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Economic Aspects of the Impact of a Condition Monitoring System on Electrical Equipment in Cement Production

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ABSTRACT: This paper discusses the economic and operational benefits of implementing an online condition monitoring system for electrical equipment in cement production. It demonstrates that the use of automated diagnostic and technical condition analysis systems can significantly reduce maintenance costs, increase reliability, and minimize equipment downtime. Based on the analysis of practical experience with integrated condition monitoring systems, the study highlights the high economic efficiency of investments in such solutions.

KEYWORDS: condition monitoring system, electrical equipment, cement production, diagnostics, maintenance, vibration analysis, failure prediction, digitalization, economic efficiency, equipment reliability, industrial automation, telemonitoring, cost optimization, industrial analytics, sustainable development.

I. INTRODUCTION

Modern cement plants are characterized by a high degree of automation of production processes and a large number of electrical and mechanical units, whose reliability directly affects the continuity of the technological cycle. In the context of increasing competition and the need to reduce production costs, the implementation of intelligent condition monitoring systems has become an important factor in optimizing maintenance and preventing potential failures [1].

The cement manufacturing process, which accounts for the largest share of global cement production, is shown in Figure 1, that illustrates the main technological stages of cement manufacturing, highlighting the points in the process where condition monitoring systems are most beneficial — particularly during clinker production and grinding stages, where uninterrupted operation of electric drives and rotating machines is critical.It consists of two main stages: clinker production and grinding. The raw materials used for clinker production include calcareous materials such as limestone and argillaceous materials such as clay [2]. The raw materials are mixed and ground either dry (dry process) or with water (wet process). The resulting powder mixture is calcined in vertical or rotary kilns at temperatures between 1,400–1,450°C. Upon exiting the kiln, the clinker is rapidly cooled to prevent the conversion of tricalcium silicate, the main ingredient of Portland cement, into dicalcium silicate and calcium oxide.

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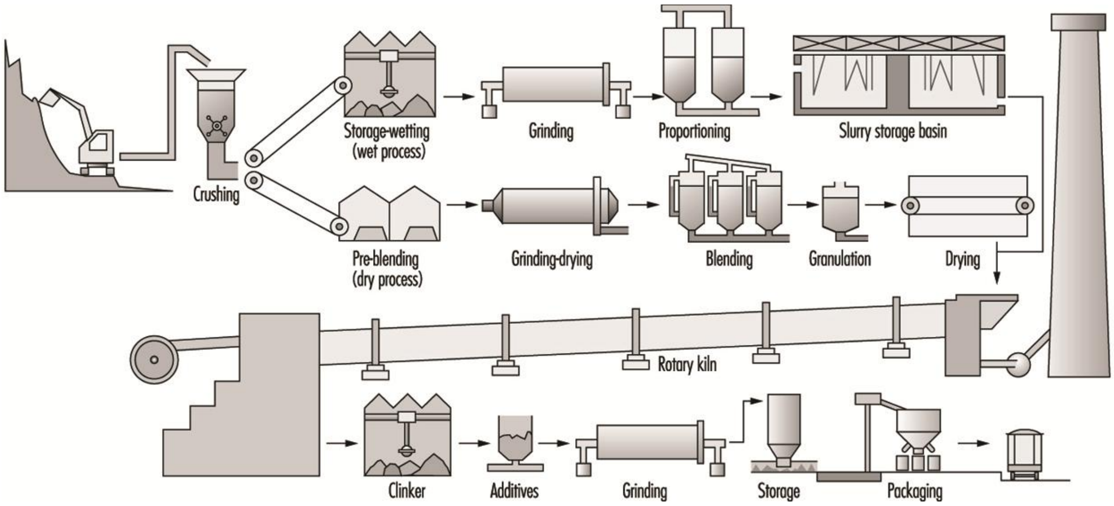

Fig. 1. Technological scheme of cement production.

The purpose of this study is to assess the economic impact of implementing condition monitoring systems for electrical equipment in cement production. The main objectives are:

- to analyze the structure of the cement production process and identify critical equipment;
- to define the functional capabilities of condition monitoring systems;
- to evaluate their influence on maintenance costs, equipment reliability, and overall production efficiency.

II. SIGNIFICANCE OF THE SYSTEM

The implementation of an online condition monitoring system in cement production plays a crucial role in ensuring the reliability and efficiency of electrical equipment. Continuous real-time observation of operating parameters such as vibration, temperature, and rotational speed enables early detection of deviations from normal conditions, preventing unexpected failures and costly downtime.

