# Maintenance Manager to control operation and maintenance of offshore wind farms

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**Abstract:** Maintenance of wind farms is of increasing importance. Especially in remote areas, where logistics and accessibility are restricted, costs of preventive as well as corrective maintenance form a substantial part of the costs of electricity. The importance of a tool that assists in feedback to the design, failure logging, configuration control and maintenance planning is evident. This paper describes the importance of such a tool, the functional specifications that should be met and the experience with implementation of such a system at a wind turbine manufacturer.

**Keywords:** Maintenance; offshore; wind turbines; wind farms; operations.

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**Biographical notes:** Theo Verbruggen joined the Stork Company in 1981 and has been involved in the development and commissioning of wind turbines and several research projects since that time. In 2001 he joined the group of Operational Techniques and Systems of the Unit Wind Energy of ECN (the Energy Research Centre of the Netherlands). In his current position his work is focused on planning, control, evaluation and optimisation of wind turbine maintenance for offshore applications.

Luc Rademakers has been working in the Unit Wind Energy of ECN (the Energy Research Centre of the Netherlands) since 1989, on the following topics: load measurements, load calculations, development of safety standards for wind turbines, reliability, safety, and risk analyses of wind turbines, and the development of maintenance strategies for offshore wind farms. Since 2000 he has been the head of the group Operational Techniques and Systems of the Unit Wind Energy.

Patrick Roost is founder and co-manager of Baas & Roost Maintenance. They specialise in the field of risk management, maintenance management and optimisation of maintenance. They employ more than 40 maintenance consultants, who are active in the process industry (chemical and food), infrastructure, (rail, road, water, energy) and utilities (energy, hospitals). Activities vary from performing risk analyses, developing and implementing maintenance concepts, carrying out quick scans and improvement projects for maintenance organisations, and the development and implementation of maintenance tools like 'Maintenance Manager' and 'Optimizer+'.

Gerhard Dersjant has been working with Thomassen International, a manufacturer of compressors and gasturbines in the Netherlands, since 1989. As product specialist he has been involved in troubleshooting, optimisation of various compressor components and studies into implementation of condition monitoring. In 1999 he joined Lagerwey and is responsible for the total operation of the service department, including maintenance engineering.

## 1 Introduction

With the development of wind parks in remote areas, the need for efficient maintenance and collecting failure and maintenance data is of increasing importance. The awareness of manufacturers, developers and operators for this subject is growing. When looking to the operational experience of onshore wind parks, there are certainly reasons to emphasise this topic. The main reason is that simple extrapolation of the maintenance strategies from onshore to offshore results in unacceptably high maintenance costs. Operating experience should be collected at an early stage, preferably from similar (offshore design) turbines, operating onshore.

However, it appears to be difficult to obtain a clear strategy on the 'data collection problem' for various reasons:

- operational experience is mostly considered as 'company sensitive' information and not available in a suitable format for further analysis and feedback
- collecting and analysing failure and maintenance data has a long-term objective whereas the objective of most service departments is mainly short-term

ECN, together with Baas & Roost Maintenance Consult, is developing a tool that not only covers planning and scheduling of maintenance, but which also facilitates configuration control, failure logging and analysis tools [1]. This tool ensures reliable collection of operational data, suitable for adequate feedback in engineering, design and maintenance.

## 2 Maintenance aspects

In order to get some feeling about the maintenance costs it is necessary to look in more detail into the elements contributing to it. Two types of maintenance are normally distinguished, i.e. preventive and corrective maintenance.

## 2.1 Preventive maintenance

Preventive maintenance is carried out on a regular basis, usually twice a year for onshore turbines. Typical activities during these maintenance services are inspections, lubrication, replacement of filters, etc. The number of man-hours typically involved in this kind of maintenance is 100-120 man-hours a year for large wind turbines (which strongly depends on the type of turbine). Additionally, a more extensive service takes place after five years and a main overhaul after ten years. For the offshore situation there is a trend to reduce the frequency of preventive maintenance to one service per year which gives a reduction in man-hours and downtime as well.

Inspections carried out during the regular services often result in actions to be carried out later on. This often requires extra visits to the wind turbine. For the onshore wind parks these pending actions can easily be clustered for the whole park, so that the cost consequences are acceptable. For the offshore situation however, every visit to a turbine requires additional transport and embarkation of personnel. So actions resulting from preventive maintenance should be clustered with the regular visits to the extent possible.

