CbM deployment analysis and methodology

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Abstract
Industry 4.0 based technologies are leading a mayor paradigm of change in industry. Concepts of "Cyber-Physical Systems" (CPS) and "Internet of Things" (IoT) are key enablers to reduce production cost and improve profitability. And maintenance cannot be unaware of this environment.
Maintenance is crucial for the availability, performance, efficiency and quality of products. So maintenance strategies should go further under these technologies. Technologies are used for the continuous characterization of systems health. As final objective is the extension of lifecycle and reduction of lifecycle cost. As first steps of this approach Overall Equipment Manufacturer (OEM) are starting to integrate much more intelligence into their equipment. This paper proposes a methodology for deployment of monitoring technologies in industrial equipment and systems.

Keywords:
Condition Monitoring, service-oriented business models, Maintenance

1 INTRODUCTION

In the new context of Industry 4.0, where fourth industrial revolution is working for more efficiency and productivity, there are some key concepts. Main goal is to run adaptable and effective smart plants using among others Internet of Things (IoT) and Cyber Physical Systems (CPS).

Plants digitalization and using systems/products information are the way to improve products, processes and services. The idea is to have mayor impacts in business using intensively internet and technologies.

Maintenance cannot be unaware of this. Maintenance is crucial for availability, performance and product quality. So if maintenance is considered as a profit centre, an evolution of maintenance strategies supported in technologies is a must. Condition Based Maintenance (CBM) and Prognostic Health Management are key enablers of this evolution [1] [2]. Anomaly and failure detection using predictive technologies and continuous characterization of systems health are the means to align maintenance actions with real equipment needs and interventions could be scheduled effectively taking into account production and exploitation restrictions. In conclusion, the intention is to cut Life Cycle Cost (LCC) of products/systems reducing inspection, shutdowns and inventory costs.

2 IOT AND CPS IN ASSET MANAGEMENT

IoT is the connection of everyday objects with internet and CPS integrates computation, storage and communication capacities with tracking and/or control capacities. In both cases there is an exponential increment of connected components and data, which deals with massive data available and with the necessity to process them (Big Data).

Internet irruption (as communication and distributed storage system) and micro-technologies (micro devices mobile, portable, use) has became possible remote predictive maintenance and control of equipment [3].

CBM is only possible if condition monitoring systems are available. Capacities of CBM are extended with PHM, where condition monitoring, health assessment and prognostics are integrated into an open and modular platform, and supported by operators with smart decision tools [4]. This support is even more important with fleets or group of components.

There are different technological barriers and gaps to overcome:

- Information and automation systems have great and not exploited potential
- Maintenance and operation practices of fleets are performed by field engineers. Remote diagnosis, equipment condition analysis, preventive and corrective maintenance are done as are scheduled in the headquarters.
- Evolution of Total Cost of Ownership (TCO) is a way to measure the transaction of customers from based in price to based in life cycle and relationships. It is gaining interest, but mainly from supplier perspective.

Main technological risks and problems are:

- There are not technical and management standards for technological system implantation
- Cost and complexity of automatic systems for maximum exploitation are high
- Lack of commercial technologies and tools for developed services
- Appropriate designs are not taken into account for exploitation of future resources when equipment is renewed
- Lack of commercial tools for life cycle cost analysis in different industrial domains

Consequently asset management is evolving depending of the needs of equipment owners, operators and users. IoT and CPS lead a new way to manage assets, because of having available real time information, bigger than currently obtainable. For example, predictive maintenance and PHM are concepts that exploit these needs. Moreover, not existing before business opportunities appear with the same physic equipment as remote services based in new business models (pay per use). The objective is to understand which the particular needs to face are.

3 CBM DEPLOYMENT METHODOLOGY

Predictive technologies and particularly PHM are structured in key processes as predictive monitoring / diagnostics, prognostics and decision support. Processes are design to characterize deviations and degradations of systems to evaluate appropriately health and prevent / anticipate failures.

In addition, information contextualization of machine operational condition and use is very important. For diagnostics, experts can use the context knowledge to make hypothesis of abnormal operation. Context knowledge supports better data analysis, enabling relevant information for hypothesis reasoning.

Relevant information of systems o enterprises depends of the maturity and result exploitation of them. Many times simple indicators are enough to have significant improvements for business decisions.

Proposed methodology is based in having a fast deployment of monitoring technology in industrial environments. On this basis, main objective of the methodology is give support to understand and clarify particular needs and structures.

