DEVELOPMENT OF A MAINTENANCE PLAN FOR AN AUTOMATED LINE FROM THE PERSPECTIVE OF AN INDUSTRIAL ENERGY MANAGEMENT SYSTEM

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ABSTRACT: Industrial Energy Management Systems (EMIs) have evolved greatly in recent decades, being influenced by technological advancements, increasing awareness of sustainability and energy efficiency, as well as increasingly stringent regulations on carbon emissions. Today, IMES are essential for optimizing energy consumption in industry, reducing costs and minimizing environmental impact. In this article, the maintenance plan for the assembly line was presented in detail so that in the future it can be studied in the long term what it means to implement an IMES system on such a line and what the percentages of benefit will be if the recommended maintenance cycles and intervals are respected on the entire line and its components.

KEYWORDS: industrial energy management systems, IoT, AI, RLS assembly line

1.INTRODUCTION

The Industrial Energy Management System (IMES) is a group of practices and technologies that industrial organizations implement to manage and optimize energy consumption. Improving energy efficiency is the main goal of an EMSI, which will reduce operational costs and environmental impact.
IMES are integrated systems that combine hardware and software technologies to collect and analyze energy consumption data in real time, thus allowing management to make informed decisions to optimize energy resources [1].
The development of a maintenance plan for an automated line, from the perspective of an Industrial Energy Management System (IMES), involves an integrated approach aimed not only at the optimal and reliable operation of the equipment, but also at energy efficiency, consumption monitoring and resource optimization. In this context, maintenance must actively contribute to

reducing energy consumption and emissions, without compromising productivity.

In the current context, of the trend of globalization and expansion of the competitive market, an important role is played by the expansion of the concerns for the implementation of quality management and availability of industrial products. In this case, the quality of production activities is appropriate to be achieved by the existence of working equipment, of high precision and productivity. Production activities must be carried out continuously, a situation that requires the existence of industrial equipment, which provides a continuous operation of the activity, and in case of failure, the shortest possible downtime. As an important component of the production process, maintenance must be carried out at a high quality level, because otherwise there is a possibility of decreased productivity in manufacturing and inappropriate economic and financial effects

2. CURRENT STATUS

Industrial Energy Management Systems (EMIs) have evolved greatly in recent decades, being influenced by technological advancements, increasing awareness of sustainability and energy efficiency, as well as increasingly stringent regulations on carbon emissions. Today, IMES are essential for optimizing energy consumption in industry, reducing costs and minimizing environmental impact.

A summary of the current state of these IMES systems is presented below:

❖ **Advanced Technologies and Digitalization**

Internet of Things (IoT):

- Use of IoT sensors for real-time monitoring of energy consumption and operational conditions of industrial equipment.
- Collecting and analyzing data to identify energy-saving opportunities and optimize processes.

Artificial Intelligence (AI) and Machine Learning (ML):

- Applying AI and ML algorithms to predict energy consumption and identify anomalies in real-time.
- Optimization of production processes and energy consumption through automatic adjustments based on the collected data.

Energy Management Systems (EMS):

- Integration of EMS systems with advanced software platforms to provide visibility and control over energy consumption.
- Functionalities such as real-time monitoring, reporting, and energy management.

❖ **Sustainability and Regulations**

Reducing Carbon Emissions:

- Implementing measures to reduce carbon emissions, in line with sustainability goals and international regulations.
- The use of energy from renewable sources (solar, wind, etc.) and their integration into the industrial energy mix.

Energy Certifications and Standards:

- Adoption of ISO 50001:20211 standards for energy management [3],[9], which provide a framework for continuous improvement of energy performance[4].
- Obtaining energy certifications to demonstrate commitment to energy efficiency and sustainability.

❖ **Operational Efficiency and Cost Savings**

Process optimization:

- Implementing Lean and Six Sigma practices to identify and eliminate energy losses in industrial processes.

- Use of co-generation and heat recovery technologies to maximize energy efficiency.

Automation and Control:

- Use of industrial automation systems (PLC, SCADA) for precise control of equipment and processes, thereby reducing energy consumption.
- Implement advanced control solutions, such as model-based predictive control (MPC), to optimize energy consumption.

❖ Energy Management and Monitoring [5]

Energy Monitoring Platforms:

- Implementation of centralized platforms for monitoring and reporting energy consumption in real time.
- Using advanced dashboards and analytics to provide detailed and easy-to-understand information about energy performance.

