. Data about failures, repair actions, the vessel usage, spare parts, and weather conditions are analysed to estimate the effort for unplanned corrective maintenance. Data from condition monitoring and load measurements are analysed to estimate the effort for condition based maintenance.

For this purpose four so called OMCE Building Blocks (BB) have been specified, each covering a specific data set. The main objective of these building blocks is to process available data in such a way that useful information is obtained. For the processing of wind farm data by the BB's, an "Event list" format is required to link the different maintenance actions to a single event.

2) The OMCE Calculator will be used to assess the O&M cost for the coming period of e.g. 1, 2 or 5 years, based on the results of the BB's. The OMCE calculator considers three types of maintenance: (1) unplanned corrective maintenance (2) condition based maintenance, and (3) calendar based maintenance.

2 OMCE Structure

The structure of the OMCE is described in detail in [2] and [5]. The OMCE structure is given in Figure 2.1. The OMCE-Calculator requires information on three types of maintenance in order to estimate the near future O&M costs:

1. Unplanned corrective maintenance: due to unexpected failures leading to immediate shutdowns, unforeseen downtimes, and unplanned maintenance actions
2. Condition based maintenance: not foreseen initially, but when it has to be carried out during lifetime it generally will be planned with minimum turbine shutdown
3. Calendar based maintenance: (or: preventive maintenance)

The input for the unplanned corrective maintenance is based on the observed failure rates (determined in the BB "Operation & Maintenance") of components and the associated repair costs (mainly equipment, materials, labour, downtime, determined by the BB "Logistics").

The input for estimating the annual costs for condition based maintenance is derived from the measured (or observed) degradation of the components (BB's "Health Monitoring" and "Loads & Lifetime") and the associated repair costs (also from the BB "Logistics").

The input for calendar based maintenance is determined as the number of repair days with associated costs for labour, equipment, spares, etc. and usually derived from the service manuals with prescribed intervals and procedures.

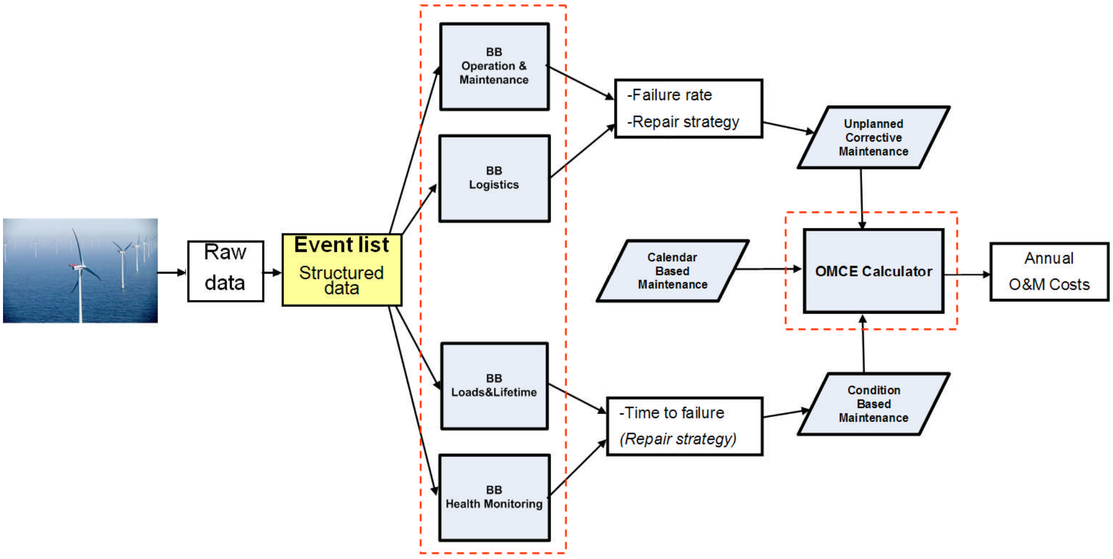


Figure 2.1: *OMCE concept showing the data flow from "raw data" to estimated O&M costs*

