A structured approach for data collection and analysis
Assess the offshore O&M strategy with OMCE

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Summary

Operation & maintenance is one of the main cost drivers for offshore wind. To aid wind farm operators in structuring their data collection processes and perform O&M strategy modelling, ECN is developing the Operation and Maintenance Cost Estimator (OMCE). The OMCE comprises the OMCE Building Blocks (BBs) and the OMCE-Calculator modules to analyse wind farm data and use those results as input for O&M strategy analyses. ECN and partner RWE defined a research project in the context of the Dutch FLOW programme with the main goal to apply the OMCE model in an offshore wind farm and assess the contribution in realisation of cost reductions.

An analysis of operational data supplied by RWE revealed that O&M data are stored in different formats and at different locations which do not correlate well. To better structure O&M data the initial Event List format is refined. The BBs 'O&M' and 'Logistics' are also further developed, verified and applied to analyse component failure behaviour and logistic aspects of repairs. A reporting system is defined which can be used to perform regular BB analyses using updated O&M data in the Event List format.

It is concluded that the majority of required information for maintenance strategy assessment is already available from existing data sources. Next steps include the integration of data collection procedures within Computerised Maintenance Management Systems and further implementation of the OMCE approach.

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

1 Introduction to OMCE and research objectives

1.1 Background

In the first half of 2013 more than 1 GW of offshore wind capacity was installed in Europe with 277 new offshore wind turbines. This brings the total installed offshore capacity in Europe at little over 6 GW in 58 wind farms [1]. With European member states planning to have more than 40 GW of installed capacity for offshore wind by 2020, thousands of wind turbines should be transported, installed, operated and maintained in the short term [2]. This means that the required effort for Operation and Maintenance (O&M) of offshore wind farms will be enormous, and control and optimisation of O&M during the lifetime of these offshore wind turbines is essential for a successful economic exploitation.

Operational expenses contribute by approximately 25% to the Levelised Cost Of Energy and are therefore one of the main cost drivers for offshore wind [3], [4]. The key to efficient operation and maintenance of offshore wind farms is a full understanding of the processes and cost drivers related to O&M. Currently most operators collect vast quantities of data produced by their wind farms in separate documents, files and databases. Yet, not all of them have the tools or the working processes available to make full use of this data and as a result are lacking full understanding of their wind farm and with that the ability to develop O&M strategies that reduce operational costs and increase revenues .

1.2 Operation and Maintenance Cost Estimator (OMCE)

To estimate and optimise the O&M costs and downtime, the amount of preventive, corrective and condition based maintenance needs to be determined. Site-specific operational data such as: component failure rates, actual repair times, vessel transfer times, spare part costs, SCADA data, data from load measurement campaigns and data from condition monitoring systems all play a role and need to be quantified. It is recognised by ECN that not all operators are able to collect these kinds of operational data in a structured manner, which allows for (semi-)automated data analysis as input for cost modelling tools. In order to improve this situation, ECN is developing the Operation & Maintenance Cost Estimator (OMCE) [5], [6].

The OMCE is designed to determine the O&M effort and associated costs for the coming period (say the next 1, 2 or 5 years) taking into account the operational experience available at that moment. Two modules can be distinguished in the overall structure of the OMCE as depicted in Figure 1-1:

1. The OMCE Building Blocks

   To process operational data, the OMCE Building Blocks (BBs) have been specified. The BBs objectives are to process and analyse (structured) wind farm data in such a way that wind farm performance information is obtained which can also be used as input for the OMCE-Calculator cost modelling tool.

2. The OMCE-Calculator

   To assess the future O&M effort the OMCE-Calculator cost modelling tool is developed. Along with other parameters the tool can take information provided by the OMCE Building Blocks into account to perform advanced maintenance strategy analyses.

