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Data Driven Decision Making in Planning the Maintenance Activities of Off-shore Wind Energy

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Abstract

Planning and scheduling for wind farms play a critical role in the costs of maintenance. The use and analysis of field data or so-called Product Use Information (PUI) to improve maintenance activities and to reduce the costs has gained attention in the recent years. The product use data consist of sources such as measure of sensors on the turbines, the alarms information or signals from the condition monitoring, Supervisory Control and Data Acquisition (SCADA) systems, which are currently used in maintenance activities. However, those data have the potential to offer alternative solutions to improve processes and provide better decisions, by transforming them into actionable knowledge. In order to make the right decision it is important to understand, which PUI data source and which data analysis methods, are suitable for what kind of decision making task. The aim of this study is to discover, how analysis of PUI can help in the maintenance processes of off-shore wind power. The techniques from the field of big data analytics for analyzing the PUI are here addressed. The results of this study contain suggestions on the basis of algorithms of data analytics, suitable for each decision type.

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Keywords: Maintenance; (Big) data analysis; Off-shore wind turbines; Decision making

1. Introduction

Wind turbines are valuable and complex products, from engineering perspective. Their complexity can be considered from different dimensions. From product design perspective, due to modular design, the stress calculations and dynamics modelling are complicated. From the perspective of installation and transportation, the wind mill contains heavy and oversized parts. The installation in the site and transportation of the components is a challenge. In addition, the maintenance of these giant structures needs crane and special equipment. If the turbines are located off-shore, these complexities would increase even more. The sea condition and limited accessibility make it even harder to install, maintain and monitor the equipment [7, 8, 27]. Through-life Engineering Services (TES) for the wind turbine plays an important role in the life time costs (life cycle costs) of the equipment. One of the main TES services is maintenance.

Maintenance process is a central service for the cost effectiveness of turbines throughout its lifecycle. As mentioned by [19] the most costs in a wind project (25-30%) are related to operation and maintenance expenses. One reason is the lack of accessibility to the wind farms as they are located in remote

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areas in the sea. Therefore, it is desirable to reduce the maintenance and service costs in the wind farms. For this purpose, condition monitoring systems has gained significant attention. These systems make it possible to control the equipment from remote. The mechanism of condition monitoring is to capture the data from each site (field data), link the data with the pervious history of the component and predict the state of equipment in future based on these values.

In order to enable better through life services, the data from the turbines are nowadays gathered and saved even more than before.

The data usually show the condition in which products are operating. Those data not only can be used for the condition monitoring but also they have the potential to provide insight and knowledge for the decision makers to improve other through life services. This data sources are called Product Use Information (PUI).

The data can be further used to improve the through life services for the off-shore wind energy. However, this has not been studied comprehensively so far. Moreover, it is still unclear, in what types of decision, which method of using the PUI can provide insight for decision maker.

In this paper, we look into the data gathered from the operation and service of the off-shore wind turbines. How these data can be useful considering the data analysis methods will be studied. Where the processed PUI can be effective to improve maintenance planning decisions in the through life services will be examined.

2. Review of literature and problem statement

2.1. TES and service knowledge

TES are referred to the required services, that support a complex engineering product to perform its functionality throughout all the stages of its lifecycle with the optimum cost [22].

The decision makers either own the service knowledge, or are involved in service knowledge creation. Typical service providers are organizations such as maintenance operators and logistic providers. Traditionally, manufactures were not service providers, i.e. delivery and maintenance services. However, the emergence of supply chains, increase in the variety of products, raise of concern for the environment and new product model such as product service systems, made the manufacturers be more involved in the services. Contract-based services for the product can lead to additional profit, and this was better than just focusing on pure production [22].

In order to make decisions and choose the right solution for any service, the TES decision makers must have knowledge of various domains. Because offering the products integrated with the services is not simple and need the expertise from various processes and domains. [22] identified the different types of knowledge that service providers need in order to offer the products integrated with service. This reference named the scope of service knowledge as knowledge of degradation or failure mechanisms, repair knowledge, knowledge of diagnosis and prognostics aligned to degradation mechanism, knowledge of use and knowledge of design function [22]. For better decision making and gaining the mentioned service knowledges, accessing to good and relevant information sources is vital. PUI is a new source of information, to help decision makers to increase their knowledge of product and necessary services. PUI can help to increase the insight about service knowledge. For instance, knowing the details about the condition of operational product can help maintenance provider to find out the main causes of the product failure.

These data can bring more transparency to the mechanisms in the product lifecycle. It can lead to decrease in service costs and therefore, through life costs of the product along its lifecycle [22].

In summary, PUI provide the opportunities for service providers to make better and more realistic decisions. However, not much research has done so far to investigate and cover this issue.

2.2. The PUI and data analysis

Product use information is defined as a term, which refers to the data from the operational product. It is also contained environmental data, use condition data, maintenance history as well as data generated by the product user. The term has been used in the literature by authors such as [3, 9, 33].

The sources of PUI for the maintenance of wind energy include the followings [20, 18]:

- RFID
- Sensors: measures of parameters for controlling of the equipment. Mainly vibration, acceleration, speed and temperature.
- SCADA system signals
- Condition Monitoring (CM) signals
- Maintenance history

In addition, these sources are usually considered in connection to the following data sources for gaining better insight. These data sources are databases of organizations such as transactional, maintenance and asset management system, energy's sales and marketing, logistics and production data [19] as well as weather and environmental data.

In order to make the PUI actionable, it is necessary to process the data. [16] modelled the PUI from cyber physical system's perspective. They proposed a so-called "5C model" which covers different levels of processing information. The model offers five layers of data processing and integration. These layers are sensor data connection, data conversion, cyber space, communication and cognition. In the cognition level the thorough knowledge of the system is offered to experts to support their decisions. There is also a configuration level, which monitors the whole system and provides feedback.

One aspect of PUI data is its characteristics. These data usually have high dimensions and large amounts. To have a grasp of the data amount, each turbine has around 30 sensors and periodically logging data [32]. Therefore, for a wind park about 50-100 wind turbines which are using the PUI, there is a need for a comprehensive large amount of data processing. Moreover, data come from several sources with different formats. The diversity of formats is also observable among the PUI sources provided earlier in this section. Another characteristics is that these data can be produced and