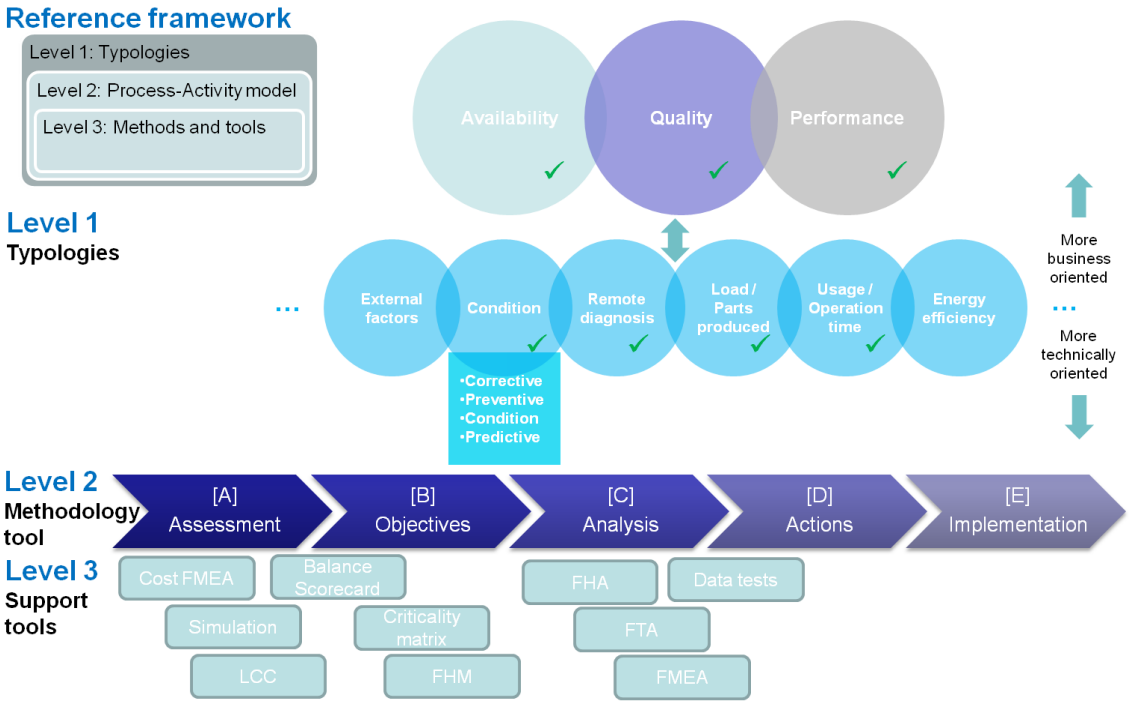

Figure 1: Condition-based Maintenance Reference Framework

Reference framework elements are:

- Typologies: Typology is used to identify in different scenarios scope and focus of activities.
- Process-Activity model: A process-activity model conceptually following a sequence of steps: assessment, objectives, analysis, actions and implementation; and supported by a novel methodology tool.
- Methods and tools: A comprehensive set of existing tools to provide support to activities and methodology steps in the upper level, and additional, more detailed insight, if needed.

The structure of the methodology is presented in the figure 1:

The typology itself has been structured in a hierarchical manner, from more business-oriented scenarios to more technically-oriented scenarios. At the top of the hierarchy the typology is close to business indicators. OEE (Overall Equipment Effectiveness) is one of the main indicators; it includes Availability, Quality and Performance. Down in the hierarchy, and more balanced between business and technical orientation, the typology includes aspects such as condition, remote diagnosis and other context aspects (load/parts produced, usage/operation time, energy efficiency, among others). These can be related to the typology in upper level in order to be more specific about the scenario. Lowest level in the hierarchy will be more technically oriented. For instance, for condition various aspects have been defined for identifying competitive maintenance strategies in this scenario: corrective, preventive, condition and predictive maintenance strategies.

Process-activity model conceptually follows this sequence of steps: assessment, objectives, analysis, actions and implementation. For facilitating and guiding the application of the methodology in practical scenarios a novel methodology tool has been developed.

Finally, on Methods and tools, consists of a comprehensive set of (existing) tools to provide support to activities and methodology steps in the upper level, and additional, more detailed insight, if needed. A number of tools have been considered and aligned with the corresponding steps in the process-activity model. This is described further in the next section, along with the methodology tool.

The developed tool to guide the methodology application intends to present global vision, promote iteration with customer, and show key information in appropriate degree of detail (where individual tools offer support and are applied when are necessary). Tool is presented in figure 2.