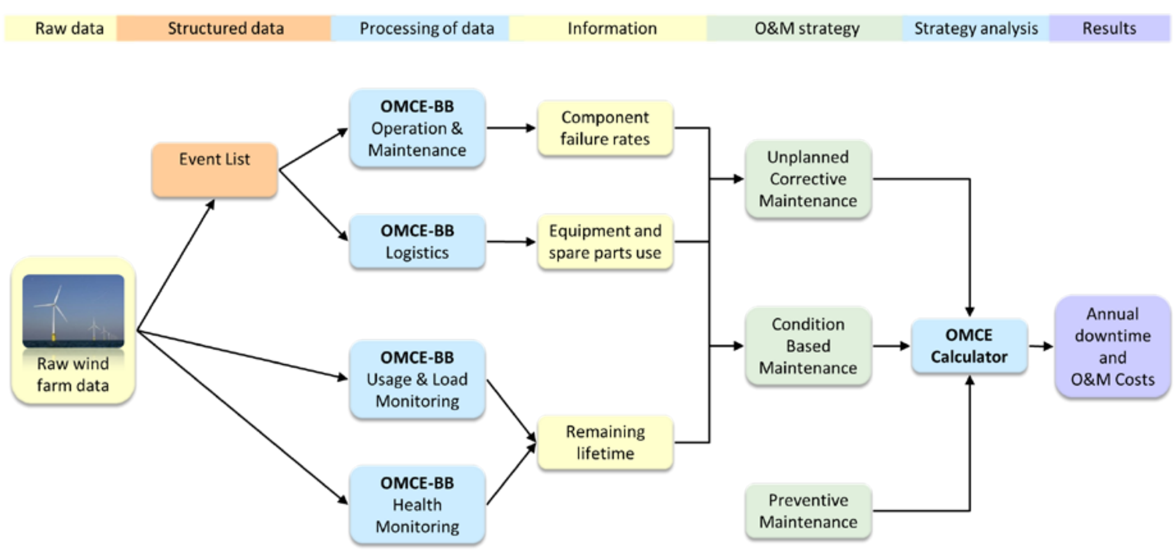

Figure 1-1: *Structure of OMCE showing the steps from structuring operational data in the Event List format through data processing with the OMCE Building Blocks and modelling O&M strategies and performing analyses with the OMCE-Calculator.*

1.3 FLOW research project and objectives

Since operators and OEMs are the owners of the operational data, ECN and partner RWE teamed up to define a research project in the context of the Dutch Far and Large Offshore Wind (FLOW) R&D programme. The main goals of the FLOW programme are: (1) accelerate deployment of (far-) offshore wind and (2) reduce costs and risk for far-offshore wind energy. Therefore, the FLOW OMCE research project is set-up with the main objective to develop and validate a baseline model of the OMCE by development of software and working procedures using data and feedback from an existing RWE wind farm.

The project focusses on further development of: (1) data collection procedures and the 'Event List' format, (2) further development of OMCE Building Blocks 'Operation & Maintenance' and 'Logistics' and (3) development of the OMCE-Calculator cost modelling tool, see Figure 1-1 [1]. This paper only addresses project results concerning procedures to structure data collection and perform analysis with the OMCE Building Blocks 'O&M' and 'Logistics'.

2 Structuring of operational data

To derive useful information from operational data which can be used as input for O&M cost modelling, it is important that data from sources related to O&M are collected in a structured manner. A first start is the inventory of different O&M data sources to determine which data is available and in what format.

2.1 O&M data sources in practice

As input for OMCE development, O&M data covering a 3 month period was provided by RWE for one of their operational wind farms. Data sources include:

- List of SCADA parameters
- Alarm list
- Meteorological and wave data
- Monthly downtime summary reports
- Daily work reports
- Turbine breakdown in RDS-PP coding
- Daily vessel reports