3 Event list and Building Blocks

3.1 Event list

Based on data of the Dutch Offshore Wind farm Egmond aan Zee (OWEZ), it was concluded that the format used by most wind farm operators for storage of data of data is not suitable for automated data processing by the BB's "Operation & Maintenance" and "Logistics" [1]. Usually, operators collect the data as different sources on a monthly basis. After some time it is not always clear how different alarms, maintenance actions, downtimes, etc. are linked with each other. Therefore within the OMCE the so-called "Event list" was introduced.

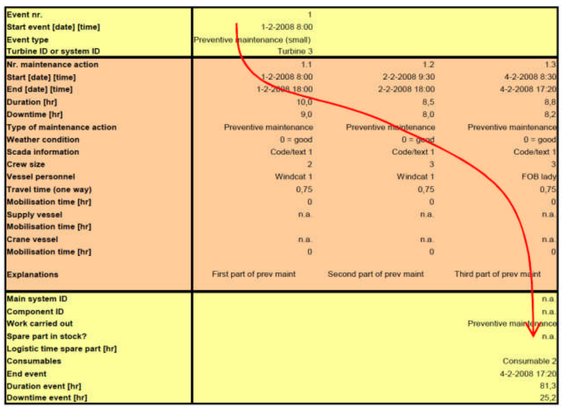
An event list can be best visualised as a list with events per turbine in a chronological order, including all fields with data and information that are relevant for further processing by the BB's. Within the context of the OMCE, an "event" is considered as one (or a series of) maintenance action(s) to prevent turbine malfunctioning, or maintenance action(s) following after malfunctioning of the turbine. The total duration of an event is often longer than the sum of the individual maintenance actions. Maintenance actions can be remote resets, visits with technicians only, or the replacement of large parts.

The location of the event list within the OMCE concept is in between the raw data and the BB's, see Figure 2.1. The data is not stored in the event list directly, yet the event list is extracted from the different data bases. This requires that the data in these data bases should be correlated.

The following requirements are relevant when constructing an event list suitable for the OMCE:

1. Provide insight how individual maintenance actions are related to the total event.
2. Each event should be classified as one of the Repair Classes relevant for O&M modelling.
3. It should contain all details about the event relevant for analyses with the OMCE calculator.

An example of how such an event list can be reported is presented in Figure 3.1. More information can be found in references [1] and [5].



Event nr.	1		
Start event [date] [time]	1-2-2008 8:00		
Event type	Preventive maintenance (small)		
Turbine ID or system ID	Turbine 3		
Nr. maintenance action	1.1	1.2	1.3
Start [date] [time]	1-2-2008 8:00	2-2-2008 9:30	4-2-2008 8:30
End [date] [time]	1-2-2008 18:00	2-2-2008 18:00	4-2-2008 17:20
Duration [hr]	10,0	8,5	8,8
Downtime [hr]	9,0	8,0	8,2
Type of maintenance action	Preventive maintenance	Preventive maintenance	Preventive maintenance
Weather condition	0 = good	0 = good	0 = good
Scada information	Code/text 1	Code/text 1	Code/text 1
Crew size	2	3	3
Vessel personnel	Windcat 1	Windcat 1	FOB lady
Travel time (one way)	0,75	0,75	0,75
Mobilisation time [hr]	0	0	0
Supply vessel	n.a.	n.a.	n.a.
Mobilisation time [hr]			
Crane vessel	n.a.	n.a.	n.a.
Mobilisation time [hr]	0	0	0
Explanations	First part of prev maint	Second part of prev maint	Third part of prev maint
Main system ID			n.a.
Component ID			n.a.
Work carried out			Preventive maintenance
Spare part in stock?			n.a.
Logistic time spare part [hr]			
Consumables			Consumable 2
End event			4-2-2008 17:20
Duration event [hr]			81,3
Downtime event [hr]			25,2

Figure 3.1: *Example of three maintenance actions (orange fields) as part of a single preventive maintenance event (yellow fields)*

3.2 *Building Blocks*

Four OMCE Building Blocks (BB) have been specified to process all available data generated by an offshore wind farm in such a way that useful information is obtained, each covering a specific data set.