Predictive Maintenance:

- Using monitoring data to predict and prevent equipment failures, leading to more efficient use of energy and reduced downtime.
- Implementation of maintenance programs based on the condition of the equipment to ensure optimal performance and energy efficiency.

❖ Ergonomics and Security

Ergonomic Design of Workspaces:

- Ensuring workstations are ergonomically designed to reduce worker fatigue and improve operational efficiency.
- Implementation of adjustable and automated equipment to minimize physical effort and prevent injuries.

Operator training:

- Providing training programmes to educate workers on good energy use practices and energy efficiency measures.
- Promote an organisational culture that supports the responsible use of energy and the implementation of ergonomic measures[6].

Industrial Energy Management Systems (IMES) are essential for optimizing energy consumption and improving operational efficiency in various industries.

3. CASE STUDY. RLS ASSEMBLY LINE MAINTENANCE PLAN

The development of the industrial activity, the achievement of the highest possible productions, at the best possible quality and with the lowest possible costs, have determined the orientation of the management of companies and experts in machinery and equipment towards the development of organizational measures and technologies that reduce the accidental stops of the machines and the reduction of the waiting times in repair, therefore of the maintenance costs. Maintenance can be considered a set of technical-organizational activities that aim to maintain, maintain and repair industrial systems in working order [7].

Maintenance work can only be carried out by appropriately qualified personnel, who have trainings done on that line. Danger zones are known and possible hazards are eliminated by appropriate means. Protective measures are taken to avoid accidents.

Maintenance intervals are designed as guides and refer only to basic system or machine maintenance [8]. If components or assemblies are subjected to test loads (e.g. sensors or cameras), adjustments or calibrations must of course be carried out on an exchange-by-exchange basis, using appropriate calibration means to ensure reliable test results (Fig.1). For components subjected to particularly high stresses or high levels of contamination, the maintenance interval can also be significantly shortened depending on the application to maintain reliable system production. The experience and technical knowledge of the operator in charge of the system are required here and should be used with caution.

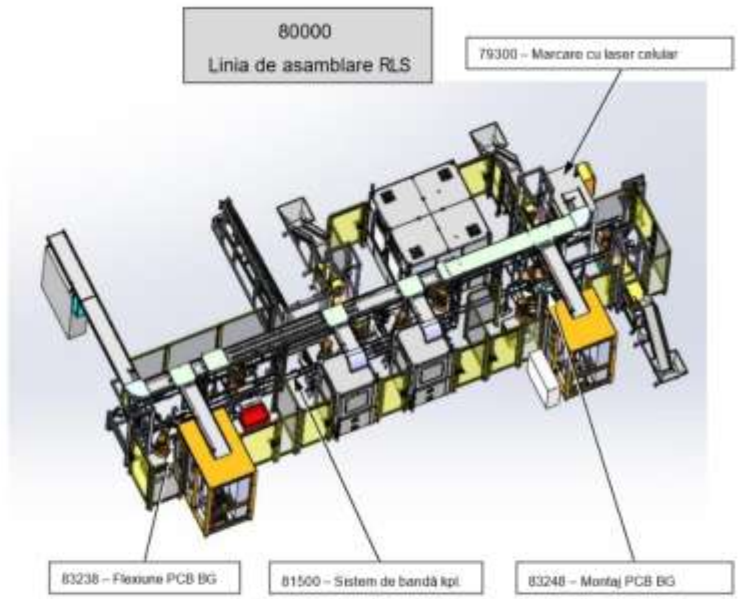

Figure 1. RLS assembly line

The preventive maintenance plan is explained in great detail in table no. 1 per stage, activities and recommended frequency.

Table 1. Maintenance plan

Activity	Description	Recommended frequency	Observations
PCB Cleaning	Cleaning with isopropyl alcohol (≥99%), antistatic brush and dry compressed air	6 months	Make sure the board is completely unplugged and discharged
Visual inspection	Check for dust, corrosion marks, cracked solder, faded components	Monthly	Use a magnifying glass or portable microscope
Checking connections	Tightening screws, checking busbars and sensing cables	3 months	Oxidation of contacts increases resistance and risk of overheating
Insulation Resistance Measurement	Test between power lines and ground	12 months	Use a megohmmeter according to the rated voltage
Thermal monitoring	Temperature measurement at critical points (MOSFETs, resistors, dissipation zones)	Monthly	Compare to the limits in the datasheet
BMS Functional Test	Verification of voltage/current measurements, cell balancing, protections	6 months	It can be done with a cell simulator or on a test bench

Firmware update	Installation of versions recommended by the manufacturer	When the update appears	May include protection and safety optimizations
Controlled storage	Dry, cool, conductive dust-free environment	Permanent	If the assembly contains cells, keep them at 40–60% SOC

The main problem with a maintenance plan is when the maintenance plan is created separately from the energy strategy, without using data from the IMES[9].

