Predictive Condition Monitoring for Offshore Wind Energy Converters with Respect to the IEC61400-25 Standard

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Summary : New maintenance and repair strategies have to be worked out for wind energy converters in offshore wind farms. A promising approach is the condition depending maintenance and repair scheduling. Basis for this is the information generated by predictive condition monitoring systems. Maintenance and repair actions can be worked out on demand and during suitable weather conditions. Mobilisation costs for staff, material and craning equipment can be optimised. An international standard for condition monitoring items should be worked out. This can be done as an additional part to the IEC61400 standard.
Keywords: Condition Monitoring, Offshore wind farms, technical guidelines, standards

1. Introduction

The report will introduce the preliminary results of the OffshoreM&R [1] project research work related to fault prediction and predictive condition monitoring. Main objective of this project is to lay the foundations for a condition depending maintenance and repair (M&R) strategy in offshore wind energy converters (WEC). For this, information generated by condition monitoring systems (CMS) will be used.

The project consortium consists of research institutes, WEC manufacturers, fault prediction system providers, wind farm operators and M&R service providers. The following list gives an overview of the partners in the project consortium with their major field of work and some of their tasks in the project:

- Institut für Solare Energieversorgungstechnik (D): development, integration and optimisation of fault prediction algorithms; System tests
- Mita-Teknik a/s (DK): Integration of communication features in WEC control systems; tests;
- Nordic Wind Power AB (S): Delivery of constructional WEC data; Integration of sensor and measurement equipment to WEC technology,
- Plambeck Neue Energien AG (D): Definition of required information for M&R optimisation; Development of new M&R strategies;
- Brüel & Kjær Vibro GmbH (D): Supply of condition monitoring and fault prediction equipment, adaptation and development of fault prediction algorithms;
- Overspeed GmbH & Co. KG, (D): Connection to wind farm management systems; Data base structure and data backup concepts; system tests;
- Gram & Juhl ASP, (DK): Integration of sensors into WEC technology, development of adaptive self learning alarm algorithms;
- Deutsche Montan Technologie GmbH, (D): Supply of condition monitoring and fault prediction equipment, adaptation and development of fault prediction algorithms, extension of communication capabilities of hardware and software;
- Risø National Laboratory, (DK): Connection to wind farm management and surveillance system "CleverFarm"; System prototype installation and field test; Data acquisition and evaluation;

This paper first gives a brief description of the required data acquisition and evaluation technology. The basic methods for a standardised communication between the WEC controller, various CMSs and a SCADA-System/FarmServer are shown. The principle functionality of the M&R scheduling tools to be developed with their suitability according to offshore wind farms will be mentioned. Finally, an overview about the relevant technical guidelines and standards according to condition monitoring of offshore wind energy converters will be given.

2. Data acquisition and evaluation

The monitoring and fault prediction functions of a condition monitoring system are based on robust sensor equipment for continuous measurements and perform online evaluation of characteristic fault indicators by use of modern digital signal processing methods. Modern type wind energy converter technology is mainly based on rotational components. Therefore, measurement of vibration on component housings and structural oscillation will yield data for the calculation of characteristic values by advanced condition monitoring and fault prediction algorithms.

The power output related to the windspeed can be used to monitor the overall condition of a WEC. By applying statistical methods to the time series of wind speed and power, e.g. the calculation of five minute mean values, the actual power characteristic can be evaluated. Deviations from the normal characteristic then will point to a problem with the WEC.

Vibration and oscillation data time series are analysed and evaluated using spectral analysis algorithms. These algorithms are based on the Fast Fourier Transform (FFT) functions, which are common in digital data evaluation. Applying FFT algorithms to

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the above mentioned signal generates characteristic spectral components, e.g. amplitudes and phases of spectral peaks. These characteristic values then will be classified according to the load conditions (power output, rotor RPM, …) of the WEC to be monitored. From this data, information about the current condition of the rotor, gearbox bearings and gearwheels, the generator, the structural health conditions of the tower and supporting structure and the condition of some other WEC components can be obtained.