- BB *Operation & Maintenance*
- BB *Logistics*
- BB *Loads and Lifetime*
- BB *Health Monitoring*

The individual BB's, have been discussed extensively for instance in [1], [2], [3], and [5]. In this paper only the most relevant specifications, capabilities and new developments are given for the BB's: "Operation & Maintenance" and "Logistics".

BB Operation & Maintenance

The purpose of the Building Block "Operation & Maintenance" is twofold:

1. Generating information about the failure behaviour of the components among others to assess the adequacy of the maintenance strategy, e.g. by means of trend analyses and ranking of failures;
2. Generating updated figures of the failure rates (and failure modes) and repair actions of components to be used as input for the OMCE Calculator.

At ECN, BB software tools are currently under development to perform ranking and trend analysis of component failure behaviour and downtime based on maintenance events stored in an Event list. An end user may perform the analyses by using a customized program with a user-friendly interface, as currently under development in the DOWES project.

As an example of the output for the BB Operation & Maintenance a trend analysis has been performed based on information captured in an Event list. The analysis of information stored in this Event list results the CUSUM plot depicted in Figure 3.2 for a main system of the turbine. The derivative to this curve is by definition the failure frequency which may vary over time, see also [5].

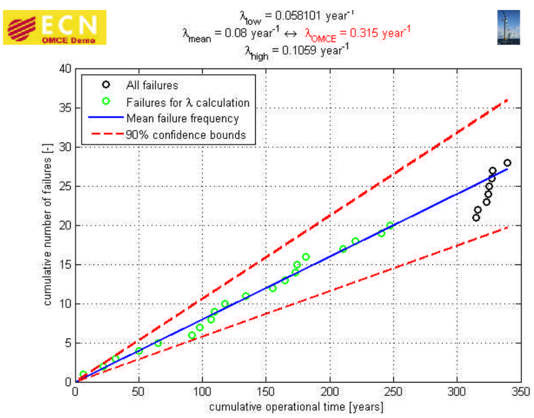


Figure 3.2: *BB O&M output of estimated failure frequency for a system based on event list*

In Figure 3.2, the failure frequency is calculated over the first 250 cumulative operational years only. Engineering judgement will be required to determine which part of the CUSUM-plot (and thus the failure rate) is representative for estimating the near future costs for unplanned corrective maintenance.

BB Logistics

The objective of the BB "Logistics" is (similar to the objectives of BB "O&M") twofold:

1. Generating information about the use of logistic aspects (equipment, personnel, spare parts, consumables) for maintenance and repair actions.
2. Generating updated figures of the logistic aspects (accessibility, repair times, number of visits, delivery time of spares, etc.) to be used as input for the OMCE Calculator.

The BB "Logistics" is developed to analyse the data and information that are available in a wind farm on logistics aspects in order to quantify the different possibilities for carrying out repairs for the OMCE Calculator.

At ECN software tools are under development for the BB Logistics as well. Based on operational information captured in the Event list, this software tool can result the logistic information both in graphs and in tables.

4 OMCE-Calculator

The OMCE-Calculator is the tool that actually runs the simulations to estimate the future O&M effort. As opposed to the well known "ECN O&M Tool" which is applied in the planning phase of a wind farm, uses long term average values as input, and is programmed in MS-Excel, the OMCE-Calculator can be applied during the operational phase of a wind farm, uses acquired operational data of the specific wind farm as input, and is programmed in Matlab [4]. Recently a first stand-alone demo version of the program is created.