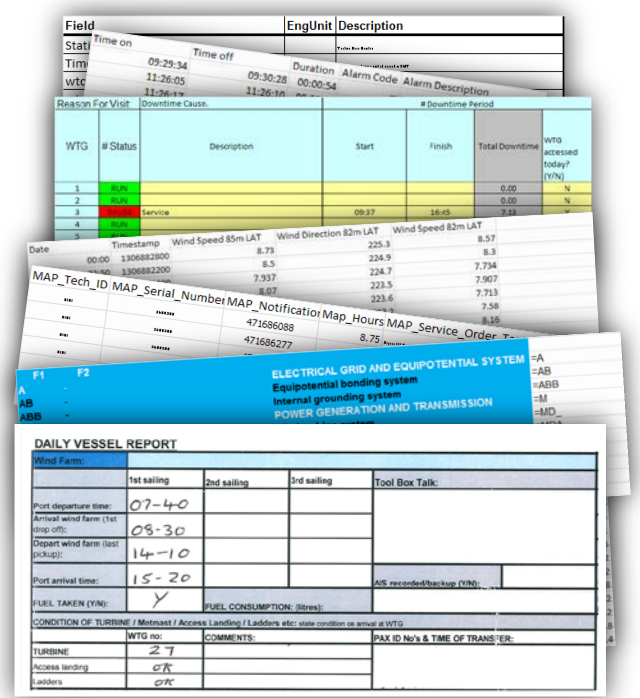

Figure 2-1: *Examples of operational data stored in different uncorrelated formats*

The inventory of available data sources revealed that O&M data is stored in many different sources at independent locations, see Figure 2-1. Additionally, the format of the data sources is different which makes it more difficult to perform automated data processing (e.g. data is seen

[1] The Building Blocks 'Usage & Load Monitoring' and 'Health Monitoring' are both seen as tools which directly use the raw wind farm data as input to generate information on the remaining lifetime of various wind turbine components. Currently ECN is developing the Building Block 'Usage & Load Monitoring' in a separate project named 'Fleet Leader', while the Building Block 'Health Monitoring' is seen as being 3rd party tools such as drive train condition monitoring systems or inspection results.

to be reported per turbine, chronologically, per month, 3 monthly etc.).

From the analysis of available data sources it was concluded by ECN that it is not clear how different alarms, maintenance actions, downtimes, etc. are linked with each other. This lack of data correlation corresponds to observations by ECN in the past, where similar conclusions were drawn [5], [6]. Therefore within the OMCE approach the so-called 'Event List' was introduced which is further discussed in the following section.

2.2 Structuring operational data in Event List format

Within the context of the OMCE, a maintenance event is considered as a (sequence of) maintenance action(s) to prevent or correct turbine malfunctioning. The total duration of an event is often longer than the sum of the individual maintenance actions. Maintenance actions can be, for example, remote resets, visits with technicians only, or the replacement of large components. The location of the Event List within the OMCE concept is in between the raw wind farm data and the BBs, see Figure 1-1. An Event List can be best visualised as a list with maintenance events per turbine in a chronological order. The following requirements are relevant when constructing an Event List suitable for data analysis:

- Combine data from various sources
- Make relations between event and corresponding maintenance action(s)
- Set events per turbine in chronological order
- Data should contain sufficient details to perform analysis with OMCE Building Blocks

Data does not have to be stored in the Event List directly, yet the Event List could be extracted from different databases. This requires the data in these databases to be correlated. Given that data sources provided by RWE were not correlated initially, ECN performed analyses of the available maintenance data to determine whether the fields of the existing Event List format could be filled and/or should be updated. This analysis has proven to be a manual step since:

- The relations between an event and the underlying maintenance actions had to be determined.
- The components and systems on which maintenance was performed was often not described or only specified in a free text-format forcing the data analyst to make assumptions.
- Not all data was available in suitable formats to perform semi-automatic correlation procedures (formats were either inconsistent or hand-written).
- It was difficult to determine the start and cause of an event (e.g. SCADA alarm or inspection result).
- Information on logistic times of spare parts and/or stock control was not supplied by the OEM.

