Study and Improvement of the Monitoring and Protection System for a Cornell Centrifugal Motor-Pump Unit Used for Dewatering *in an Open-Pit Mine - Case OF KCC Company*

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Abstract: ***This thesis focuses on the study and improvement of the monitoring and protection system for a Cornell centrifugal motor-pump unit used for dewatering in an open-pit mine operated by Kamoto Copper Company (KCC) in the Democratic Republic of Congo. Effective water drainage is essential to ensure the safety of mining operations and preserve the integrity of equipment. The analysis of the existing system revealed several shortcomings: lack of centralized supervision, low-performance sensors, and limited responsiveness to anomalies. These deficiencies lead to unplanned shutdowns, increased risk of mechanical failure, and reduced productivity. To address these issues, technical solutions were proposed, including the integration of smart sensors, the implementation of a SCADA system for remote supervision, and the automation of alerts. A simulation of the new system was carried out to validate its effectiveness and demonstrate improvements in reliability, safety, and performance. The results show a clear improvement in operational control and a significant reduction in risks associated with the motor-pump unit. This work paves the way for a sustainable modernization of drainage systems in open-pit mining operations.***

Keywords: motor-pump monitoring, open-pit mining, SCADA system, predictive maintenance, dewatering system

1. Introduction

Open-pit mining, while economically viable, presents numerous technical and environmental challenges. One of the most critical is the management of groundwater and surface runoff, which can compromise slope stability, slow down operations, and damage equipment. To address this, drainage systems play a vital role, particularly centrifugal motor-pump units, which ensure continuous water evacuation to storage or treatment areas.

In this context, Kamoto Copper Company (KCC), operating in the Katanga region of the Democratic Republic of Congo, uses Cornell motor-pumps for dewatering its mining pits. Although these units are robust, they are exposed to extreme conditions: load variations, the presence of solids, voltage fluctuations, and prolonged humidity. These factors increase the risk of failure, premature wear, and operational interruptions.

The monitoring and protection system associated with these motor-pumps is therefore a strategic component. It not only detects anomalies in real time but also prevents major breakdowns through automatic shutdown mechanisms, alerts, and diagnostics. However, the current system has limitations: low-sensitivity sensors, lack of centralized supervision, and poor integration with predictive maintenance tools.

This thesis aims to thoroughly study the current system's operation, identify its weaknesses, and propose concrete improvements based on modern technologies (IoT, SCADA, smart sensors). The goal is to enhance drainage reliability, optimize equipment lifespan, and ensure the safety of mining operations.

2. Presentation of the Motor-Pump System

2.1 Context of Use in Open-Pit Mining

In open-pit mining, drainage is a critical operation to ensure worker safety, slope stability, and uninterrupted production. The accumulation of water, whether from groundwater or rainfall—can lead to landslides, flooding, or production shutdowns. To effectively evacuate this water, mining companies like KCC rely on powerful and durable motor-pump units.

2.2 Description of the Cornell Motor-Pump Unit

The Cornell centrifugal motor-pump unit consists of two main components:

- The electric motor: typically, three-phase, designed to operate in demanding industrial environments.
- The centrifugal pump: capable of moving large volumes of water with sufficient pressure to overcome the elevation differences of the mining site.

Typical technical specifications:

Element	Description
Pump type	Single volute centrifugal
brand	CORNELL
Manometric head	Up to 150 meters
Nominal flow rate	Up to 350 m3/h
Motor type	Electric ou thermal (Diesel)
Motor power	between 52 KW and 69 KW
Motor speed	1800 rpm
Fuel Tank capacity	Up to 1000 litres
Pump Materials	Stainless steel, cast iron, bronze depending on the model
mounting	On rigid frame or trailer, sometimes in container
applications	Mine dewatering, irrigation, drainage, industrial water transfer
Advantages	High hydraulic efficiency, robustness, simplified maintenance, long lifespan

2.3 Specific Operating Conditions at KCC

The KCC mining site presents challenges:

- High temperatures and abundant dust
- Presence of solid particles in the water (sand, sludge)
- Electrical voltage fluctuations
- Difficult access for maintenance operations

These conditions require constant monitoring of the motor-pump unit to prevent failures and optimize its lifespan.