To perform fault prediction and condition monitoring tasks in horizontal axis wind turbines, specific sensor configurations and also the above mentioned data acquisition and evaluation algorithms are required. These items are described in various publications, e.g. in [1, 2]. Therefore, they will not be discussed here in detail.

3. Communication

For the communication within a wind energy converter itself and from the wind energy converter to the outside world, new approaches will be used. The idea is that one or more CMSs installed in a WEC communicate in a client/server structure. For this, an Ethernet network with TCP/IP protocol is suitable. Ethernet LANs have become a quasi standard in the WEC internal and also in the wind farm communication . For outside communication there are other solutions possible, e.g. WLAN from a wind energy converter to a centralised SCADA system or Farm Server. The principle structure of the communication network in a WEC and with centralised units of the wind farm is shown in **fig. 1**:

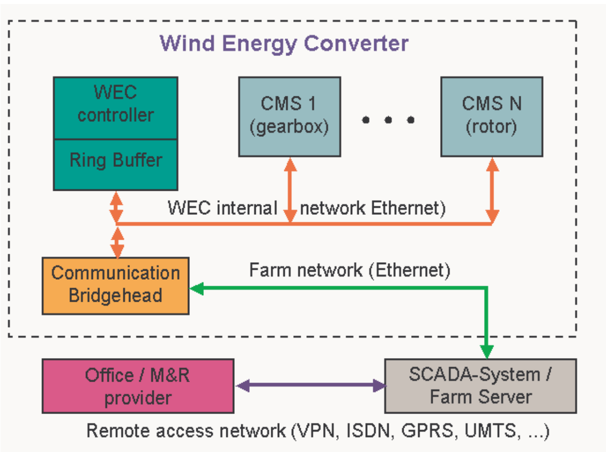

Fig. 1: Communication in wind energy converters

To operate a CMS in a wind turbine some more communication with the internal controller is required. There are three types of signals, which have to be made available for one or more condition monitoring systems in a wind energy converter. The first group of signals consists of condition monitoring system specific sensor signals. For example, this can be signals from vibration sensors for a gearbox and bearing condition monitoring system or signals from a conductivity sensor for an oil quality condition monitoring system. Since these signals are very specific due to the individual monitoring task, it makes no sense to broadcast them to other condition monitoring systems.

The second group, consisting of time critical analogue, digital or pulse hardware signals coming from the wind energy converter's control system, could be useful for more than one of the condition monitoring systems. To provide all the relevant CMSs with these signals, a hardware data bus configuration is recommended. An example for such a configuration is given in **fig. 2**. The mentioned signal specifications (analogue: 4-20 mA signals, digital/pulse. 0/24 V signals) meet the industrial standards for process measurement technology and are well proven to be robust against electromagnetic interference problems. By use of galvanically separated coupling units (e.g. opto coupling devices), interference between the condition monitoring system and the wind energy converter's control system can be avoided.

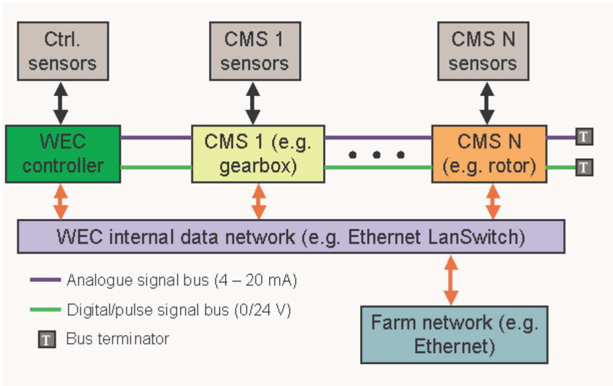

Fig. 2: Data bus structure for communication between CMS and the WEC controller

The third group of signals consist of status information about the actual wind energy converter performance. These signals could be the active power output, the wind speed and several temperatures of bearings and gearboxes. The signals are used for classification of different characteristic values generated by the condition monitoring system's evaluation algorithms. Since the classification process is not time critical, these signals can be provided as time stamped numeric data files. An internal time synchronisation device will be required to perform the classification with numerical data, e.g. a network time protocol (NTP) server. Broadcasting of the data files can be achieved by use of a client/server structure, where the condition monitoring systems will download data files from an internal server running on the WEC controller.