The OMCE-Calculator demo specifications are based on long term experiences with ECN's O&M Tool. The specifications include:

- Designed for operational phase of wind farm
- Limitations are considered in: vessels available, weather limits, spare parts etc.
- User-friendly input to define the three types of maintenance and their repair strategies
- Failures are modelled according to the Poisson process, while the distribution of failures is analysed by the Monte Carlo method
- All repairs are analysed in time by time-domain simulations for which historically recorded meteo data is used as input for accessibility

The structure of the time-domain simulation process is given in Figure 4.1. Here, the number of simulations performed will provide results with respect to the uncertainty in the failure distribution.

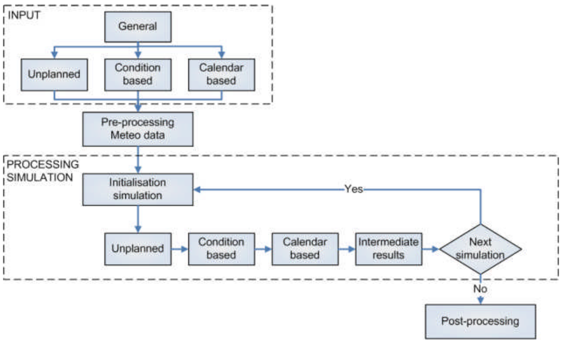


Figure 4.1: *Simulation process of OMCE-Calculator*

As an example of the repair modelling for corrective maintenance, consider the illustration in Figure 4.2. Once a failure has occurred it will require some organisation and logistics time for the equipment, crew, and spares to be ready. It is than possible that equipment will have to wait for a suitable weather window to access the wind farm before the actual maintenance event may start. In between the inspection, replacement, and repair phases it is possible that organisation, logistic, and weather window downtime occur again due to e.g. required equipment or spares not directly available.

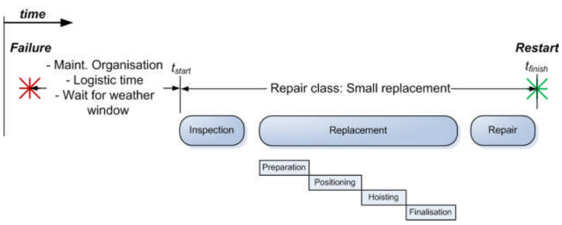


Figure 4.2: *Planning a small replacement in time*

After a number of simulations is executed by the OMCE-Calculator, the post processor is used to generate plots and tables with costs, downtimes, cost drivers, and uncertainties.

To demonstrate the capabilities an example project is defined for an imaginary wind farm with 100 turbines of 2.8 MW. An average failure rate per turbine of $\lambda_t = 4.5\, year^{-1}$ is distributed over the components. The goal of the analysis is to investigate the impact of the number of access vessels for corrective maintenance on the wind farm technical availability. The analyses are made for 250 simulations with a length of 2 years.

The results given in Figure 4.3 show that two access vessels is the optimum. The analyses with 3 access vessels results only in a very marginal increase in wind farm availability. Similar analyses can also be made for the number of spares available in stock.

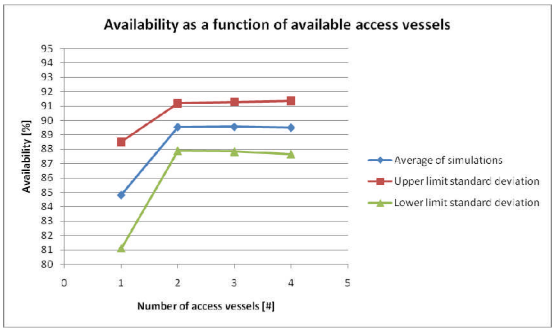


Figure 4.3: *OMCE-Calculator demo results; wind farm availability as a function of vessels available*

Future developments of the OMCE-Calculator will include determination of requirements for the full version based on experiences with the demo.

5 Acknowledgements

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6 References

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