From an operational standpoint, the system supports the transition from scheduled maintenance to predictive maintenance, optimizing the use of resources and extending equipment lifespan. Economically, it provides significant cost savings through reduced unplanned repairs, improved production stability, and lower spare-parts inventory.

Moreover, the integration of monitoring systems with plant-wide automation platforms enhances data transparency, supports informed decision-making, and contributes to the overall digital transformation of cement manufacturing. Thus, condition monitoring becomes not only a technical tool but also a strategic element of sustainable and cost-effective industrial development.

III. MATERIALS AND METHODS

The online condition monitoring system is a complex of hardware and software tools that provide continuous observation of equipment performance parameters in real time. Measuring devices record key indicators — vibration, temperature, rotational speed, and other parameters reflecting the machine's operating condition. Modern condition monitoring tools such as those described in [3] enable continuous measurement of vibration, temperature, and rotational speed, providing real-time insights into machine health.

As components wear out, the system registers deviations from baseline values, enabling early detection of potential faults. The software platform performs data analysis and trend visualization while generating alarms when parameters exceed acceptable limits. Thus, the engineering staff can respond promptly to anomalies and plan maintenance work without disrupting the production process.

The equipment's condition is displayed at the external software level in Dewesoft X, enabling rapid decision-making. Figure 2 demonstrates how real-time data visualization in Dewesoft X software supports fast decision-making by maintenance teams and enhances operational transparency.

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Fig. 2. Condition monitoring software.

Economic Significance of Implementation

One of the key effects of introducing condition monitoring systems is a significant reduction in maintenance costs. Early detection of defects eliminates unplanned downtime and emergency repairs, which often require considerable financial and time resources.

The economic effect E of introducing the monitoring system can be expressed as:

$$E = \frac{C_1 - C_2}{C_1} \times 100\%$$

where C_1 is the average maintenance cost before implementation and C_2 is the cost after implementation. For instance, when maintenance expenses decreased from €51,803 to €2,134, the cost reduction reached approximately 95.9%, confirming the substantial savings achieved through predictive maintenance.

Operational data analysis showed that the use of an integrated online monitoring system made it possible to reduce maintenance costs by almost 96%. This was achieved through the transition from a reactive maintenance strategy (after failure) to a predictive maintenance approach based on diagnostic data.

Instead of simply reducing costs, the system introduces a data-driven maintenance culture, improving asset lifecycle management and optimizing maintenance scheduling based on actual equipment conditions rather than fixed intervals. Similar cost reduction results have been reported in other industrial studies [4], confirming the reliability of predictive maintenance strategies.

IV. RESULTS AND DISCUSSION

Continuous data collection and remote access capabilities create favorable conditions for remote monitoring and diagnostics of equipment. This is particularly important for large industrial enterprises, where the operation of complex systems requires the involvement of highly specialized experts.

Integration of the condition monitoring system with production management platforms (PLC, SCADA) ensures a high level of process transparency and allows the formation of a unified digital database on the condition of all critical equipment units. The data obtained are used not only for diagnostics but also for maintenance planning, personnel training, and analysis of production efficiency.

Despite the clear advantages, the implementation of condition monitoring systems faces certain challenges. These include the high initial investment cost, the need for qualified personnel to interpret diagnostic data, and the integration of new systems with existing automation infrastructure. Such factors must be considered when evaluating the overall economic feasibility of the project.

The economic efficiency of condition monitoring systems is manifested in a high rate of return on investment. In cement production, payback is often achieved after preventing a single major breakdown that could have resulted in prolonged downtime and significant financial losses.

As a result of implementing the monitoring system, the following improvements were achieved:

- Maintenance costs were reduced by nearly 20 times;
- The number of unplanned equipment shutdowns decreased;
- The technical readiness coefficient increased;
- Overall productivity and process stability improved.

Thus, investments in digital monitoring systems are strategically justified and provide a significant long-term economic effect.

V. CONCLUSION

The application of condition monitoring systems for electrical equipment in cement production represents an essential direction in the digital transformation of modern industry. These systems enable a shift from traditional schedule-based maintenance to intelligent, predictive management of equipment condition.
Implementation results show that online monitoring leads to a substantial reduction in operating costs, minimized downtime, and improved process reliability. Under growing requirements for production efficiency and energy economy, such solutions have become an integral element of the sustainable development of the cement industry. The conducted analysis confirms that the adoption of predictive maintenance based on real-time condition monitoring significantly enhances operational efficiency and reduces overall maintenance expenditure. Future research should focus on developing comparative models for different monitoring technologies and creating predictive algorithms for economic performance assessment of electrical equipment in cement plants.

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