2.4 History of Failures and Incidents

An analysis of KCC's maintenance reports reveals:

- Frequent shutdowns due to motor overheating
- Damage caused by dry running (absence of water)
- Excessive vibrations not detected in time
- Failures of bearings and mechanical seals

3. Analysis of the Existing Monitoring and Protection System

3.1 Objectives of the Monitoring System

The primary role of a motor-pump monitoring and protection system is to:

- Detect operational anomalies in real time
- Protect the motor and pump from extreme conditions
- Prevent major failures through early alerts
- Facilitate maintenance operations with reliable data

In KCC's mining context, these functions are crucial to ensure operational continuity and avoid costly shutdowns.

Evolution of Machine Monitoring
Machine monitoring has undergone a significant transformation in recent years. Initially, its primary goal was

to detect early signs of degradation, allowing for the preventive shutdown of equipment before serious damage occurred.

This protection was typically ensured through alarm triggers or automatic machine shutdowns, especially when certain parameters—such as vibration amplitude—reached thresholds deemed unacceptable for proper operation.

Today, monitoring has become a central component of maintenance strategy, particularly within the framework of conditional preventive maintenance. This approach relies on real-time analysis of operating data (vibrations, temperature, pressure, etc.) to anticipate failures and intervene only when conditions warrant it, thereby optimizing costs and equipment availability.

3.2 Steps of the monitoring process

Machine Monitoring Process: Detection and Diagnosis

The machine monitoring process is based on two main and complementary phases: detection and diagnosis. These steps help identify anomalies, understand their causes, and guide maintenance actions.

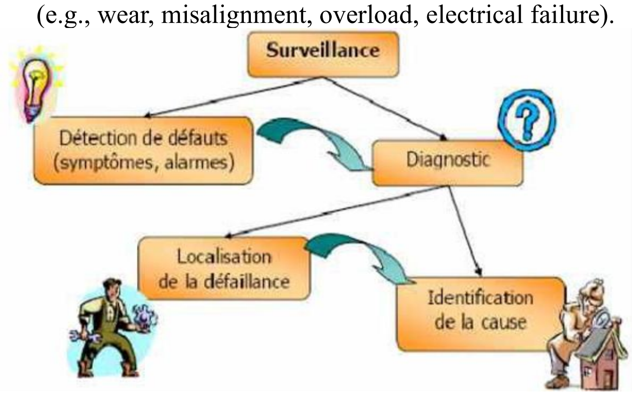
3.2.1. Detection

Detection aims to determine the presence of a fault that could affect the operation of the process or equipment. It involves:
- Analyzing operating parameters (vibrations, temperature, pressure, etc.)
- Identifying symptoms that indicate an anomaly
- Detecting deviations from normal operating thresholds

This phase allows early signs of degradation to be spotted before they lead to major failures.

3.2.2. Diagnosis

Diagnosis takes place once a fault has been detected. It allows for precise characterization of the anomaly and guides corrective actions. It consists of two sub-steps:
- Localization: This involves determining the type of fault affecting the process, based on indications related to the component in question (e.g., bearing, motor, sensor).
- Identification: This aims to define the exact cause of the observed symptoms by identifying the nature of the fault (e.g., wear, misalignment, overload, electrical failure).



3.3 Components of the Current System

The existing system relies on conventional elements:
- Temperature sensors: to monitor motor overheating
- Pressure sensors: to detect pressure drops or blockages
- Thermal relays: to cut power in case of overload
- Magneto-thermal circuit breakers: to protect against short circuits
- Manual control panel: with indicator lights and control buttons

3.4 Monitoring Methods

Monitoring is mainly:
- Manual: operators check parameters directly on the control panel
- Reactive: interventions occur only after an alarm or shutdown
- Non-centralized: each motor-pump is monitored independently, without coordination

This limits the ability to anticipate failures or analyze degradation trends.

3.5 Identified Limitations and Weaknesses

The analysis of the current system reveals several shortcomings:
- Limited sensor sensitivity: some anomalies are not detected in time
- No event logging: no record of past incidents for analysis
- No remote supervision: equipment cannot be monitored from the control center
- Delayed interventions: failures are often discovered after damage has occurred

These weaknesses increase the risk of unplanned shutdowns, equipment deterioration, and financial losses.

3.6 Operational Consequences

The impacts on mining operations are significant:
- Reduced availability of motor-pumps
- Increased corrective maintenance costs
- Greater safety risks for personnel
- Overall reduction in site productivity

These findings justify the need to improve the monitoring and protection system.
I can now translate the next chapter on proposed improvements or help you compile a bilingual version of your thesis.