Main steps within the methodology tool are:

- Business perspective
- Technical objective
- Technical analysis
- Data monitoring

In relation to the process-activity model of the framework Figure 1, the business perspective step is associated to Level 2 step [A], the assessment of the relation between

business model or plan and the impact of the technologies. The next step, technical objective, is related to step [B], where the objective of the technical approach pursued is stated. Technical analysis and data monitoring steps are related to step [C], and they provide the detail resulting from the analysis of the technologies in relation to the objectives. Finally, from the information available, step [D] is related to the decision on needed actions, such as technology / process adoption / implementation. This step is facilitated by the iterative application of the methodology and subsequently derives in refinement of the information. Step [E] corresponds to the actual implementation of the results.

Tool intends to connect business analysis (e.g. costs, profits) and hardware and software development of technologies.

As basic tool some test and data gathering was done to clarify, configure and adjust the system. Additionally, test helps to algorithm definition. Modal and functional analysis of failures and effects are done to make clear these aspects in some systems.

Finally, a typology of generic algorithm is obtained for information extraction using monitored data which facilitates this business models:

- Use: typically is a cumulative algorithm of collected data. Mainly used to obtain time duration or number of events.
- Events: In a stored data set of a parameter events are detected. Mainly, thresholds are applied to verify if some level has been exceeded (detected event) or not (normality).

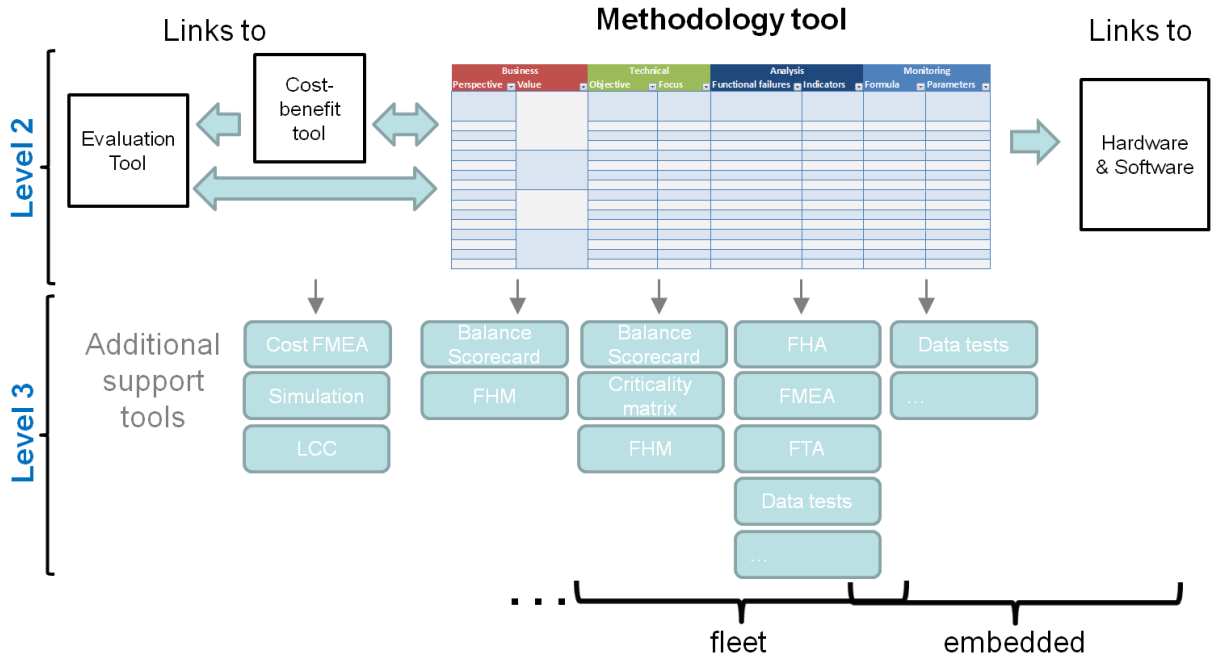

Figure 2: Methodology tool

4 USE CASE

Selected use cases business model is oriented to offer products and services associated to added value of maintenance, which is a source of additional and stable income.

To implement the methodology interviews are done, different aspects are studied, and results of analysis are reflected in the tool. Iteratively content is improved to clarify and understand necessities.

There is a potential impact in different business aspects, mainly in maintenance and life cycle cost reduction, as well as life cycle extension and reusability of components/systems. Asset condition and diagnosis enable new business models. Moreover, relevant context aspects identified are use and operation time, load and produced parts, operation conditions.