## 2.2 Corrective maintenance

For corrective maintenance, the classification given in Table 1 is appropriate for most offshore wind energy applications

**Table 1** Failure classes

| | *Type of corrective maintenance* |
|---|---|
| F1 | Alarm with remote reset |
| F2 | Alarm with repair (consumables) |
| F3 | Alarm with replacement (medium sized components) |
| F4 | Service with repair |
| F5 | Service with replacement |
| F6 | Failure of large parts |
| F7 | Lightning |

During operation, a failure normally results in an alarm, which implies a corrective maintenance action (F1, F2, F3, F6 and F7). Small repairs can often be solved during a first visit. However for the onshore wind parks it often happens that a failure results in more than one maintenance action because of wrong or incomplete diagnostics or missing of the correct components or consumables.

Repair and replacement actions resulting from regular service often require additional visits to the turbine (classes F4 and F5). For the offshore situation, these actions should be clustered with the regular maintenance visits.

## 3 Maintenance costs

When the costs for maintaining wind turbines are calculated, based on on shore experience (logbook data) and with more or less identical maintenance strategies, it is concluded that:

1. the costs for maintenance become unacceptably high
2. the annual costs of corrective maintenance tend to be higher than costs for preventive maintenance whereas onshore these costs have the same order of magnitude

**Table 2** Maintenance costs offshore

| *Type of maintenance* | *Annual Costs (€/kWh)* |
|---|---|
| Preventive maintenance | 0,005 – 0,012 |
| Corrective maintenance | 0,010 – 0.019 |

It is clear that maintenance costs, which are in the order of 20% of the costs of the total energy generation costs, should be decreased significantly in order to make offshore wind energy competitive.

As already mentioned, the basic data originates from logbook data. Further interviews with operators and technicians are usually necessary to obtain further details. The entire process is time consuming and shows room for improvement. It emphasises the need for adequate tools for effective feedback.

## 4 Drivers for cost reduction

Maintenance costs can be reduced by several measures, which are summarised in Table 3 below.

**Table 3** Measures for reduction of O&M costs

| *Preventive maintenance* | *Corrective maintenance* |
|---|---|
| Reduction of:<br>• number of services<br>• downtime<br>• manhours | Reduction of:<br>• number of failures<br>• downtime<br>• manhours |
| Improvement in:<br>• efficient management<br>• clustering of pending actions | Improvement in:<br>• diagnostics and remote completion<br>• diagnostics and efficient completion<br>• repair provisions<br>• diagnostics and redundancy |

The improvements in Table 3 can be achieved by:

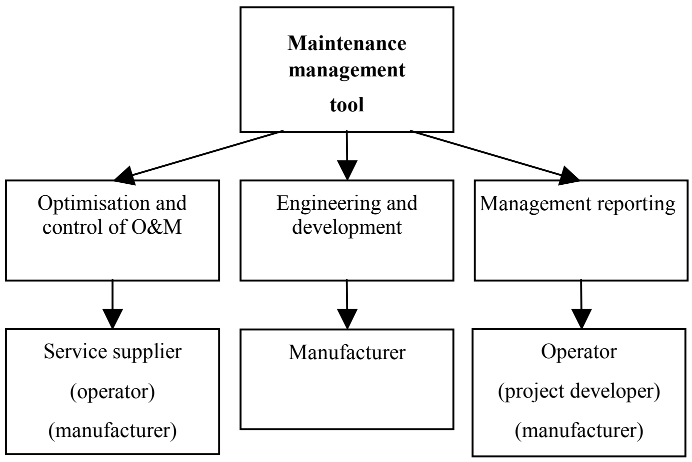
1 an adequate feedback for improvement of the design and maintenance schedule and procedures

2 adequate and easy accessible configuration control for efficient organisation, scheduling.

