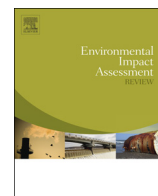




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Modeling and simulation of offshore wind farm O&M processes

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ABSTRACT

This paper describes a holistic approach to operation and maintenance (O&M) processes in the domain of offshore wind farm power generation. The acquisition and process visualization is followed by a risk analysis of all relevant processes. Hereafter, a tool was designed, which is able to model the defined processes in a BPMN 2.0 notation, as well as connect and simulate them. Furthermore, the notation was enriched with new elements, representing other relevant factors that were, to date, only displayable with much higher effort. In that regard a variety of more complex situations were integrated, such as for example new process interactions depending on different weather influences, in which case a stochastic weather generator was combined with the business simulation or other wind farm aspects important to the smooth running of the offshore wind farms. In addition, the choices for different methodologies, such as the simulation framework or the business process notation will be presented and elaborated depending on the impact they had on the development of the approach and the software solution.

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Introduction

Motivation

Over the past two decades, onshore wind energy technology has seen a ten-fold reduction in cost and is now competitive with fossil and nuclear energy in many areas worldwide (Musial et al., 2006). The offshore wind energy branch, however, is still in its early stages, especially as long term projections considering the higher costs for maintenance and servicing are only slowly achieving scientific significance. Nonetheless, there is a broad consensus about their key role in achieving the climate policy targets and the associated energy turnaround (at least for Germany). The goal of the German government is to produce approx. 25.000 MW output through offshore wind farms by 2030, which is more than all German nuclear power plants have been producing until recently. After the successful implementation of initial offshore wind farms such as Alpha Ventus (Germany), Horns Rev (Denmark), and Thanet (UK), numerous offshore wind projects worldwide are either in the planning phase or already under construction (as of March 2013). Yet most of those newly planned offshore wind farms, at least for Germany, will be located much further outwards compared to the “near shore” farms from Denmark. This poses new challenges regarding accessibility and the planning of maintenance. The decisive factor for the success of these and future offshore wind farms is to effectively

address the technical challenges and ensure economic feasibility (Klinke et al., 2012, 1). One main challenge in that regard is that the standardization of the processes is still in a very early stage, compared to other high-end technology sectors, which is also due to the high number of correlating processes and their respective causes or involved parties.

Main objective

The main objective of the project *SystOp Offshore Wind* described in this paper is to determine the relevant players in offshore wind energy sector and identify their interactions, including the capturing of all resulting business processes that influence the continuous smooth running of maintenance activities of offshore wind farms.

Following the description of the processes, they were analyzed in order to deduce critical elements, such as resources or influences on other processes including feedback loops. The main purpose of the process depiction was to establish a basis for communication between the partners that further enabled and evaluated the importance of different stages as well as critical aspects that should be taken under special observation. The different levels of communication and of cooperation were thus made more transparent, enabling a higher security level considering long term planning and projections.

Furthermore, through the combination with business process simulation, it was intended to test the model design and improve processes in question where possible as well as offer alternative courses of actions, which would present additional possibilities to decision-makers and offer concrete, measurable data depending on the choices made.

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Approach and outline

In order to guarantee a broad scientific range different market players in the wind park sector were contacted, such as operators, service companies, owners, transport companies, harbors, airports and employment companies. Some of them contractually agreed to give an insight into their perception of business processes, their resources and their data. A questionnaire was designed including general questions about tasks, resources and typical problems, which provided a substantiated code of practice to describe the project demand for all participants. In successive on-site visits the understanding of their individual business processes with a focus on interfaces to other stakeholders grew (see *Offshore wind farms*). This included reviews of processes already depicted with stakeholders during different meetings, i.e. different iteration phases. In regular workshops with different special subject areas all industry partners were brought together to discuss intermediate results.

The resulting models are the basis for reference models, which will be an adequate communication base for all market players (see *Process overview*, *Choice of suitable notation: BPMN 2.0*, *Risk assessment and analysis of O&M processes*). Additionally, the models provide the basis for the risk analysis and simulation experiments. For determining critical processes, stakeholders, activities and interactions as well as optimization measures risk analysis was conducted (see *Risk assessment and analysis of O&M processes*). For investigating the dynamic runtime-behavior of the wind farm system simulation methodologies were used. Simulation allows the comparison of alternative system configurations by means of key figures like process efficiency and process lead times, the detection of modeling errors and critical elements such as deadlocks or resource bottlenecks (see *Objectives and expected benefits*, *Simulation with BPMN 2.0 models*, *Tool development*).