Based on the analysis some of the fields of the Event List format have been updated to match the available on-site data. Examples of such fields are the travel time of access equipment and the number of hours of weather downtime. An example of how the updated Event List format can be structured is presented in Figure 2-2.

Event nr.		*1*	
Start event	[date/time]	15/02/2013 09:33	
Event type		Corrective maintenance	
Turbine ID or BOP ID		1. Turbine A	
Nr. maintenance action		*1.1*	*1.2*
Start	[date/time]	15/02/2013 09:33	16/02/2013 08:30
End		15/02/2013 14:33	16/02/2013 17:00
Duration	[h]	1.05	8.50
Downtime	[h]	5.00	8.50
Type of maintenance		Inspections	Replacement (finalisation)
Weather downtime	[h]	4.00	0.00
Scada alarm code		0001	0010
Scada description		Temperature error	Turbine stopped by operator
Reported labour hours	[h]	2.00	
Crew size		2	
Access equipment		Access vessel	
- travel time (heading out)	[h]	0.75	
- travel time (return)	[h]	1.00	
- fuel consumption	[dm^3]	200	225
Second equipment		n.a.	n.a.
- travel time (one way)	[h]		
- mobilisation time	[h]		
Third equipment		n.a.	n.a.
- travel time (one way)	[h]		
- mobilisation time	[h]		
Explanations		Pitch motor overheated	Replaced pitch drive blade A
Main system_ID		MDC Blade adjustment	
Component ID		GL001 Pitch drive assembly A	
Work carried out		*Replacement*	
Spare part in stock		Yes	
Logistic time spare part	[h]	2	
Consumables		n.a.	
# consumables			
Total labour hours	[h]	***27.50***	
End event		***16/02/2013 17:00***	
Duration event	[h]	***31.44***	
Downtime event	[h]	***31.44***	

Start and definition of event

Definition of individual maintenance actions

End of event and reporting

Figure 2-2: *Example of updated Event List format with two maintenance actions in columns (white fields) as part of a single corrective maintenance event (yellow fields)*

ECN concluded that with the existing data sources it is already possible to fill more than 90% of the required fields in the Event List format, making the data suitable for further analysis with the OMCE Building Blocks. Additionally, the structuring of available data in the Event List format is seen as a wind farm specific task, since most wind farms will have different operational data sets available (e.g. due to another OEM, existing service contracts, company specific operational procedures etc.).

The analysis of available data and setting up the Event List manually has proven to be a labour intensive task. Therefore, future research will focus on assessing the feasibility of and implementing procedures for automated transfer of digital operational data to the Event Format. This work will commence by linking the information to be collected for the Event List to a newly set-up Computerised Maintenance Management System for one of RWE's new offshore wind farms.

3 Analysis of operational data

Once operational data is available in a structured format such as that proposed by the Event List, it is suitable for further processing to (1) obtain insight and knowledge in the performance of the wind farm, and (2) obtain required input parameters for cost modelling tools. In the FLOW OMCE project, BBs ‘O&M’ and ‘Logistics’ are further developed, verified and applied to analyse the failure behaviour of components and logistic aspects of repairs respectively.

3.1 Data analysis with OMCE Building Blocks

Within the context of the OMCE approach, ECN defined BB O&M to obtain information about failure behaviour of components and BB Logistics to obtain information on equipment and spare parts used.

3.1.1 Failure behaviour

To process the structured data with the goal to obtain information on the failure behaviour of components, the Building Block: ‘Operation & Maintenance’ has a twofold objective:

1. Generate information about the failure behaviour and downtime of components to assess the adequacy of the maintenance strategy.
2. Generate updated figures of failure rates (and failure modes) and repair actions of components to be used as input for the OMCE-Calculator.

The information on failure behaviour can be obtained from the structured data in the Event List by means of a ranking analysis to show the contribution of each system or component to the overall number of failures and downtime for which an example is depicted in Figure 3-1. The next step is to perform a trend analysis to determine the corresponding failure frequencies.