4. Proposed Improvements to the Monitoring and Protection System

4.1 Objectives of the Improvements

The main objective is to design a monitoring and protection system that is:
- More responsive and intelligent
- Capable of preventing failures before they occur
- Connected to a centralized supervision platform
- Easy to maintain and adaptable to the mining site's conditions

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4.2 Integration of Smart Sensors

To enhance anomaly detection, the following installations are proposed:
- Digital temperature sensors with programmable thresholds
- Differential pressure sensors to detect obstructions
- Accelerometers to monitor motor and pump vibrations
- Water level sensors to prevent dry running

These sensors offer greater precision, digital communication, and compatibility with modern systems.

4.3 Implementation of a SCADA System

The SCADA (Supervisory Control and Data Acquisition) system will enable:
- Real-time supervision of all motor-pump units
- Historical data logging for analysis
- Graphical display of parameters (temperature, pressure, flow rate, etc.)
- Alert notifications via SMS or email in case of anomalies

This system can be connected via local network or radio link depending on the site configuration.

4.4 Automation of Alerts and Shutdowns

The new system will include:
- Dynamic threshold algorithms to trigger intelligent alerts
- Programmable relays to automatically cut power in hazardous situations
- Human-Machine Interface (HMI) to facilitate operator interaction

This will allow faster responses to anomalies and help minimize damage.

4.5 Proposed Architecture

The functional diagram of the improved system includes:
- Sensors connected to a Programmable Logic Controller (PLC)
- The PLC linked to a SCADA server
- The server accessible from the control center
- A database for event logging

5. Achieved Results

1) Rapid Anomaly Detection
- Deployment of smart sensors (vibration, temperature, pressure)
- Real-time monitoring of critical parameters
- Early identification of malfunctions before they lead to major failures

2) Automatic Shutdown in Case of Failure
- Integration of a programmable logic controller (PLC)
- Automatic triggering of safety shutdowns when thresholds are exceeded
- Reduced risks associated with delayed human intervention

3) Improved Visibility of Operational Status
- Centralization of monitoring data
- Continuous tracking of pump unit performance
- Event logging for analysis and planning

4) Reduction of Unplanned Downtime
- Significant decrease in unexpected interruptions
- Improved operational availability
- Optimized uptime of industrial installations

5) Lower Maintenance Costs
- Fewer urgent corrective interventions
- Reduced premature wear of components
- Better planning of maintenance operations

6) Transition to Predictive Maintenance
- Use of data to anticipate failures
- Shift toward a maintenance strategy based on actual equipment condition

6. General Conclusion

The study conducted on the monitoring and protection system of the Cornell centrifugal motor-pump used for drainage in KCC's open-pit mine has highlighted the limitations of the existing setup and the risks it poses to equipment safety, operational productivity, and long-term durability.

Through an in-depth analysis of system components, monitoring methods, and recurring incidents, technical solutions were proposed to modernize the system: smart sensors, SCADA supervision, automated alerts, and connected architecture. The simulation of these improvements demonstrated their effectiveness in terms of responsiveness, reliability, and reduced operating costs.

The positive impact on mining operations is clear: improved equipment availability, optimized maintenance, enhanced safety, and accelerated return on investment. These results confirm the relevance of a proactive and technology-driven approach to managing critical equipment in mining environments.

This work opens promising perspectives, including the integration of artificial intelligence for predictive maintenance, the use of wireless sensors in hard-to-reach areas, and the development of digital twins to simulate system behavior. It provides a solid foundation for the digital transformation of drainage infrastructure in open-pit mining.

7. Recommendation

At the conclusion of this study, it is strongly recommended that the company KCC adopt a gradual approach to the widespread implementation of an automated monitoring and protection system across all its critical installations. This recommendation is based on the compelling results obtained during the experimental phase, which demonstrated a significant improvement in operational reliability, a reduction in unplanned downtime, and better control over maintenance costs.

To ensure effective and sustainable implementation, the following actions are advised:

- Standardization of monitoring equipment: Adopt a unified architecture for sensors, programmable logic controllers (PLCs), and supervision interfaces to facilitate system integration, maintenance, and future upgrades.
- Strengthening internal competencies: Establish a continuous training program for technical staff focused on mastering supervision tools, data analysis, and intervention procedures.
- Rigorous performance tracking: Develop dynamic dashboards to measure real-time gains in availability, energy efficiency, and operating costs.
- Periodic system evaluation: Conduct regular technical audits to identify areas for improvement, anticipate deviations, and ensure the system remains aligned with operational requirements.

In summary, this recommendation aligns with a strategy of predictive maintenance, proactive asset management, and sustainable performance, which are essential pillars in any modern industrial environment.

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