E-maintenance Platform Applied to a Logistics Vehicle System

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ABSTRACT

The technological evolution, with particular relevance for information technology, and the need for a deeper integration for the maintenance area in the global strategic management of a company, contributed to the e-maintenance phenomenon. On the other hand, the concepts related to the maintenance should be more related to remote maintenance. This way, the development of e-maintenance platforms, seen as the aggregation of software and hardware and others technologies incorporated, allows the implementation of services, which were determining to the development of this concept.

In this work is presented an e-maintenance platform applied to an automatic system application of weighting vehicles used in the cement industry. The system is based on the permanent monitoring of the critical components degradation, which trough an alert system, allows anticipating the failures by sending notifications orders on time to work teams with specific qualifications. The application was developed in Framework SLV Cement of *Cachapuz* Company. This platform has several management modules which allow defining and monitoring the flow of information.

Keywords: *E-maintenance*, Preventive Maintenance, Proactive Maintenance, Failure detection, E-maintenance platforms, Decision support systems.

1. INTRODUCTION

In the past, maintenance was seen as a simple repair job, in which the machines were operated until a failure happened, because there was no way to predict when a failure would happen. In the 50's reliability engineering practices began bringing out the concepts of preventive maintenance and planned maintenance, based on the well-known "bathtube curve" [1]. The planned maintenance usually led to the interruption of ordinary production operations and to the induction of damage, caused by the lack or inadequate interventions. After these and other limitations being identified, in the 70's it was proposed a new concept of preventive maintenance, called Condition-based Maintenance, i.e., Conditioned Maintenance. In this maintenance method, the preventive actions are taken when the symptoms of failure are recognized through the monitoring or diagnosis, allowing taking appropriate actions at the right time, preventing possible failures.

Taking into account a more efficient maintenance and strategies adequate to fabric systems based on e-automation, the new approaches to maintenance are of great prominence. This new reality is included in a context in which there is access to information in real time and a deep integration between production and maintenance. In fact, this led to a new paradigm called e-maintenance. Currently there are several different concepts and definitions for this term, but the most adequate definition to the approach of this work is the one that considers the e-maintenance as a proactive maintenance technology based on the Internet. It consists of a real-time remote assessment of the degradation condition of systems assets, such as equipments, products or processes. The e-maintenance plays an important role in the existing companies, allowing that in the future the maintenance has a status and a good strategic positioning that doesn't have now, as the several contributions, either in the scientific community or in business world, will be of critical importance to statement of e-maintenance as a scientific subject. This work aims at contributing to that. Although this it belongs to the academic world, it is closely connected to the business reality.

This work seeks to contribute to the reinforcement of e-maintenance platforms in the industry. This way, the wok is organized as follows: in section 2 there is made an analysis to the maintenance sector, in its multiples aspects, having as a reference the e-maintenance. In section 3 are presented some e-maintenance platforms created in the last years in the academic and business world; in section 4 are pointed out the main features of the e-maintenance support system. At last, in section 5 are presented the conclusions.

2. MAINTENANCE IN THE PERSPECTIVE OF THE E-MAINTENANCE

Nowadays, the maintenance assumes an increasing domination in the productive sector mostly because of the increasing demand for productivity, availability, safety, product quality and customer satisfaction in a context where profit margins are more and more tight [2]. In fact, the maintenance function plays an important role in the company's ability to compete based on cost, quality and meeting deadlines, as a synchronization between maintenance and production requirements is inevitable [3]. The development of the maintenance concept in the field of "breakdown and repair" to "predict and prevent" technologies is ideal for e-maintenance [4], which has an undeniable impact on customer services, product quality and cost reduction. On the other hand, the maintenance is carried out to a level of degradation of the equipment, instead of the traditional practices, like the MTBF (Mean Time Between Failures) that are replaced by the latest technologies such as the MTBD (Mean Time Between Degradation).