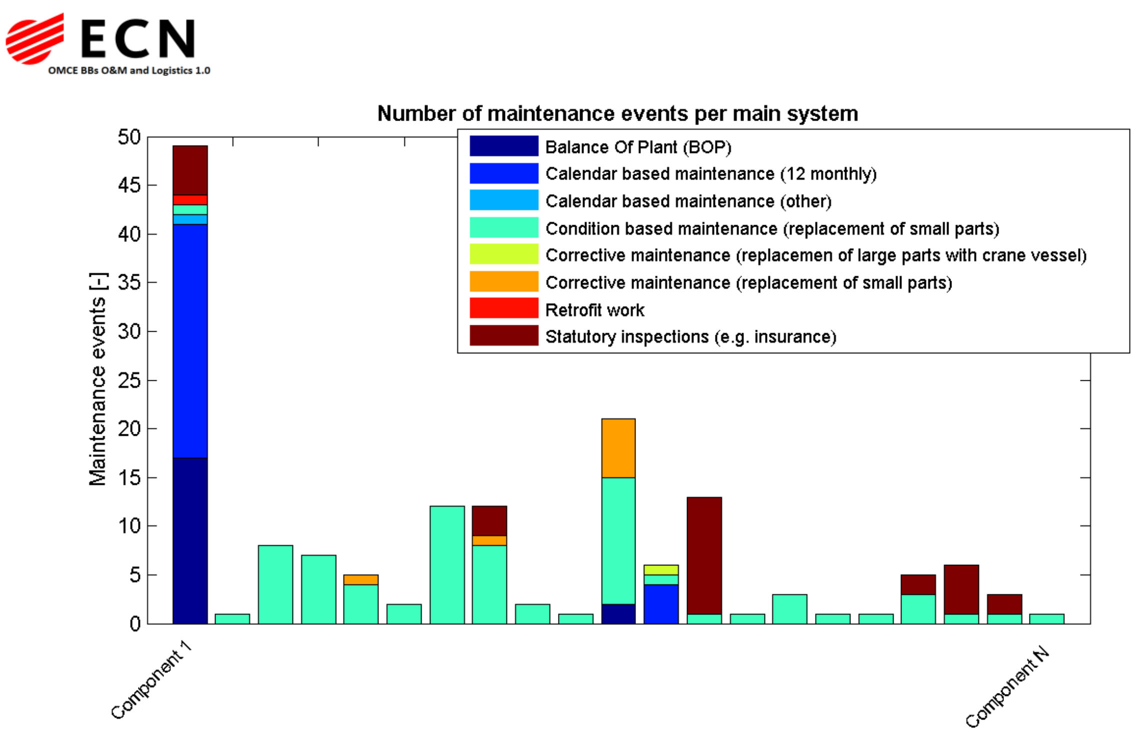

Figure 3-1: *Examples of BB O&M ranking analyses results: overview of number and type of maintenance events per component*

3.1.2 Logistic aspects

To process the structured data with the goal to obtain information on equipment and spare parts used, the Building Block: 'Logistics' also has a twofold objective:

1. Generate information about the use of logistic aspects (equipment, personnel, spare parts, consumables) to assess the adequacy of vessel and spare part usage.
2. Generate 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 logistic aspects can be derived from the structured data in the Event List by analysis of *equipment*, *spare parts* and *repair classes* for the different types of recorded events (e.g. corrective, condition based etc.).

An example of the analysis of repair classes is depicted in Figure 3-2. Here, CDF plots for the time to organise, repair duration and number of technicians are displayed for a number of recorded repair maintenance actions which are classified as 'Repair, cleaning 4'.

