Significance of the Predictive Maintenance Strategies for SMEs

Mincho B. Hadjiski, Lyubka A. Doukovska, Stefan L. Kojnov,
Vladimir V. Monov and Vassil G. Nikov
Institute of Information and Communication Technologies - Bulgarian Academy of Sciences,
Acad. G. Bonchev str., bl. 2, 1113 Sofia, Bulgaria
hadjiski@uctm.edu, {doukovska, vmonov}@iit.bas.bg, slk@iinf.bas.bg, vasilnikov@abv.bg

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Abstract: The predictive maintenance is key to long-term profitability of a company in the manufacturing sector it can have a big impact on the supply, quality and price. The main methods are Total Productive Maintenance (TPM) and Reliability Centered Maintenance (RCM) and they must satisfy the requirements of the various small and medium-sized enterprises (SMEs). The paper identifies the barriers to the implementation of TPM within SMEs. Based upon our analysis a methodology for an integrated management system for predictive maintenance or the Advanced Integrated Maintenance Management System (AIMMS) is presented. The results presented in this paper show that AIMMS supports strategic decisions for predictive maintenance and it helps increase the equipment effectiveness by prioritizing the criticality of the equipment focusing on specific resources, increasing profits based on the Return On Investment (ROI).

1 INTRODUCTION

The predictive maintenance includes four stages: predictive diagnosis, estimation of potential looses, decision making for device maintenance and maintenance schedule arrangement. Technological diagnosis as the basis for predictive maintenance is established field of scientific and applied investigations. Predictive maintenance based on diagnosis, prolongs the life of machines and aggregates, reducing downtime, maintain optimal level of production, ensure compliance with the precise timing of delivery of production (raw materials, energy), allows for effective management of maintenance of facilities.

According to the International Standardization Organization (ISO) "Prognostics is time for estimation of damage and risk for one or several future damages", (ISO, 13381-I, 2004). Thus technological diagnosis can be understood as a process of estimation of Remaining Useful Life (RUL) before damage occurs, which is estimated based on the current status of the facility and last operating mode.

In world practice is increasingly accepted that predictive maintenance can play a key role in the long-term profitability of a company in the manufacturing sector with a major impact on timely delivery, product quality and its ultimate cost. The importance of maintenance increases in terms of increasing both the productivity and also the quality requirements which can only be achieved with a well-developed and organized maintenance strategy.

In this sense, according to recent advances in technology there have been developed and tested many methodologies, tools, techniques and strategies. The main methods are Total Productive Maintenance (TPM) and Reliability Centred Maintenance (RCM); the developed options are designed to meet the specific requirements of individual users, which are usually small and medium-sized enterprises (SMEs) operating in a very dynamic business environment. This paper focuses on identifying difficulties for the implementation of TPM within SMEs.

In recent years there has been increasing interest in the operation and management of industrial maintenance in a number of organizations. This is due to the increasing pressure on manufacturing organizations to meet customer and corporate requirements; the available equipment and productivity are central to achieving this goal. According to the authors' quote from a paper (Chan, 2005), "Recent trends show that on the whole many production

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systems do not function as expected when it comes to cost effectiveness in terms of their operation and maintenance. Lots of companies often operate with reduced capacities and reduced productivity, while the prices of their products are high." A number of modern maintenance practices for technical support are designed to allow organizations to target strategic resources to achieve the maintenance tasks that are considered crucial for the effective and efficient operation of the equipment such as the Total Productive Maintenance (TPM). A number of organizations announce improvements in existing equipment, reliability and reduction in the maintenance costs after the implementation of TPM; the presented results are published in (Blanchard, 1997; Cooke, 2000). The benefits of TPM are often defined as an increase in the quality of products, availability of equipment and reduction of operative costs, according to the authors of (Cholasuke, 2004; Bohoris, 1995; Al-Najjar, 1996). In (Nakajima, 1988) it is assumed that TPM is used primarily because it integrates the functions of production and maintenance, but more importantly is that it redefines the role of operators and support engineers.

The author of (Nakajima, 1988) Nakajima is often accepted as the founder of the Total Productive Maintenance, (TPM); he assumes that the goal of TPM is to increase the efficiency of the equipment as well as to maximize the volume of production from this equipment. This is the result of an effort to achieve and maintain optimal conditions for the equipment in order to prevent unexpected failures, the speed decrease and the qualitative defects during the manufacturing process according to (Bamber, 1999). Via the application of TPM it is also expected to be possible to raise the moral of employees and their satisfaction from the job, suggesting the integration of workers into every aspect of the applied TPM. The majority of generally accepted definitions in TPM, used in (Barnes, 2002; Baglee, 2003; Baglee, 2010), are based on five main pillars outlined by Nakajima.