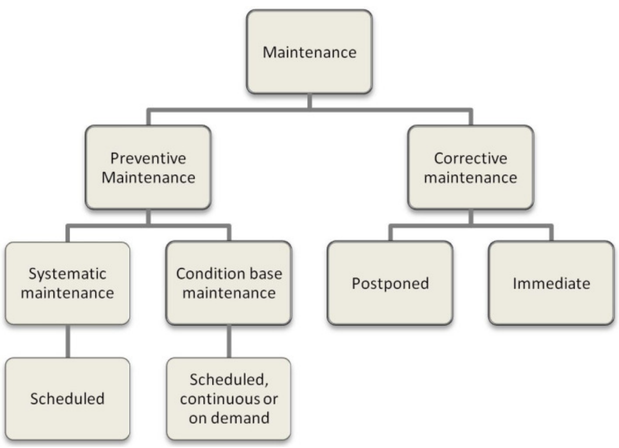

Figure 1. Structure of the maintenance system
(Figure adapted from [5])

The maintenance is "the combination technical, administrative and management actions, during the life cycle of a good, meant to keep or replaced it, in the most economical way, in a state that can fulfil the required function". The concept of maintenance refers to two maintenance strategies, as illustrated in Figure 1. On the one hand, there is a preventive approach, in which the maintenance is carried out in order to prevent malfunction or failures. On the other hand, there is a corrective approach, acting after its breakdown or failure.
The Conditioned Maintenance is based on the monitoring of the components degradation parameters, and on the subsequent actions. This way, the maintenance activities will only begin after the evaluation of conditional parameters, which can be monitored at regular intervals, on demand or permanently. The scheme of this monitoring is presented in Figure 2.

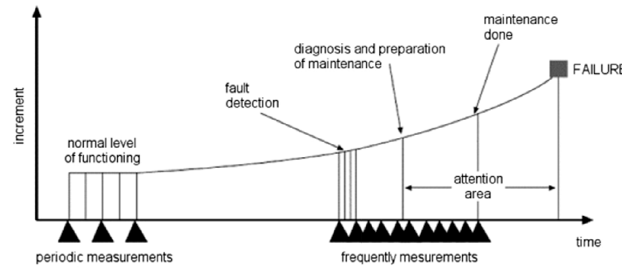

Figure 2. Conditioned maintenance
(Figure adapted from [6])

The e-maintenance concept emerged at the beginning of the 21st century, as a result of the development of more efficient maintenance strategies and service, applied to modern manufacturing systems. In parallel, other approaches to maintenance were developed, such as the proactive maintenance based on conditions, collaborative maintenance, remote maintenance, access to information in real time and the integration of production with the maintenance [7]. This whole set of approaches converged and contributed to the emergence of a new paradigm that has been called e-maintenance.

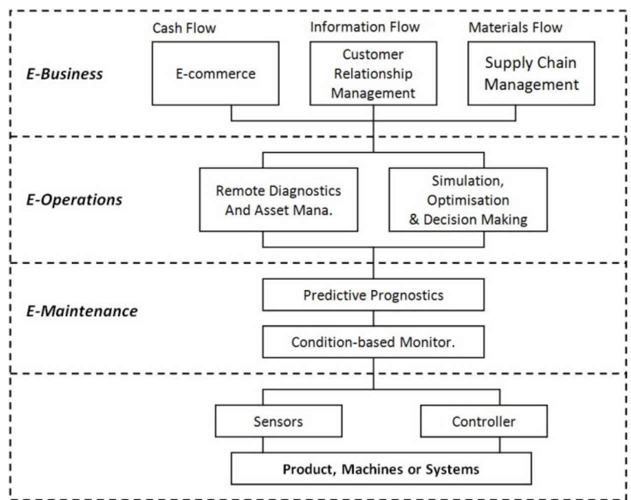

Figure 3. A company's view of e-maintenance
(Figure adapted from [4])

Although there is not a coherent definition for a e-maintenance intelligent system, it can be defined as a predictive maintenance technology based on the Internet and Web-enabled which consists on the intelligent evaluation of the machine degradation, e-prognosis and e e-diagnosis in order to allow manufacturers and customers to have the machinery under conditions of "near-zero-failure". The remote evaluation and real-time information about the performance of the machine requires the integration in several technologies, including sensors, evaluating agents, wireless communications, virtual integration and interface platforms. In general, the e-maintenance can be considered a symbol of gradual replacement of traditional types of maintenance [8] by more predictive/proactive types. Regular periodic maintenance should be advanced and shifted to an intelligent maintenance philosophy to satisfy the manufacturers' high reliability requirements [9]. Koç and

Lee [10] referred the e-maintenance (system) as a predictive maintenance (system), which only provides monitoring and predictive prognostic functions. Figure 3 presents that view of the e-maintenance and its integration on the company [4].

3. E-MAINTENANCE PLATFORMS

The e-maintenance emergence ascribed to the development of research platforms, which allowed students, research group and companies to study in detail this concept. It is supported by software platforms, hardware and new communication technologies, and is part of a new service called e-maintenance. The majority of the platforms that have been created in the last years is used nowadays, such as ICAS, PROTEUS and TELMA, among others.