This requires efficient tools for all parties involved in maintenance and operations:

- The manufacturer, owner of the design needs to give feedback to the engineering department for modification of current models and design information for new turbines. The manufacturer will also have a responsibility for the second line maintenance supporting the first line maintenance which can be improved by adequate feedback.
- The operating company wants to optimise the revenues of the park. Insight into the maintenance costs, failure behaviour and downtimes is essential information for making decisions about improvement of the operation. Insight into maintenance status and efficiency assists the operator in controlling the maintenance supplier.
- The project developer will be more interested in life cycle costs for planning new projects with a reasonable risk level. Decisions will often be based on track-record information. It is obvious that this information will be based on data from manufacturers and operators, so the interest of the developer is indirect.
- The service supplier performs the maintenance task on a contractual basis and has an interest in minimising the costs. This can be achieved by good planning of the maintenance activities based on reliable diagnostics. An extra visit is very expensive.

**Figure 1** Specifications




Based on these considerations, the functional specification for a tool has been derived.

## 5 Functional requirements

A tool that is currently under development, called the Maintenance Manager, appears to be helpful for different parties involved in wind energy. The package covers the requirements as described in the following paragraphs.

### *5.1 Planning and scheduling*

The preventive maintenance actions should be defined and scheduled up to an appropriate level of detail. For wind turbines the maintenance actions are mainly cleaning and inspections. For this application the half and/or yearly maintenance can be defined as one action, including costs, materials and services involved. In case of non-conformity, non-conformity reports should be generated and a follow-up maintenance action should be defined.

### *5.2 Configuration control*

Configuration control is a very important requirement for wind turbines, especially in remote areas. The tool as developed incorporates a general part list at the level of the type of the wind turbine with the actual components used linked to that parts list for each individual turbine. Besides the identification of the parts, the system also offers the possibility to define the major technical specifications. The possibility to include a serial number as compulsory for certain components is also required. Specific to wind turbines is also that the parameter settings for specific component can be stored in the system. A log file is also incorporated to keep track of the changes.

### *5.3 Failure logging*

In order to collect failure data in a systematic way, logging should be based on a Failure Mode and Effect analysis (FMEA). In this FMEA, failure modes and causes are predefined at component level. These FMEA-data of generic wind turbine components are linked to the actual components in the turbine. If a failure occurs with respect to that component, the failure cause and effects can simply be copied from the FMEA. This ensures uniform reporting of failures by different persons and opens the possibility for further analysis.

Besides statistical analysis, this approach also opens up the possibility to develop an expert system, which will assist the maintenance engineer in failure diagnostics.

The disadvantage of this approach is, of course, that the implementation of the tool before having it operational for end users requires much effort. The FMEA should have a level of detail that is in line with the analysis of failures to be performed afterwards. This will be different for all users. A manufacturer is often interested in detailed feedback, whilst an operator experiences the details as ballast.

## *5.4 Analysis*

The tool offers the possibility to export data to Excel or Access, for further analysis. Because this is experienced as laborious, an extensive analysis module has been added to the tool. Standard analysis tools available in the tool are:

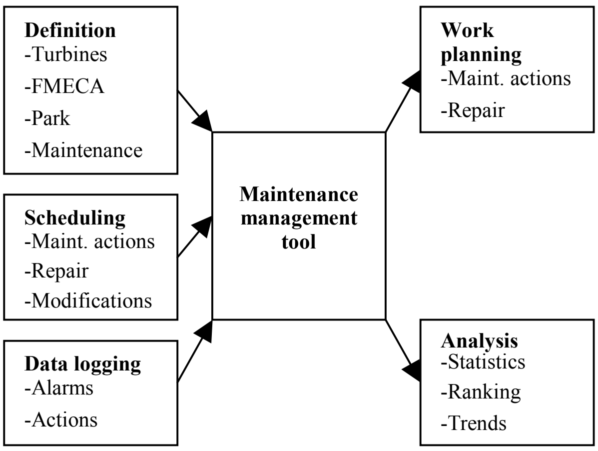
- Calculation of Mean Time To Failure (MTTF) and Mean Time To Repair (MTTR) of systems and components
- ranking of failed components based on the number of failures, maintenance costs or downtime
- trend analysis for tracing the wear of some components. e.g. brake pads
- ranking of component data (most critical failure mode, supplier, cause, etc.)

The population of turbines on which these analyses can be performed is selected based on choosing:

- the type of turbine
- the time frame (calendar based or operational hours based)
- the regions in which the turbines are in operation
- wind farms
- main systems
- components or group of components

These analyses are considered as sufficient for the user to perform general analysis. For specific or detailed onetime failure, analysis export to Excel is possible. The structure of the program and the requirements of the different users is given in Figure 2.

