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After-sales maintenance service strategies optimization. An offshore wind farm case study

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Abstract: After-sale maintenance services for machine manufacturers can be a very profitable source of incomes. Although historically machine manufacturers have mainly been focused on improving their production processes, in the last years many machine manufacturers have also included after-sale service processes into their business strategies. When defining after-sale services, one of the main difficulties is to identify, firstly, which maintenance requirements has each asset, secondly, which maintenance strategy (i.e. corrective-preventive-predictive mix) should be followed in each particular case, and thirdly which resources are needed to schedule and perform the maintenance tasks. With the purpose of supporting this decision making process concerning asset management strategies, in the proposed research it is developed an agent-based simulation tool that allows to identify the correct maintenance strategy. The experiments performed for this particular study allows identifying critical service parameters and resources vs. results (i.e. availability and benefits) trade off optimization for an offshore wind farm case study.

Keywords: After-sale services; Asset management; Offshore wind farms; Agent-based simulation

1. INTRODUCTION

Until recently, most machinery fabrication companies have specially been focused on the production and the selling of new equipments. Thus, the improvement of maintenance and modernization processes in machinery fleets is quite a new field for many of them. As a result, it is becoming crucial to develop new tools that facilitate the decision making process about these issues.

Especially in maintenance management, it acquires high relevance establishing adequate maintenance strategies that optimize the assets availability and the life cycle costs. Therefore, the aim of this research is to develop a tool which facilitates the maintenance decision making process concerning a pool of machines in order to be able to improve after-sales services. The tool has been developed in a simulation environment and it is focused on a case study for an offshore wind farm.

Different maintenance strategies have been modelled in the simulation tool, identifying their performance according to the availability and the reliability cost. A brief sensitivity analysis has also been conducted in order to indentify the critical parameters of the offshore wind farms maintenance management.

2. BACKGROUND

Within the machinery fabrication sector, the main objective of the customer is to have their machines available when required, without unexpected downtimes; in order to be able to satisfy the demand when required. Hence, in order to avoid unexpected stops, the customers have usually planned their own maintenance activities (Crespo, 2007); and if a failure happened, they would report it to their suppliers. As a result of this feedback, many machinery suppliers have realized that they have gathered a lot of data about the operational behaviour of their sold machines' pool, which can be used to improve their life cycle management.

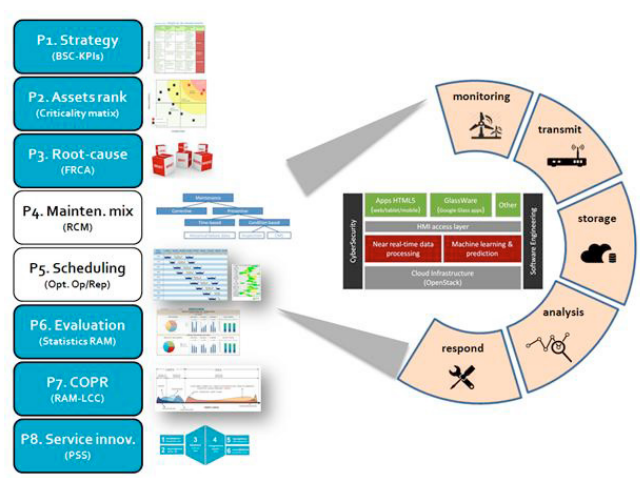

Fig. 1. After-sales maintenance management framework (Castellano et al., 2016)

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Therefore, many machinery suppliers have started to analyse these data and offer maintenance services to improve the availability of their sold machines in a profitable way (Chen and Popovich, 2003). Furthermore, in order to facilitate this after-sales management process for a pool of machines, a particular management framework that follows 8 phases is proposed in Castellano et al. (2016), based on the framework proposed by Crespo (2007) (see Fig.1).