2 INTEGRATED MANAGEMENT SYSTEMS

Since 1996, the management of industrial sites is aware of the need of implementing systems to support all business processes (Dochain, 2008; The ANSVISA 95 Enterprise, 2005). These systems are known as Enterprise Resource Planning (ERP). Systems of this type are rapidly moving in large industrial complexes, but they remain almost completely cut off from existing DSC or SCADA. "Islands of automation" appear that are not at all related informationally and functionally to the general business management. Since the beginning of the 21st century this fragmentation begins to be overcome with the introduction of an intermediate layer of management – the Manufacturing Execution Systems (MES) (ISA the Instrumentation, Systems and Automation Society, 2005). These systems are a bridge between the technology management and the business management, so they perform a variety of roles for the operational management.

The purpose in (Staykov, 2013) is to make an analysis and assessment of the increasing need of using sophisticated software systems for managing business processes. The most important thing is the information and the success of every business depends on how fast and effective managers deal with information.

The structure of the integrated management systems primarily reflects the functions that must be implemented in a modern integrated management system of an industrial enterprise. It does not contain in itself a generalization of the methods and the tools for integration. This is essential, especially in the wide variety of engineering solutions that the world's leading providers offer. Therefore the accepted in 2005 standard ISA-95 is of great help to overcome internal fragmentation between control functions, built most often with different strategies, a specific vision and with a different magnitude. This is an international standard for the integration of business systems and control systems for the production processes shown in Figure 1.

This structure is *operative* and it includes next four hierarchical levels.

Level 1 and Level 2 are functionally grouped and comprise the management of individual devices and parameters. The generic name Process Control Systems (PCS) is accepted for them. The so formed block for Technological Management is treated as a generalized function in the specific problems (design, operation, adjustment) and it can be seen as composed of two levels. The timeline of the PCS-level are hours, minutes and seconds.

Level 3 comprises all tasks of operative management and it is accepted to be marked as MES. The main functions of this level are:

- Complete description of the production schedule;
- Management of production resources (people, equipment, materials);
- Specific dispatching of production with an

already formulated production schedule;

- Optimization of the production process;
- Monitoring of the overall production process;
- Analysis of the production process (quantity, quality, time schedule);
- Reliability and security of production;
- Reliable communication, acquisition and archiving the operational information;
- Implementation of the necessary operative instructions, as well as forming the tasks for 1-2 level (PCS).

The timeline of Level 3 are days, hours and minutes.

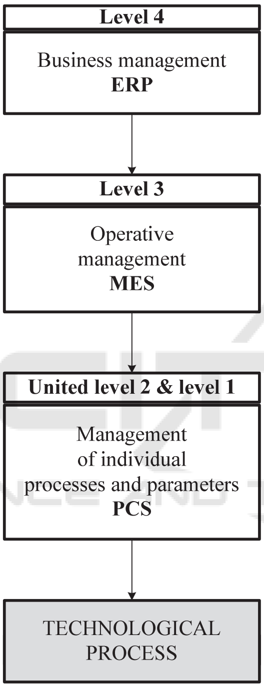

Figure 1: Production processes.

Level 4 is the level of business planning and logistics – ERP. The main functions of this level can be divided into two groups.

Functions directly related to the formation of the tasks for Level 3 (MES). These include:

- Production planning;
- Long-term production schedule;
- Define the requirements for manufactured products;
- Determine resource constraints, level of inventories, material consumption;
- Implement the supply chain of raw materials, production expedition, the overall logistics of the enterprise.

Functions relating to the overall business management, to cover:

- Financial accounting – books, fixed assets, payables, receivables, cash management;
- Management accounting – define cost and cost of production, cost control;
- Management of the supply chain – planning and schedule of supply, processing requests, purchases;
- Management of human resources – recruitment, training, remuneration, dismissal of staff;
- Project management – project-and-resources planning for their implementation, distribution of work, pricing and payment, timetables, implementation units, management activities;
- Management of customer relationships – sales and marketing, customer contact, market analysis;
- Comprehensive business analysis.