As the offshore wind farm sector is still young and as the standardization of the components is yet lacking maturity, there are currently many different approaches as well as different technologies in place: e.g., different structures of platforms naturally also need different processes and related resources to be maintained, which of course has to be reflected by modeling and simulation.

On this basis the modeling of the German offshore wind farm Alpha Ventus begun, which meant the integration of all relevant and accessible data from different projects, such as detailed information of the two different wind turbines in place, including their interior components (at least the data that was made available). In addition to the information considering the technical components, data was gathered from Fino 1, which is a research weather station in close proximity to the offshore wind farm Alpha Ventus, as basis for the used weather generation model (see *Simulating wind operation and weather impacts*).

Offshore wind farms

Stakeholders and their interactions

Offshore wind farms have a large amount of different parties involved, infrastructures, interactions between them and interfaces. Fig. 1 depicts the most common dependencies of the operation and maintenance of offshore wind farms. It also provides aspects that are identical for onshore and offshore sections, notably divided through the different background colors. The icons represent the parties involved and infrastructure/resources required. Arrows between them indicate interfaces on the one hand and for the interactions on the other. The interactions are defined as staff, material, waste, finances and information. Different kinds of parameters, e.g. lead time, are implied within the interfaces.

The stakeholder analysis focused on the influences of the parties involved and the effects of their operation and maintenance processes. The critical parties involved as well as secondary stakeholders were identified in detail.

In posters similar to Fig. 1 the interactions were represented in different colors respectively for the different possible interactions of an OWF in maintenance. For each type of interaction, a specific color has been assigned: red refers to personnel, blue to material, and purple to waste; and green is related to finances and black to information. The interactions can be partitioned into message flows, i.e. the ones between the pools, and sequence flows and the ones within the pools.

O&M processes

The operation and maintenance (O&M) processes include all technical and administrative measures that lead to the operation of an offshore wind turbine (OWT) or a respective group of turbines, e.g. a wind farm. They have to take all framework conditions and requirements of the operation phase of an offshore wind farm (OWF) into account and satisfy those to ensure a regular and continuous operation mode.

The process operation, operational management, maintenance as well as modification, which are required for a safe and constant operation of the OWF, are included in the operation processes. The maintenance processes ensure a functional condition of the OWT and its auxiliary plants or the return to this state. Operational and maintenance processes generally comprise technical and organizational tasks.

The operation processes considered in the System Offshore Wind Farm are defined as execution processes: operation, standstill/attendance, maintenance, dangerous situation and operational management.

Out of the operation processes mentioned, the execution process “maintenance” could be adjusted to the most extent regarding process flows and its optimization. Due to this fact, this process was analyzed more closely within *SystOp Offshore Wind*.

In the first instance the status “maintenance” of an OWF contains four main processes DIN 31051 (2003): inspection, maintenance, repair and improvement.

Modeling offshore wind farm processes

An on-site recording of the process flows should be guaranteed to survey and to map the processes realistically. During the multiple surveys, which were partially stretched over several days, experts were interviewed, existing process models were discussed, and with help of specifically designed questionnaires several parameters were recorded.

The results generated in this way provide the data basis for the risk analysis and simulation. Up to now the following main processes (among others) were recorded:

- Repair of small-components of an OWT
- Repair of an operation platform
- Annual maintenance and periodic inspection of an OWF
- Maintenance of the supporting structures
- Repair of large components, in particular rotor blades and gears
- Application procedures by federal police and customs duty
- Legal situation and handling with waste from the EEZ (Exclusive Economic Zone)

Process overview

For a standardization of terms, different detail levels of the process chain Offshore Wind Farm were defined. In order to classify the processes they were divided in the following groups: execution, main and sub-processes, process steps and elementary processes (BTC AG, 2010; Fischermanns, 2012).

Process life-cycles can be ordered hierarchically. Very long running, roughly described project phases contain more detailed cluster processes consisted out of main and sub-process, which at least contains short-running, elementary processes which describe concrete human activities.

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