As stated in (Castellano et al., 2016), the first phase of the framework involves the definition of indicators, objectives, strategies and responsibilities within after-sales maintenance management. The aim is to ensure that the strategy and operating objectives of the after-sales maintenance are aligned with the business strategy and objectives. The second phase involves identifying the criticality of the systems, subsystems and components of the machines sold according to their reliability, as well as the consequences arising from the failures (e.g. cost of the unavailability of the machinery in the customer's processes, corrective costs for each failure, and safety and environmental costs). The third phase involves analysing the reasons for the lack of reliability affecting the different systems, subsystems and components of high criticality identified in the previous phase. At the same time, solutions should be proposed during this phase in order to eliminate or diminish critical failures' effects, identifying their root causes.

The fourth phase involves establishing the maintenance plan for the model of the machine whose pool is to be attended through the after-sales service. The prioritisation of critical elements identified in phase 2 is a key input for orchestrating the maintenance mix (i.e. corrective, reliability based and condition based preventive). Once the preventive after-sales maintenance plan has been designed in phase 4, phase 5 involves dimensioning the resources of both own and subcontracted nature (e.g., multi-brand services companies). Within phases 4 and 5 it is suggested the use of monitoring systems and data storage systems, in order to be able to improve and adapt the maintenance strategies to be followed.

Based on the data recorded in the management systems according to the after-sales maintenance service (e.g., CMMS), in phase 6 it is assessed the performance of the maintenance plan proposed. Thus, if it is necessary, resources and maintenance activities will be reorganized in order to attain or improve the goals set in phase 1. Phase 7 deals with the RAM-LCC, which stands for Reliability, Availability, Maintainability and Life Cycle Cost (Parra et al., 2012; Woodward, 1997; Woodhouse, 1993). Once established the equipment's RAM-LCC, it opens up a whole range of servitization possibilities (Baines et al., 2007) for machines' pools. Finally, phase 8 involves the identification and the design of the different after-sales services, in order to align them with the business strategies.

Among all the phases described, this research is centred on the application of phases fourth and fifth to the wind energy sector, in order to improve offshore wind farms' availability (currently near 60% (Feng et al., 2011; Faulstich et al., 2010)) through the analysis of the maintenance strategies, taking into account both the scheduling and the need of resources. The main reason to consider this case study was the interest of a leading wind energy company in developing a preliminary-prospective theoretical study to analyze the potential of using a simulation approach to test the impact of some maintenance strategies over availability metrics for an offshore wind farm.

Traditionally, several maintenance strategies have been studied for the wind energy sector in order to reduce operation and maintenance costs and improve availability. Among these strategies risk-based maintenance, condition based maintenance or reliability centred maintenance have been the most researched ones (the reader is addressed to Barberá et al. (2013) for further information). More recently, for the particular case of the offshore wind energy case study, opportunistic maintenance strategies have also been researched (Sarker and Faiz, 2016; Zhu et al., 2016).

Nevertheless, currently, mainly corrective maintenance and minor preventive inspections are performed in the wind energy sector (Ding and Tian, 2012). So, in order to change this trend and facilitate the application of different maintenance strategies to the offshore wind farms and see their real availability and economical impact, a simulation tool has been developed. This simulation tool bears at the same time several factors that have not previously been considered together, but which directly affect the maintenance strategies' performance according to different authors:

- Identification of adequate corrective, preventive and predictive maintenance tasks mix in order to optimize the wind farms maintenance management (Bevilacqua and Braglia, 2000).
- Efficient planning and evaluation of wind farms' maintenance tasks (Jacquemin, 2007).
- Identification of the spare parts locations, taking into account the wind farm distances and weather conditions (Besnard, 2013).
- Identification of the technicians' locations (Besnard, 2013).
- Decisions about transport's critical economical aspects (Van Bussel and Bierbooms, 2003): number of boats to be bought, need of special boats for spare parts over 2000kg, special boats location and use of helicopters, etc..

3. RESEARCH OBJECTIVE AND METHODOLOGY

The main objective of this research is to improve the availability of an offshore wind farm through analysing the impact of different maintenance strategies. To do so, a preliminary simulation decision support tool has been developed to model and test different strategic maintenance.

The software environment used for its development is the AnyLogic software, which allows agent based modelling and simulation. The main reason for using the agent based modelling and simulation technique is that it has been proved