The timeline of the ERP-level are months, weeks or days. For purposes of this paper we are interested in the functionality of the MES-system.

The main merit of the standard ISA-95 is that it summarizes the experience of the leading academic institutions and companies worldwide in the way of overcoming the isolation between the technological management (PCS) and the business level (ERP) by creating a level of operative management MES. The ISA-95 standard defines the conditions for the integration of ERP and MES, on the one hand, and MES and PCS, on the other.

Standard ISA-95 decides primarily structural and information problems of integration. It to some extent does not repeal or does not replace the considerable experience in the application of various features in the specific automation on the four levels, accumulated for decades.

3 ANALYSIS OF THE BEST PRACTICES

1. In every industrial enterprise there are potential opportunities for improvement, which are in the range 1–10% by economy of energy resources and raw materials of 3–5%, 2–7% for increased product-ion (http://www.automation.siemens.com, http:// www.honeywellprocess.com/en-us).

2. Doing good business and in particular industrial management becomes more and more expensive.

3. Existing SCADA and DCS can not be changed frequently. The best approach is the old control systems to continue to work, by adding new technologies of control (Figure 2).

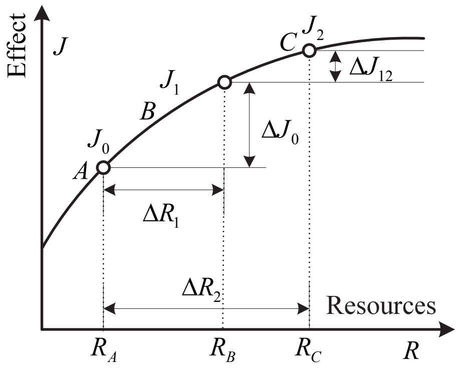

Figure 2: Process control effectiveness.

4. In deciding to develop the management system one must take into account the influence of many factors.

- The estimated economic impact of flexibility, quality improvement, increased productivity and reduced production costs;
- Spent money, effort and time;
- Reaction of the operating personnel;
- Security of humans and also of the facilities;
- Satisfy environmental and governmental regulations.

Unlike the position shown in Figure 2, we have a multicriteria problem.

5. Reengineering the system must take into account the specific circumstances:

- The degree of automation and information links;
- Different final goal to develop the system;
- The hardware and software from different vendors;
- Lack of prospects henceforth uses only one supplier.

6. Only a holistic approach can be effective. Information integration basically influences its realization.

7. The human factor is critical to the success of the integrated system. To do this:

- People need to understand the functions of the system;
- They must feel that they are part of the system with their expertise;
- They should not be overloaded by an extra loading;
- They must be sure that the system is safe and comfortable for them.

8. Outlines of some important drawbacks of private character:

- Monitoring of key industrial indicators – economic efficiency, safety and reliability is incomplete and it affects negatively the quality of decisions;
- Underestimated is the use of knowledge, especially on condition of the unanimous assessment that skilled and experienced-knowledge workers continuously retire without an equivalent replacement with new footage;
- Archival records are used less or not at all (Castiliio, 2013);
- The management of second and third level is more intuitive than based on online recommendations from DSS;
- Security systems (SSMs) are underestimated from terrorism and from unauthorized access, especially in terms of increasing wireless communications.

Figure 3 generalizes the management scheme, interpreting standard ISA-95 on functional level as multidimensional multistage system.

Provided, but not addressed in the standard division of the general part of technology management (PCS) at two levels (1 and 2) is considered an important structural feature. Each level is described as being of universal attributes, each of which is multi-dimensional and functionally different for each of the four levels. The following below attributes are considered.

- Hierarchical level;
- Tools for program-technical realization (SCADA, RLS, DCS, MES, ERP) R;
- Used mathematical models M;
- Criteria J and restrictions L in the optimization problem;
- Functions performed F;
- Control algorithms or decision making A;
- Information functions I;
- Operative and control actions O, U;
- Information disturbances d.