The Integrated Condition Assessment System (ICAS) project is a commercial software developed by IDAX Inc., which rights are owned and licensed by the U. S. Navy. It has a configurable architecture, like a clamshell, which allows the implementation and monitoring of machinery and Condition-based Maintenance (CBM). Currently ICAS is installed in more than 100 ships of the U. S. Navy [11].

In order to experiment the e-maintenance concept, not only from the research standpoint, but also taking into account the industrial requirements, CRAN (*Centre de Recherche en Automatique de Nancy*) had designed and developed a complete e-maintenance platform: the TELMA platform [12]. It is based on the physical process related to the automation architecture and to the maintenance architecture. It was developed from components of the market to have, as far as possible, features in an industrial context. The TELMA platform supports a physical process dedicated to the unreeling of metal strip. This process is similar to the concrete industrial applications, such as sheet metal or reel paper cutting. The platform is located in Nancy University and was developed mainly to support e-maintenance, by incorporating consistent proactive maintenance strategies in OSA/CBM [13] and by assessing the strategic impacts of the performances of a production global system: productivity (availability, maintainability, …), quality, costs, etc.

The original idea of the PROTEUS project [14], dedicated to the industrial maintenance, is based on the integration of all the necessary tools, which multiple functions may comprise the detection of alarms and the management of spare parts, in order to optimize costs and improve productivity. This optimization can be seen as an extension of the principles of automatic control in the company and, in particular, of the concept of "closed loop" applied to the production process. Therefore, the goal of the PROTEUS is the integration of several subsystems by a generic architecture (based on the Web) and coherent models of heterogeneous components.

4. SLV_EMAINT PLATFORM

SLV – Logistics Vehicle System

The SLV Cement application [15] is an application which aims to the logistics automation of weighting processes of the cement industry. The SLV introduces the concept of self-service, which culminates in a high level of autonomy and in the minimization of errors, allowing drivers to make the operation of loading or unloading in a completely autonomous way. The system aims to the optimization of loading and unloading trough a set of heuristics, which allows the management of maximum number of vehicles inside the plant and the at the charge and discharge stages. It also aims to the planning of a route vehicles must travel to complete the defined transactions correctly and give drivers the ability to independently carry out the loading and unloading operations. That is to say, the SLV gives access 24/7 to the industrial unit, leading to a fair reduction of the number of operators related to the locals of the operations, as seen in Figure 4.

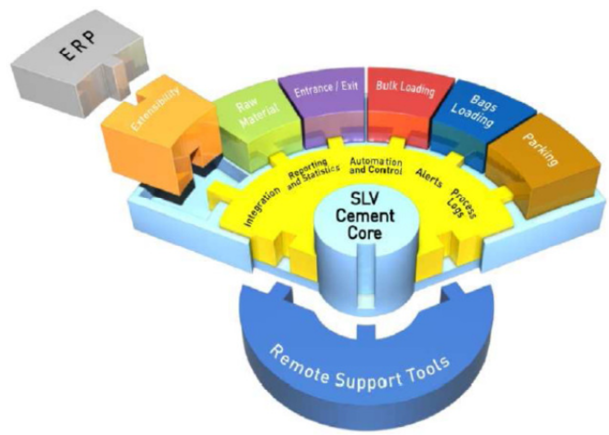

Figure 4. SLV Platform

The logical SLV platform was designed and developed for the Microsoft environment, with a customize information system database in SQL Server 2000/2005, and it was also implemented using universal protocols and the latest technologies, providing the necessary flexibility and robustness to the solution, enhancing its development.

The communication between system's participants is supported by a network that provides a high performance availability and safety. Through this analytical platform it is possible to give managers all the information about the business, the capital and the decision-making, as this information is collected from different sources, combined, treated and subject to a calculation, ending in a set of reports, indicators and detailed charts – Figure 5.