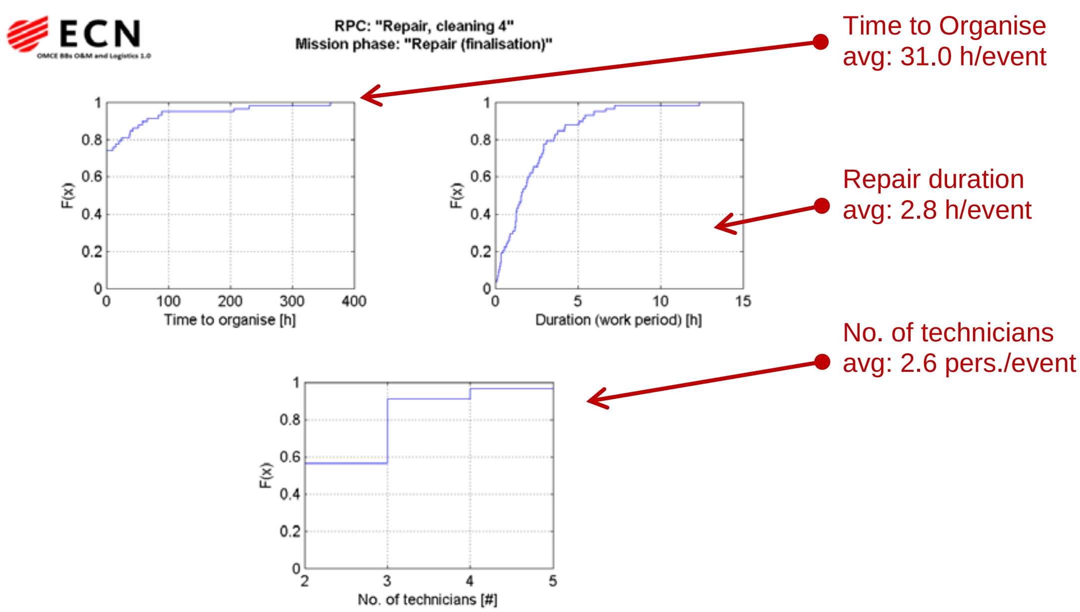

Figure 3-2: *Examples of BB Logistics repair class analysis results; CDF plots for: Time to organise, Duration and Number of technicians.*

3.2 Reporting of wind farm performance

The Building Blocks analyses should be performed using updated O&M data in the Event List as input which can be compared to previous analyses results. In order to assist the user of the BBs in performing the analyses and have a quick overview of the wind farm operational data, ECN is developing a customized reporting system. The reporting system is consisting of three sections: (1) the report profile, (2) profile analyses and (3) report dissemination as described in the following sections.