Each level receives its task from the preceding hierarchical level, including certain requirements in the form of specifications S_i, volumes V_i, criteria J_i, limitations L_i:

$$r_i = \left(S_i, V_i, J_i, L_i \right) \tag{1}$$

The task is a vector comprising N_i components to each i-th level:

$$r_i = \left(r_{i1}, r_{i2}, \ldots, r_{ij}, \ldots, r_{iNi} \right) \tag{2}$$

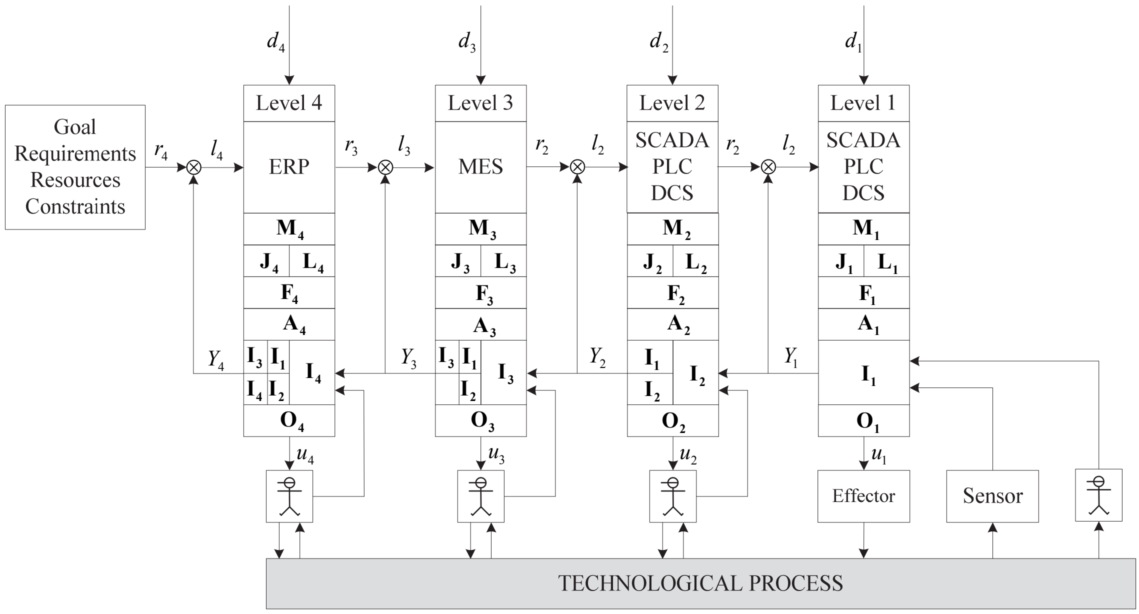

Figure 3: Generalized scheme.

The feedback y_{ij} is an assessment of the operation of each j-th element of i-th level E_{ij} and it has the same structure as the task r_i.

The aim of each level is to minimize the error e_i in terms of the specified criterion J_i with constraints S_i, V_i, L_i through controls u_i:

$$u_i = \arg \min_{S_i, V_i, L_i} J_i\left(e_i, u_i\right) \tag{3}$$

Criteria J_i and specifications S_i, volumes V_i and limitations L_i are vector and are different for each j-th E_{ij} element at level i:

$$\begin{aligned} J_i &= \left(J_{i1}, J_{i2}, \ldots, J_{ij}, \ldots, J_{iNi}\right) \\ S_i &= \left(S_{i1}, S_{i2}, \ldots, S_{ij}, \ldots, S_{iNi}\right) \\ V_i &= \left(V_{i1}, V_{i2}, \ldots, V_{ij}, \ldots, V_{iNi}\right) \\ L_i &= \left(L_{i1}, L_{i2}, \ldots, L_{ij}, \ldots, L_{iNi}\right) \end{aligned} \tag{4}$$

The controls u_i similarly are vectors, like the expressions (4), but each element E_{ij} may have several effects due to multidimensionality of the control:

$$u_{ij} = \left(u_{ij1}, u_{ij2}, \ldots, u_{ijk}\right) \tag{5}$$

Operational impacts u_i can be both automatic controllers and also the actions of the operating personnel. A multistage system reflects both the hierarchical subordination of the lower level with respect to the upper one and also the inverse information influence of the lower level at the upper one. Each level has full access to the information at a lower level, but it adds also new information in the information flow upward as a result of the specific management and information processes at its own level.

4 CONCLUSIONS

Management of industrial complexes is gaining acceptance as a functional problem with multiple criteria the decision of which is possible only via a holistic approach.

Rapid development and application in DCS and SCADA receive a number of information technologies. Information integration is a key in building ERP, MES and PCS joint systems.

The methods of artificial intelligence (neural networks, fuzzy logic, genetic algorithms) and those based on knowledge (expert systems, autonomous agents, CBR) and especially the hybrid systems are still used only occasionally, but they possess a significant potential.