A compilation of the required data and their underlying signals for performing condition monitoring and fault prediction tasks in WECs is given in the upcoming international standard IEC61400, Part 25: "Communication for monitoring and control of wind power plants". The part 25 is quite close to its publication and defines the naming convention for the data, the routines for data transfer in the mentioned client/server structure, the data formats based on the XML file format standards and many things more. The requirements of the IEC61400-25 will be integrated in the CMSs and in the WEC controller systems which are supplied by the OffshoreM&R project partners. The communication system then will be tested in the laboratory and also in some field test WEC installations.

4. Maintenance and Repair Strategies

Offshore WECs require specific strategies for M&R actions. Most of the actual planned offshore wind farm projects will be sited in the North Sea with distances of 50 km and more to the coast line. Therefore, the farms will be exposed to severe climate conditions like high waves and storms over periods of several weeks. This can prevent service teams from access the farm's offshore WECs for quite a long time.

M&R actions on offshore WECs will be quite cost intensive. M&R Personnel have to be taken out by boat or helicopters. Heavy equipment and spare parts have to be transported also by ships. Replacement of main components often require external cranes. Due to the above mentioned distance, all these actions are very time and money consuming. Below, there are different approaches for M&R strategies described with their advantages and disadvantages with respect to offshore WECs:

Cyclic M&R strategy
With this strategy, the system will be inspected and maintained cyclically. Cycle times will be matched to the requirements of the respective system components, e.g. components, which show first indications of wear or fatigue, will be replaced. This strategy requires regular access to the system. **Advantages**: downtime probability is low, M&R activities can be scheduled quite good and spare part logistics is easy. **Disadvantages**: components will not be used up to their maximum lifetime, therefore it is cost intensive. M&R scheduling can be confused by climate (wind farm can be unreachable for several weeks in the North Sea).

Break down M&R strategy
M&R activities will not take place or will be reduced to a minimum. The system will be operated until a major failure of a component will result in a shut down. **Advantages**: Low M&R costs during operation phase. **Disadvantages**: High risk of consequential damages resulting in extensive downtimes. No M&R activity scheduling possible. Spare part logistics is complicated, long delivery periods for spare parts are likely.

Condition depending M&R strategy
System components will be operated to a defined condition of wear and fatigue. When this condition is reached, the component will be maintained and/or replaced. **Advantages**: Components will be used up to their lifetimes. Downtime probability is low. M&R activities can be scheduled quite good. Spare part logistics is easy. **Disadvantages**: Required reliable information about the remaining lifetime of the system components. High effort for condition monitoring hardware and software required.

One part of the work in the OffshoreM&R project is to investigate an optimised M&R strategy for offshore WECs. Figure 3 shows the time depending condition of a technical system like a WEC with respect to the applied M&R strategy in principle.

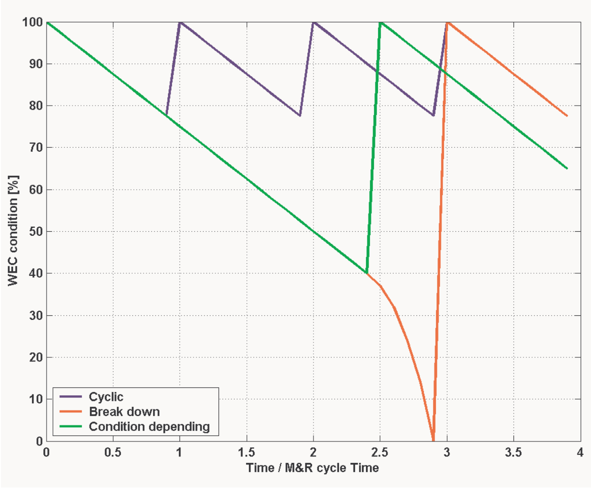

Fig. 3: Comparison of different M&R strategies [3]

The cyclic M&R approach for offshore WECs means that components which are exposed to wear and fatigue, like bearings or gearboxes, have to be replaced regularly. Even if these components are not at the end of their lifetime and can be repowered after revision, a big share of the costs for such a M&R strategy then will result in the supply for cranes and M&R personnel. Transport of spare parts, components and personnel to the wind farm also will be quite cost intensive, due to the distance from the next suitable harbour. For a distance of e.g. 50 km a 6 hour travel time by ship can be assumed both ways.