Globally, these categories of indicators are identified:

- Use: based for example in hour / operations and anomalies in use
- Condition and diagnosis: based in diverse sensors (vibration, temperature, oil sensors, speed...)
- Performance: Related to produced or consumed energy, or number of operations
- Condition: Abnormal condition detection in a stored set of data, typically from two or more parameter. Threshold could be applied in parameter normality or any other algorithm

Depending on algorithm results alarm/action list is implemented in each case. Below improvement process steps are presented, mainly in Analysis and Actions part of the methodology.

4.1 USE CASE ULMA Carretillas

ULMA Carretillas elevadoras has more than 30 years of experience and offers integral logistic for all types of storage. Main objective is to offer to customers a turnkey solution to obtain maximum efficacy in storage, reducing costs and improving productivity. ULMA offers exclusive commercial advice, with innovative financial figures and equipment rental, and technical advice and preventive maintenance very highly rated by customers. ULMA has 2000 lift-trucks in long and short term rental.

Maintenance is crucial in order to provide adequate service. Business typology is based to give capacity to customers with a fix price. An improvement or evolution of the business will be to move to a pay per use business, where monitoring the use of the trucks is a must to know the fee to be charged. More over life cycle cost of the truck will be ULMA's responsibility. Other important point

is the needs of controlling and improving battery life, because 90 % of equipments have batteries.

Figure 3: ULMA Carretillas: range of products

Once ULMA Carretillas needs are checked, an analysis of the needs, capacities and resources is done to achieve selected objectives. It is important to see which the areas to strength are. Business objectives are promote short term rental, where is important business potential. Company's maturity to achieve service based business is assessed and gaps are checked and prioritized.

One of the results is the necessity of continuous monitoring of critical trucks, so a fleet management platform is suggested for electric and diesel trucks. Potential impact could affect to nine business aspects, between others, life cycle extension, reutilization increase, maintenance cost reduction, and life cycle cost reduction. Different key indicators where identified to be monitored, including operation time, truck use time, impacts and condition monitoring. To check monitoring capacities, a fast data acquisition of truck signals where done and potential monitoring signals where checked to obtain needed indicators.

Thus, truck condition monitoring system is developed having into account needed indicators and first monitoring data test in the field. In addition, due to truck specifications hardware size, weight and communication are particular.

In the particular case of the batteries, where monitoring them is critical the solution is provided by ESENERGIA based on Pulse technology. In addition to monitor batteries, this system also works in energy accumulators when start to sulphatate, since the very moment of their manufacture, and the process speeds up with every load. Sulphates become glass formations, and cover battery cells, thus reducing the capacity of the battery and even making it useless. Pulse Technology separates those glass formations from lead, and makes the battery recover almost all of its previous capacity, which will lead to life cycle extention.

This way, hardware needs and levels are specified and ad hoc system is designed for trucks with capacity to monitor status, performance and detection of events.

5 SUMMARY

New business models are appearing around production companies, lot of them related to maintenance activities which aid to cover customer necessities, not other than assure asset correct operation, minimizing production costs of new machines.

Moreover service based companies are also involved in this changes finding synergies with productive companies and developing joint services where production companies are not able to reach, due to geographical or technological reasons.

In this sense, companies should be involved in renewal steps and search of new business solutions and/or complemented to traditional ones. New technologies are enabling new business models and capacities.

CBM is the most cost-effective maintenance strategy, but in addition sensors could lead to give new capacities to OEM, going from just production to give value added services. Main objective of the article is the presentation of the methodology used and show its application in one use case. It is an approximation to help in the implementation of Condition Monitoring and Fleet Management strategies.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] Lung B, Levrat E, Crespo Marquez A, Erbe H (2009) Conceptual framework for e-Maintenance: illustration by e-Maintenance technologies and platforms. Annual Reviews in Control, pp. 220–229

[2] Alexandre Voisin, Gabriela Medina-Oliva, Maxime Monnin, Jean-Baptiste Leger, and Benoît Iung (2015) Chapter 5: Fault Diagnosis System Based on Ontology for Fleet Case Reused, in Editors: Ebrahimipour, Vahid, Yacout, Soumaya, Ontology Modeling in Physical Asset Integrity Management, Springer

[3] Arnaiz. A., Conde E. (2010) Nuevas tecnologías en mantenimiento predictivo. Cuadernos AEM.

[4] Bengtsson M, Salonen A. (2009) On the Need for Research on Holistic Maintenance. Proc. 22nd International Congress on Condition Monitoring and Diagnostic Engineering Management; p. 165-172.