Improving Wind Turbine Maintenance Activities by Learning from Various Information Flows Available Through the Wind Turbine Life Cycle

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Abstract Maintenance of the offshore wind turbines imposes high cost, effort, and risk on the wind farm owners. Therefore, it is highly demanded to make the wind turbine maintenance activities more reliable and cheaper. To achieve this goal, the focus of current research is to investigate how the available data through the life cycle of an offshore wind turbine can be utilized to improve the maintenance activities. In this work, it will be investigated, how to integrate information feedbacks from the operation phase of an offshore wind turbine to the maintenance stage. A comparison will be done afterwards between the proposed method and existing data-driven maintenance approaches in wind turbine and other industries such as aviation and shipping.

Keywords Offshore wind turbine · Product life cycle information management · Maintenance · Data mining and machine learning

Introduction

The product life cycle information management (PLIM) is the process of gathering, organizing, exchanging, and analysis of key information through all phases of a product's life cycle, which starts with the new idea development and continues with the design, realization, usage, and maintenance and ends with the disposal of the product. In the PLIM process there are different data sources in each of the product's life cycle phases and different information flows to deal with. So far, plenty

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of technologies, such as eXtensible Markup Language (XML), Radio-Frequency Identification (RFID), and Product Embedded Information Devices (PEID), have been developed to support the management of information flows through the life cycle stages.

A problem within the PLIM process is that the captured information flows become weak after the product enters the usage and operation phase, because the data about the condition in which the product is operating or being used is usually not available (Jun and Xirouchakis 2007). This gap has been addressed recently and some advances are made to track and collect product-related data after it enters the usage and operation stage (Abramovici et al. 2008; El Kadiri et al. 2013). Although some advances in this field have been achieved, still there is a need to utilize data in an effective way to improve the information exchange and to integrate the information feedbacks from the usage phase to the other stages of the product life cycle such as the maintenance phase.

An attractive application field of PLIM process is the maintenance of offshore wind turbines. These turbines generate electricity from wind and are located in sea or other bodies of water. The estimated life cycle of a wind turbine is 20 years. Maintenance activities of offshore wind turbines cause most of the costs through the turbine's whole life cycle. According to the National Renewable Energy Laboratory (2013), the operation and maintenance (O&M) activities of offshore wind turbines form one fourth of the lifetime cost of an offshore wind farm and among different O&M tasks, maintenance activities account for almost the largest portion of O&M effort and cost. Therefore, it is highly demanded to reduce maintenance and repair expenses and improve availability of the wind turbines.

To achieve this goal, the focus of current research is to investigate how to enhance offshore wind turbine maintenance activities by utilizing the various data collected during the usage and operation stages. It will be investigated how to generate information feedback flows from the usage phase to the maintenance phase.

Motivation

The main factor that motivates the use of PLIM process in the maintenance of offshore wind turbines is saving of costs. There are various reasons, which make the maintenance activities of offshore wind equipment costly. First of all, the wind turbines are located in the areas surrounded by water and they can only be accessed by boat or helicopter. The use of boat or helicopter depends strictly on the weather condition, because if an unexpected failure occurs turbines are not available until the condition of the sea becomes calm and safe for dispatching the personnel to the site for repair. Also, the distance from shore and number of personnel, who need to be dispatched, as well as turbine's sophisticated technology are among the other parameters, which increase maintenance costs. Therefore, new ways should be developed to reduce expenses arising by breakdown or fault occurrences.

There are currently two maintenance plans for wind farms: corrective maintenance and preventive maintenance. Corrective maintenance is performed when a failure has occurred. In this case, the malfunctioning part will be repaired or replaced. Preventive maintenance involves annual services of the equipment and is usually done in the summer, when the weather condition is more stable (National Renewable Energy Laboratory 2013). In preventive maintenance, some of the components, which are exposed to wear, are changed in a timely manner. Changing the parts on a regular basis is a good strategy to prevent failure, but it imposes extra costs on the system. Because most of the parts being replaced still have not reached their end of lifetime and could have been in service for a longer time. Predictive maintenance approaches can be used instead to help determine the condition of in-service equipment and to predict when maintenance should be performed. This approach saves cost comparing to scheduled preventive maintenance, because by knowing which equipment needs maintenance, the maintenance work can be optimized better (Mobley 2008).

Most predictive maintenance approaches are developed for rotary equipments such as aircraft jet engines and onshore wind turbines (Hameed et al. 2009; Schwabacher and Goebel 2007). The current methods do not consider the special specifications of offshore equipment such as weather condition. Thus, there is a need for research relating to improve maintenance activities in a way to reduce expenses and to meet the specific requirements of offshore conditions.

Moreover, most of the available techniques of predictive maintenance do prediction based on limited data sources. One way to improve predictive maintenance activities is to estimate a better behavior of the system, based on historical data from various data sources and considering the link between a problem and the information from downstream product life cycle phases. For example, one problem in a rotor of a specific wind turbine can be traced by the test results of the manufacturer. Therefore, by linking various data sources and further analyzing them, we can track each maintenance problem more accurately and send feedback to the other stages of product life cycle.

Problem Definition and Research Objective

The problem in a broad view is how to integrate data-based methods, which use life cycle data in offshore wind turbine maintenance. Another part of the problem which needs investigation is to identify best available maintenance strategies either data based or non-data based and compare them with each other as well as with the proposed method. The objective of this study is to investigate how available information of one stage of offshore wind turbine life cycle like usage and operation phase can be converted into effective knowledge. How this generated knowledge can be integrated in the turbine's life cycle in a way that makes improvement to other life cycle phases like maintenance phase. From the practical aspect the objective is to investigate the possibility of developing a maintenance strategy for the offshore wind farms.

Research Methodology

First, different data sources, such as supervisory control and data acquisition (SCADA) system, maintenance operational data, statistical data, weather data, spare part inventory data, drawing plans, geographical and other possible sources, should be identified. Second, the relevant indicators should be selected and measured. Then the data is modeled by means of machine learning and statistical techniques and used to develop a maintenance strategy. Finally the performance of the method is assessed and compared with those of other existing methods.

Expected Results

The expected outcome of this research would be a computer algorithm designed or developed to integrate the information collected from various data sources. This algorithm will be written in a suitable technical software language (e.g., R, or MATLAB). The algorithm will be tested on data available from an offshore wind turbine.

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