The break down strategy can be ruled out completely for offshore WECs. Even failures of relative small and dispensable components can lead to severe consequential damages. For example if an oil filter is blocked, the bearings and wheels of the gearbox can take irreparable damages, which require replacement of the complete component. Another aspect is that most of the component failures are likely to be related to the actual load condition of the WEC and also are likely to happen during high load conditions. This means that most of the shutdown events related to component failure will occur during high wind periods. During such periods, accessibility to offshore WECs is likely to be bad. Downtimes within such periods will lead to high production losses.

Looking at the advantages and disadvantages of the different M&R strategies described, it can be found that a condition depending strategy will be most beneficial for offshore WECs [3, 4]. An interesting approach to economically optimise such a strategy is the Reliability Centered Maintenance (RCM) method. For many years it is used in several fields of industrial M&R activities and lead to cost reduction e.g. within the offshore oil and gas industry. The method is based on case studies to define the consequences of faults with respect to the safety of personnel, environmental impacts, production availability and material losses and costs. A detailed description of the RCM method can be found in [6].

5. Relevant technical guidelines and standards

During the last years it becomes more and more obvious that an international standard for the field of condition monitoring in WECs is required. A first step towards this was made by the German Allianz Zentrum für Technik (AZT). AZT has worked out a paper with requirements for CMS in WECs. On the basis of this and some other papers, a technical guideline has been formulated by the Germanischer Lloyd Wind, Germany. On the international level, there is currently a standard worked out, which deals with the communication in WECs and wind farms. The following **table 1** gives an overview about some of the relevant existing guidelines and standards and their contents and actual status:

Item	Contents/subject	Status
IEC61850: "Communication networks and systems in substations"	Definition of communication between energy supply units and energy distribution units; grid structures service models communication protocols and data structures	partly published, some parts under revision
IEC61400: "Wind turbine generator systems"	Standard for all aspects of WECs, e.g. Power curve measurement, noise levels, lightning protection, ...; Communication definitions referred to the IEC61850.	partly published, some parts under revision
Report of the „Allianz Zentrum für Technik" (AZT), Germany	Definition of „Requirements for Condition Monitoring Systems for WECs" (title of the report); Hardware and software recommendations for use of CMS in WECs	published
Guideline Gothaer Versicherung, Germany	Definitions of „Principles of condition depending M&R in WECs" (title of the guideline)	published
Guideline Germanischer Lloyd Wind	„Guideline for the certification of Condition Monitoring Systems für wind energy converters"	published

Tab.1 Guidelines and standards

In the course of the project OffshoreM&R it has been found that the above mentioned IEC61400 should be extended by an individual part dealing with fault prediction and condition monitoring items. Therefore, the partners of the OffshoreM&R project will actively contribute to the formation of a new IEC project team, which then will work out a draft version for the new part of the IEC61400 to be discussed on the international IEC meetings.

6 Conclusions and outlook

WECs in offshore wind farms require new M&R strategies for which the predictive condition monitoring can be a basis. In the OffshoreM&R project, the required developments according to data acquisition, data evaluation and communication are currently under development. M&R strategies are evaluated according to their suitability in offshore wind farms.

Future activities within the project will be the testing and optimisation of the above mentioned data processing and communication items. From the results of M&R strategy evaluation process, an optimised offshore wind farm M&R scheduling will be obtained. An important activity will be the contribution to an international standard for predictive condition monitoring as a subpart of the IEC61400.

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