Generally ERP-MES-PCS systems are developed successfully to increase the competitiveness of industrial complexes in the globalized world.

The successful implementation of an approach to predictive maintenance taking into account the nature of activities in SMEs, it must be based on three main objectives. First, to allow the user to formulate a strategy of maintenance. Second, to convert the limited available data into knowledge to develop a strategy for maintenance. Third, to allow the user to record and measure the effect of the new strategy for support, to ensure that future decisions are based on facts and accurate data. The successful implementation of the formed in this way model would lead to the possibility the structure and the elements of the model to create efficient and effective strategy to support SMEs.

The main problem in developing a maintenance strategy is bounded by the lack of appropriate documentation and the ineffective analysis of available data. The reasons for this may be the lack of time for an understanding of the existing technology, and human relations in general. In particular, the staff must record their deeds and actions that relate to the problem; besides there must be measured the quantifiable, measurable benefits, which in the short term is difficult to achieve. Progress is possible if you use a simple system for recording and analysis that can be easily accessed and updated. The present research shows that technology is able to solve emerging needs but it requires innovative adaptations to solve the existing problems.

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REFERENCES

http://www.automation.siemens.com

http://www.honeywellprocess.com/en-us

Al-Najjar B., 1996. Total Quality Maintenance. In *Journal of Quality in Maintenance Engineering* 2 (3), 4–20.

Baglee D., M. Knowles, 2010. Maintenance strategy development within SMEs: the development of an integrated approach, In *Journal Control and Cybernetics*, 39 (1), 275–303.

Baglee D., R. Trimble, J. MacIntyre, 2003. An investigation into the perceived barriers to total Productive Maintenance in small and medium enterprises. In *International Conference on Manufacturing Research*, University of Strathclyde, Professional Engineering Publishing.

Bamber C. J., J. M. Sharp., M. T. Hides, 1999. Factors affecting successful implementation of TPM: A case study perspective. In *Journal of Quality in Maintenance Engineering* 5 (3), 162–181.

Barnes D., 2002. The complexities of the manufacturing strategy formation process in practice. In *International Journal of Operations and Production Management* 22 (10), 1090–1111.

Blanchard B., 1997. An enhanced approach for implementing TPM in the manufacturing environment, In *Journal of Quality in Maintenance Engineering* 3 (2), 69-80.

Bohoris G. A., C. Vamvalis, W. Trace, K. Ignatiadou, 1995. TPM implementation in Land-Rover with the assistance of a CMMS. In *Journal of Quality in Maintenance Engineering*, 1 (4), 3–16.

Castillio O., P. Melinand, J. Kasprzyk, (Eds), 2013. *Recent Advantages on Hybrid Intelligent Systems*, Springer.

Chan F., F. Lau, S. Chan, S. Kong, 2005. Implementation of Total Productive Maintenance: A case study. In *International Journal of Production Economics* 95(1), 71–94.

Cholasuke C. R., R. Bhardwa, A. Jiju, 2004. The status of maintenance management in UK manufacturing organisations: results from a pilot survey. In *Journal of Quality in Maintenance Engineering* 10 (1), 5–15.

Cooke F. L., 2000. Implementing TPM in plant maintenance: Some organizational barriers. In *International Journal of Quality & Reliability Management* 17 (9), 1003–1016.

Dochain D., W. Marquardt, S. Won, O. Malik, M. Kinnaert, J. Lunze, 2008. Monitoring and Control of Process and Power Systems: Adapting to Environmental Challenges, Increasing Competitivity and Changing Customer and Consumer Demands, In *IFAC World Congress*, Seoul, Korea, 7160–7171.

ISA the Instrumentation, Systems and Automation Society, 2005. *The ANSVISA 95 Enterprise — Control System Integration*, Research Triangle Park, NC, USA.

ISO 13381-I, 2004. *Condition monitoring and diagnostics of machines-prognostics – Part: General guidelines.* Int. Standard, ISO.

Nakajima S., 1988. *Introduction to TPM: Total Productive Maintenance*. London, Productivity Press.

Staykov B., T. Atanasova, V. Monov, L. Doukovska, 2013. The ERP Systems in Modern Business and Corporate Management, In *Proceedings of the International Symposium on Business Modeling and Software Design – BMSD'13*, Noordwijkerhout, The Netherlands, 281–285.