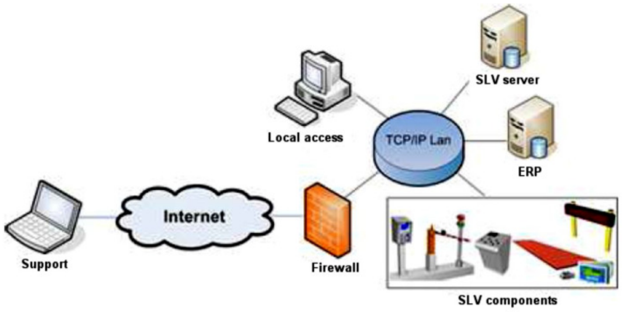

Figure 5. Communication between SLV agents

Currently the maintenance of the system on the field has a preventive and corrective component. However, since we are before high availability systems, more reliable approaches are necessary to ensure the continuity of the service. We are dealing with critical systems, which possible failure of a certain component of the system implies stopping the whole plant. Part of the solution was creating a e-maintenance platform, which allowed the optimization of the entire maintenance process of the system trough timely diagnosis which are supported by the analysis of the components degradation, predicting and warning a potential service failure. The SLV_EMAINT manages the maintenance teams (usually multidisciplinary), and provides them the means to quickly solve problems, by sending emails or SMS warnings, with the necessary documentation.

SLV_EMAINT

The developed system was based on a modular architecture in order to ensure the goals as well as to allow a future evolvement. Figure 6 presents the foundation of developed the platform architecture [16].

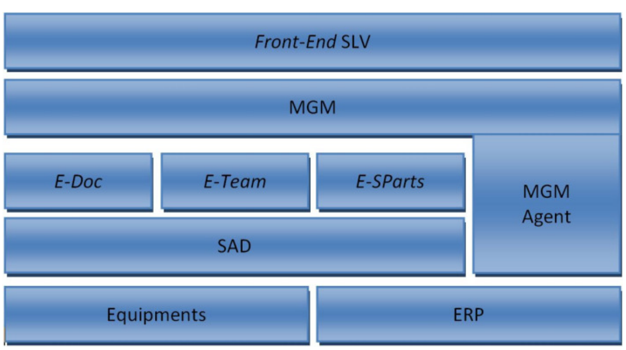

Figure 6. Basis architecture of the SLV_EMAINT system

This architecture is based on two central components: the Front-End – responsible for the management of the existing functions in the module ensure its integration in the SLV platform from the user's standpoint, and the Maintenance Management Module (MGM) – a central module to manage the de e-maintenance functions ensuring the planning and control of maintenance tasks to be accomplished. This module allows defining the incidents (setting rules for intervention) and to generate maintenance services (applications for effective intervention). It makes the link with additional modules such as e-doc (document management), e-team (team management), e-sparts (spare parts management) to maximize the efficiency of the maintenance actions.

Figure 7 illustrates the general appearance of the *front-end* SLV, with the "EMaintenance" tab expanded related to the developed platform features.

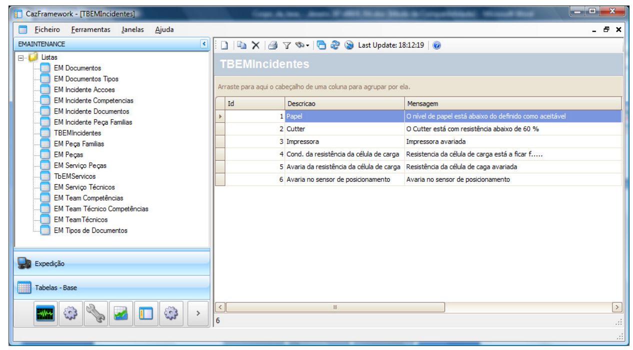

Figure 7. Front-End SLV Interface [16]

The MGM module is used in the planning and control of the maintenance tasks to be performed. At this are defined and characterized different alarm systems, the workflow execution and intervention criteria. This module is the core of the application of e-maintenance that smoothly articulates the needs for action with the allocation of operational resources, physical and documentary support more appropriate to the tasks to perform.

Therefore, maintenance tasks are based on a philosophy which is in turn based on conditions provided by the basic principles described as:

1. ***Incidents*** – definition of intervention processes, through pre-established conditions. The system is configured according to the specific installation and it can be continually updated with the definition of new incidents.
2. ***Services*** - Process or application to intervene on the system, associating the relevant actions to solve an incident.
3. ***Agent validation*** - validation process engine or periodic creation of conditions for maintenance services on automatic mode.

Figure 8 presents the interconnections between the principles previously referred and the relationship between entities, in which the flow of the maintenance process is defined.