**Figure 2** Structure of the maintenance management tool



## 6 Application area

There appears to be much interest in such a tool from many sides: manufacturers, operators, project developers and service companies. The administration and management of maintenance from wind parks is often considered as an increasing problem keeping pace with the number of turbines and parks. A tool to cover this is considered as very welcome. However, for onshore, the urgency is often not sufficient to invest in the development of adequate tools; the initial effort is quite high. Mostly standard tools are used for understandable reasons: price and time. However, for offshore applications the situation is different. Requirements with respect to reliability become harder, which has consequences for the design. The operators and service companies can simply not afford to waste money due to an unstructured maintenance approach. This possibly creates some room for investment in tools for adequate feedback of operational experience and efficient organisation of maintenance.

## 7 Implementation

ECN, together with Baas & Roost Maintenance, developed such a tool. This tool meets the functional requirements as described above. The basis of the tool is a maintenance management tool, suitable for stand alone industrial installations. This package has been modified in such a way that it complies with the structure of wind farms. It has also been extended with respect to configuration control for software and settings. An additional module has been developed in order to perform standard analysis based on user defined selection criteria.

The package is now being installed at Lagerwey the Windmaster. The policy of this company is to perform second line maintenance (support of first line maintenance) itself. First line maintenance is done by specialised and qualified maintenance suppliers, based on guidelines provided by Lagerwey the Windmaster.

In this case, the Maintenance Manager has been installed for a wind park in Peckelsheim (Germany), which consists of eight Lagerwey 50/750 wind turbines.

The implementation includes:

- preparation of the FMEA
- definition of the structural breakdown of the wind turbines
- import of the parts list
- linking of components to FMEA items and parts list data
- definition of the wind park(s)
- starting up of the system at the manufacturer's site
- implementation of the system at the service supplier
- implementation of the system on the laptops of the service employees

Preparation of the FMEA is a specialised task, which should be performed together with maintenance technicians. The required level of detail depends on the need for feedback from the system to the user. For a manufacturer who wants to have adequate feedback to the engineering department, a high level of detail is required.

The structural breakdown of the turbine is normally defined during its design. For this application, the structural breakdown of the turbine included two levels: building blocks and components. This structure and related TAG-numbers can be copied in this tool, together with defining the links to the FMECA.

When the parts lists are available in a suitable format, they can be read into the program. This parts list may include also type numbers, suppliers, costs, etc.

When this basic information is available in the system, the park can be defined. This can be performed by copying the turbine with a new identification. Also other turbine types can be included in the park.

At this moment, the system has been implemented at the manufacturer's site. This is a test version that includes workstations for:

- Central Service Centre (CSC, manufacturer)
- Regional Service Centre (RSC, service supplier)
- service employees

The authorities of the users at the three levels are different. At the CSC-level, users are authorised to modify e.g. the maintenance schedule, which is locked for lower level users. Modifications of the configuration are also implemented at the CSC level. At the RSC level work planning can be defined and modified. At the level of the service employee, performed action can be reported. During this phase, extensive testing is essential.

The next step will be the implementation of the system at the RSC. Due to organisational aspects and acceptation risks, implementation of the system at the RSC has been delayed.

## 8 Conclusion

There exists much interest in a tool as described above. Despite the accurate event registration of SCADA systems, possibilities to perform analysis especially for identifying the most critical items with respect to maintenance costs are often poor and time consuming. Data on the actual maintenance actions is often missing in the SCADA system. The structured failure logging opens the possibilities to perform the required analysis on demand.

However, the implementation of such a system requires a significant effort that forms a serious drawback. Another problem is that it also has consequences for the organisation of maintenance. This change can only be realised successfully when users experience that the tool helps them in doing their job and not as an extra work load. This requires an accurate implementation trajectory.

The implementation of the system at Lagerwey the Windmaster has been finished. However full implementation of the system in the service organisation, i.e. the RSC and the service employees, has been delayed. With the current system, the risk of non-acceptance by the end users was considered too high, which makes additional modifications necessary.

## Reference

**1** Rademakers, L. *et al*. (2000) *Risk Based Maintenance Management to Reduce the Operational Costs of Wind Energy*, DEWEK, p.49.