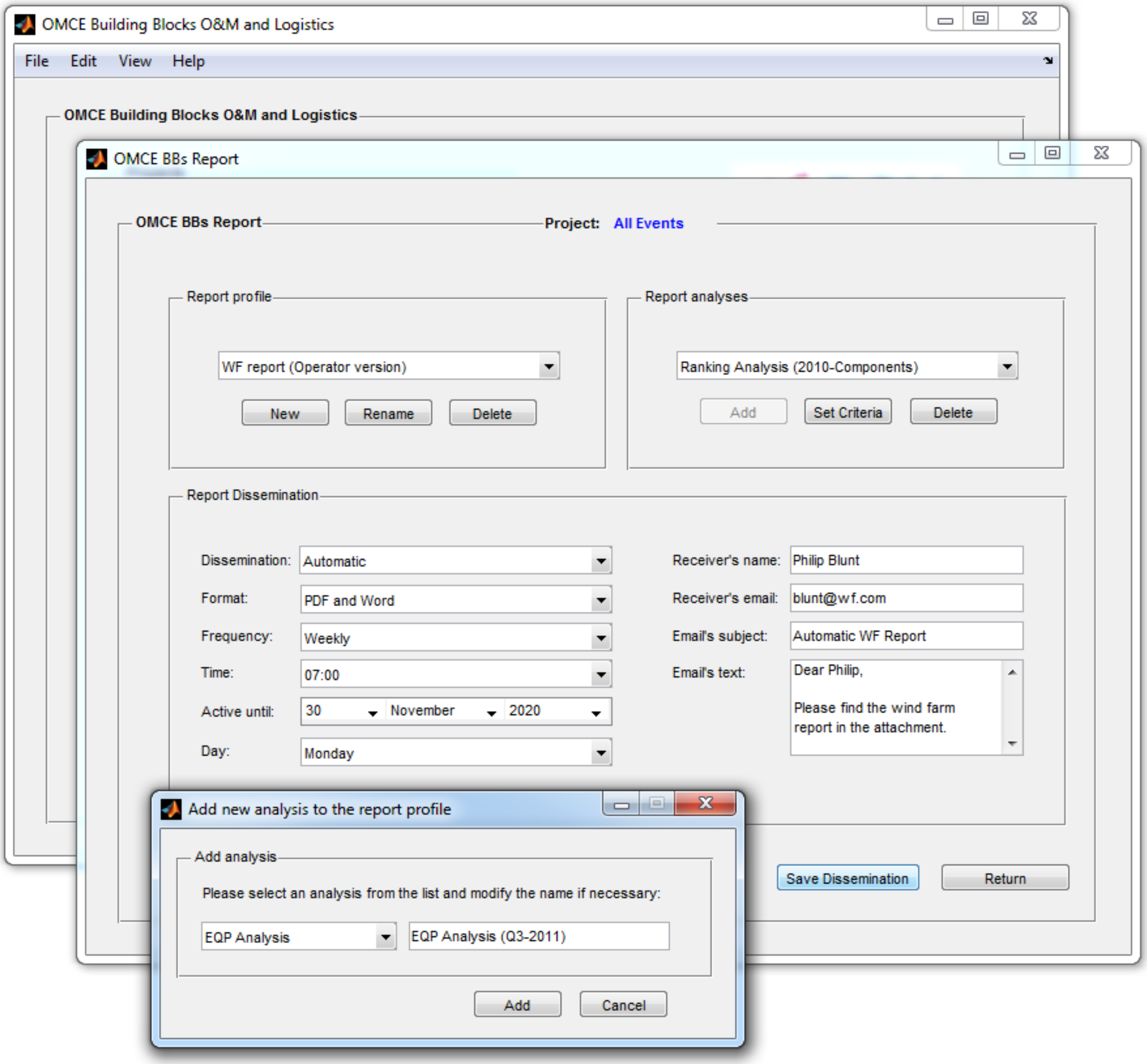

Figure 3-3: *Reporting system of OMCE Building Blocks with report profile, report analyses and report dissemination options.*

3.2.1 Profile

The report of wind farm performance could be generated for different purposes. Aspects important for a wind farm operator could be different from aspects important for the owner of the wind farm. In the reporting system of OMCE BBs it is possible to define different report profiles for different users of the report, like the wind farm owner or the operator.

3.2.2 Analyses

As discussed before the OMCE BBs include different analyses to generate information on failure behaviour of wind farm components and logistics aspects. For example, a user may be interested to report the number of failures of wind turbine components over different time periods which will require multiple trend analyses to be performed. This is possible by adding multiple analyses to the report profile. In this way two similar analysis types with different criteria can be included as well.

3.2.3 Dissemination

For each report profile a report file can be generated manually as a PDF or Word file containing plots and data tables of the analyses results. It is also possible to use automatic dissemination. By using automatic dissemination the user of OMCE BBs will receive periodic reports (like weekly or monthly) in his or her email to have a quick overview of the different operational aspects of the wind farm. An example of the generated report is given in Figure 3-4.