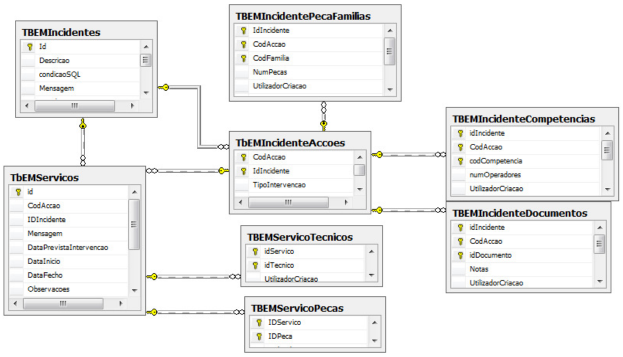

Figure 8. Entities' relationship [16]

These relationships ensure the interconnection and monitoring of the systems on time, to the set of key variables through which the events and intervention procedures to solve real ort potential functioning problems are triggered.

The developed interface is an abstraction of the systems' physical component. The SLV_EMAINT module receives a set of information that have been read, processed and sent by the physical means responsible for the connection between equipments (automations, HMI systems, sensors, load cells, etc.) and the Enterprise Resource Planning (ERP). On the other hand, the implementation of a generic and wide-ranging module which comprises a diversity of entities is not simple to execute. Therefore it must include a large set of connections to ensure the abstraction with the different entities to be integrated and monitored. Therefore, and taking into account the context of this work, a prototype was developed in a case study, in which the concept is shown, based on ordinary situations during the functioning period of the system.

So, with this new system is intended to seek an improvement of maintenance procedures flowchart optimizing the current maintenance levels of paper, Figure 9.

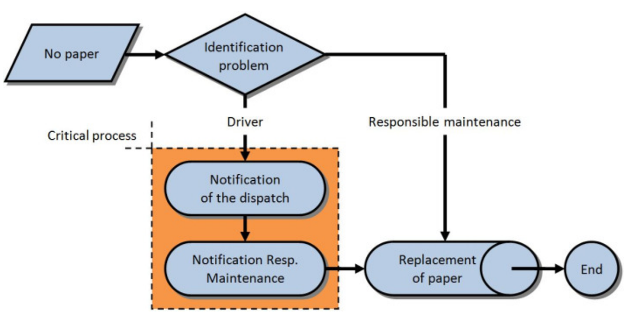

Figure 9. Current flowchart of the paper level maintenance [16]

Now maintenance teams conducting periodic reviews to validate visually the ideal time to replace the paper. Inherent to this procedure is a set of critical factors such as incorrect assessments, validation ranges or misfits consumption unforeseen scenarios that will result in the disruption and lack of paper with the impossibility of issuing the documentation to the driver. Related to this process, which is fallible, the driver makes the notification of the dispatch which forwards the notification to the responsible for the maintenance with the respective break of the index of quality of service and the urgent intervention by the maintenance teams to replace the paper.

The change in this philosophy was translated into flowchart depicted in Figure 10, able to anticipate possible critical situations, as it is based on constant monitoring critical levels, defined by the head of the holding, which may also take advantage of the historic of the plant in order to forecast consumption and trends.

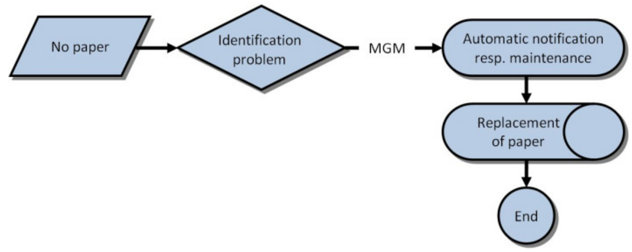

Figure 10. Case study, malfunctioning of the printer [16]

5. CONCLUSIONS

With this work we intended to develop a new module to the SLV Cement of *Cachapuz* managing system. The developed module – the e-maintenance SLV_EMAINT platform – endowed the system with maintenance management capabilities, data acquisition, monitoring the components' degradation, parts management, documental and team management. The adoption of appropriate maintenance strategies, with the potential that e-maintenance introduces, contributes in a decisive way to the optimization of production efficiency. Moreover, the analysis of the indicators and permanent monitoring of the components has a big importance to ensure high levels of availability. It is important to note that maintenance teams have effective alert tools, supported by documental modules, simplifying and avoiding execution errors. The orders are supplemented with information on the whole set of accessories and spare parts necessary to solve incidents. This leads to effective and quick interventions, enhancing the continuity of the service, an important fact to the units of continuous production.

Another important aspect of this work is related to the cooperation between organizations. With this solution, maintenance is a task carried out either in partnership, by local teams with variable settings or by the support staff of *Cachapuz*.

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