As a consequence of this situation, opportunities for energy optimization (e.g. detection of energy-inefficient equipment) are not identified or correctly prioritized [10].

The following steps should be recommended to follow:

- Time-based planning only, not operating conditions or energy consumption
- Failure to identify low energy efficiency equipment
- Lack of use of historical energy consumption data
- Neglecting stand-by or shutdown operation
- Lack of a maintenance plan for auxiliary systems
- No energy KPIs related to maintenance activities

The concept of preventive maintenance has a multitude of meanings. A literal interpretation of this term defines a maintenance program that aims to eliminate or prevent corrective and/or reactive maintenance [11]. A more comprehensive preventive maintenance program will call for the periodic evaluation of critical equipment/machines/systems to detect potential problems and immediately schedule the necessary interventions that will prevent any degradation of operating conditions [12].

The diagram of the complete preventive maintenance cycle for a one-PCB intended for cells is shown in Figure 2.

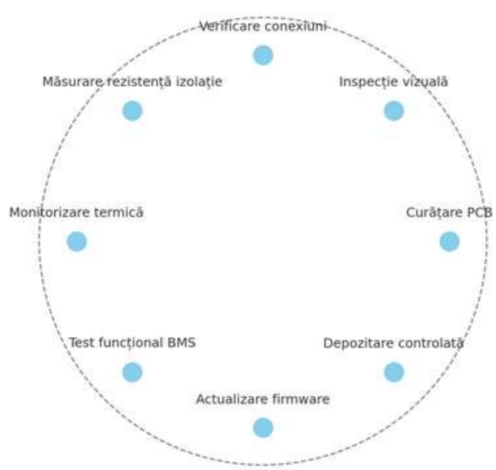

Figure. 2. Diagram of the complete preventive maintenance cycle

The implementation of preventive maintenance at the present time varies in a wide range. Certain programs are extremely limited and consist only of Number of defects, Time, Commissioning, Lifetime, Wear, lubrication and minor adjustments [13]. A real and efficient preventive maintenance program involves planning repairs, lubrication, adjustments, reconditioning for all equipment/machines/subsystems within an industrial system. The common denominator of these interventions is the correct programming in time according to the statistics presented above [14].

Preventive maintenance represents a superior qualitative leap in a modern maintenance system, regardless of the industrial branch or the production specificity, because it provides all the necessary information for: - early detection of the occurrence of failures; - their location; - diagnosing faults; - calculation of the safe operating time of the machine [15].

4. CONCLUSIONS

The maintenance plan in an IMES is **multidisciplinary**, uniting mechanics, automation, energy and IT. The goal is not only to reduce breakdowns, but **to continuously optimize energy consumption through intelligent maintenance**. This approach helps to reduce costs, increase the lifespan of equipment and comply with environmental regulations [16].

In the case study, the maintenance plan for the assembly line was presented in detail so that in the future it can be studied in the long term what it means to implement an IMES system on such a line and what the percentages of benefit will be if the recommended maintenance cycles and intervals on the entire line and its components are respected.

An Energy Management System (IMES), according to the ISO 50001 standard, uses the **PDCA** (Plan-Do-Check-Act) cycle to monitor and continuously improve energy performance. An energy management system designed according to this ISO 50001,[17] standard creates the premises for the appropriate and proportionate selection of measures of a systematic approach to achieve continuous improvement of energy performance, energy efficiency, energy use and energy consumption leading to higher performance and to ensure the trust of employees and stakeholders [18].

The issue of optimizing energy consumption in production systems has received attention with the increase in concern for sustainability[19],[20]. We believe that research related to energy optimization has a high applicative value and a vast research space. Through reasonable programming of O&M (operation and maintenance), energy savings can be achieved without changing the structures of the production system, which will pave the way for the progressive promotion of sustainable production paradigms[21].

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