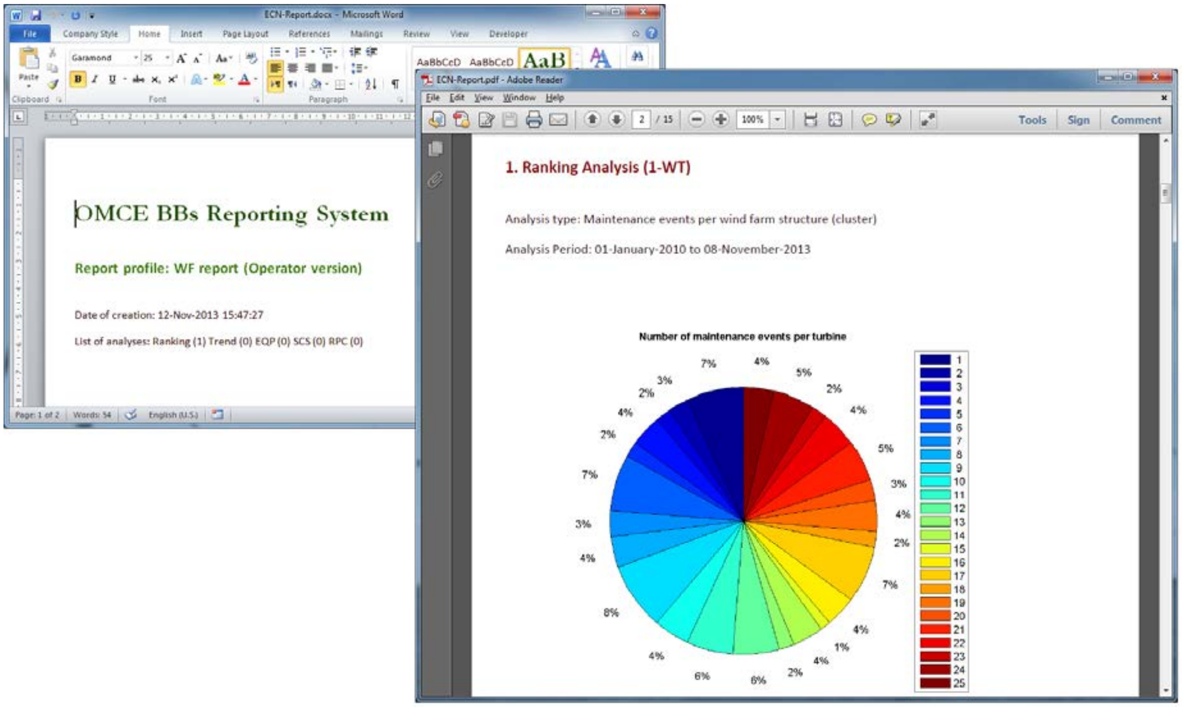

Figure 3-4: *Example of OMCE Building Blocks customized report output*

Further development of the reporting module is on-going through the FLOW OMCE project.

4 Conclusions and next steps

To reduce operational costs and increase revenues for offshore wind farms it is essential that operators structure their data collection processes to obtain information for:

1. A good insight in the operational performance of the wind farm
2. Input for cost modelling tools to improve the O&M strategy

From the analysis of available data sources it was concluded that it is not clear how different alarms, maintenance actions, downtimes, etc. are linked with each other. However, a manual analysis revealed that by existing data sources it is already possible to fill the majority of the required fields in the Event List format, making the data suitable for further analysis with the OMCE Building Blocks. The structuring of available data in the Event List format is seen as a wind farm specific task which should be automated if possible.

By using the structured data in the Event List format, the BBs 'O&M' and 'Logistics' are further developed, verified and applied to analyse the failure behaviour of components and logistic aspects of repairs respectively. A structure for a customised reporting module to regularly perform (updated) data analyses with the OMCE Building Blocks is set-up and implemented in the software.

Next steps achieved through the FLOW OMCE project will be:

- Integration of data collection procedures within operator Computerised Maintenance Management Systems.
- Expanding the data analysis and reporting possibilities of the OMCE Building Blocks based upon user feedback.
- Implementation and validation of the OMCE approach in an offshore wind farm using the information generated by the wind farm through the Event List and OMCE Building Blocks as input for performing O&M strategy studies with the OMCE-Calculator cost modelling tool.

5 Acknowledgements

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