IMPLEMENTING A REMOTE CONDITION MONITORING SYSTEM FOR SOUTH AFRICAN GOLD MINES

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ABSTRACT

The South African gold mining industry is currently under a lot of financial pressure due to electricity tariff increases, strikes, increased minimum wages and volatile commodity prices. Besides decreasing electricity consumption, mining companies have started looking towards improved maintenance strategies to reduce the operational costs of mines.

There are a great variety of maintenance strategies being used in different industries worldwide. In the South African mining sector, maintenance strategies are however not being implemented according to any specific process. This also applies to the condition monitoring of machines, which serves as the foundation of a properly structured and efficient maintenance strategy. There are different possible causes for this, which are different for each mine. Some mines lack proper infrastructure for monitoring machine conditions, while others simply do not have the required technical resources to implement and maintain a proper condition monitoring system.

Specialised condition monitoring systems are also expensive to implement and maintain, while requiring continuous manual user input to analyse and identify machine deterioration. This paper will therefore focus on developing an implementation process for a basic remote condition monitoring system on South African gold mines. This process will include the implementation of an alarm notification process that can be used to structure the maintenance strategy.

The developed process was used to deploy the same basic condition monitoring system on different South African gold mines within the same mining group. The resulting system was further used to centralise condition monitoring data from these mines for easier access and simplified reporting.

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1. INTRODUCTION

The world is witnessing one of the most significant technological evolutions in the history of mankind. The fourth industrial revolution is the result of the digitalisation brought on by the third industrial revolution. It is the fusion of technologies that connects the physical and digital worlds to optimise operational efficiency and reliability. This is hinged on the analysis of high volumes of data, which is the result of low-cost sensors and the decreasing price of computer processing power. This revolution is also evolving at such a rapid pace that it is disrupting all industries worldwide, including the mining industry. One of the most affected aspects of the mining industry, is the operational reliability of critical equipment through effective maintenance.

1.1 Background

Maintenance costs in the mining industry can account for 20 – 50% of the total operational costs of a mine [1]. The primary cause of lost production time and increased maintenance costs can be attributed to early component failures [2]. This means that optimising maintenance strategies through an efficient condition monitoring system can lead to significant savings in terms of both maintenance costs and production losses.

South African gold mines rely primarily on five types of mine support systems (MSS’s) to keep underground working environments safe and enable sustainable mining operations. These MSS’s are mine dewatering-, mine ventilation, compressed air-, refrigeration- and winder systems [3]. Due to a lack of SCADA integration of winder systems on most South African gold mines, they will not form part of the condition monitoring implementation process.

Since these systems are of such importance and mainly powered by machines, the failures of these machines must either be avoided, or attended to immediately when they occur. The most expensive maintenance strategy is a run-to-failure or corrective maintenance strategy and it should therefore be avoided as far as possible. Preventative maintenance on the other hand can either be time based or condition based and is done at specific intervals or when certain condition-based criteria are met. Maintenance resources on South African gold mines are also limited, which would make condition based maintenance more desirable since it is less resource intensive [4].

Condition based maintenance ideally requires a condition monitoring system to support it and improve its efficiency. However, condition monitoring equipment are very expensive to maintain and requires specialist knowledge to operate. The MSS machines are exposed to very harsh operating environments, which makes the use of specialised condition monitoring equipment to continuously monitor machine conditions in gold mines impractical.

There is thus a need for a more structured approach to condition monitoring in the South African mining industry. The best way of accomplishing a standardised condition monitoring process is by following a generic implementation process for a condition monitoring system. A process will thus be developed to implement a basic remote condition monitoring system on South African gold mines. Such a process needs to have minimal implementation costs that can put gold mines under more financial pressure. The system will therefore only use existing monitoring infrastructure and a minimal data logging resolution. The proposed data communication for the basic condition monitoring system that will be implemented is illustrated in Figure 1 below.
Figure 1: Condition monitoring data communication

The layout in Figure 1 shows that the system can be divided into three sections, which are the gold mines, the data processing and user interface. In the first section condition monitoring data is collected on individual gold mines by data loggers. The second section represents a centralised data processing server that receives, processes and archives collected condition monitoring data from various gold mines over a secured network. Lastly, section three illustrates a web-based user interface that uses the processed condition monitoring data to present machine and system conditions visually.

The condition monitoring data from the different gold mines will be sent over a secure GSM network to a central server for storage and processing as shown in Figure 1. It is however important to know how and where condition monitoring fits into the different types of maintenance strategies before developing a suitable implementation process.

1.2 Maintenance strategies

Maintenance can be categorised into two main categories, namely corrective maintenance and preventative maintenance. Corrective maintenance is done when a machine fails and is done to return it to its correct state. This type of maintenance cannot be planned or anticipated [5]. Corrective maintenance can further be subdivided into two categories, namely deferred and immediate maintenance. Preventative maintenance can be defined as the care and servicing of equipment or facilities by personnel to keep them in a satisfactory operational state. Preventative maintenance is done either to prevent imminent failures or to keep them from developing into major failures. This type of maintenance can be planned according to its occurrence, either based on the condition of machines or predetermined intervals. Condition monitoring can therefore be considered as a supportive component of preventative maintenance [4].

Condition monitoring systems on South African MSS’s would enable maintenance personnel to actively monitor machine conditions and enable them to do preventative maintenance. It would also notify maintenance personnel directly of machine parameters that are exceeding their predetermined limits. This would help mine personnel evaluate the system’s health by monitoring the individual machines that make up the MSS’s and prevent production losses due to machine failures. These MSS’s are primarily driven by specific machines and configurations for each system.
Compressed air is generated on the surface by compressors ranging in size from 1 MW to 15 MW of installed capacity [6], [7]. Deep level gold mines have at least two main ventilation fans on the surface, with one constantly running. These ventilation fans can range in size from 100 kW to 3 MW each [8]. Refrigeration systems on deep-level mines use refrigeration plants, or fridge plants, to chill water to between 3 °C and 6 °C [9]. Mine dewatering systems use multistage centrifugal pumps to extract excessive water from mining areas and prevent flooding [10]. Winders are used in the South African mining industry to transport mine workers or reef vertically between mining levels and to the mine’s surface [11]. The machines involved in these MSS’s need to be properly maintained to ensure uninterrupted and sustainable mining operations.

The machines are monitored by sensors that transmit parameter values to the centralised Supervisory Control and Data Acquisition (SCADA) computer of each mine via field IO modules and a PLC [12]. Most of these sensors are installed upon the commissioning of such a machine, since it legally required [13]. A control system, such as a SCADA system, can be defined as one or more devices that are used to manage and control the function of other devices. SCADA systems are responsible for the collection and transfer of information to a central location. They are also used to do analyses and for the control of some processes while displaying the relevant information to an operator [12].

A typical control system consists of three basic components, which are a master SCADA station, remote assets like PLC’s and a communication medium [12]. The SCADA computer can share process data with other computers over an OPC (Open Platform Communications) connection. OPC is a set of standards that allows for the reliable and secure data communication of devices from different vendors [14].

1.3 Generic CM system components

SCADA systems are not typically being used in the mining industry specifically for condition monitoring purposes, but for the remote control of processes and monitoring of process data. These SCADA systems along with other infrastructure can be incorporated into a basic condition monitoring system with minimal additional capital expenditure. A generic implementation process is however required to do this properly, which will also help identify shortcomings in existing infrastructure. A layout of the basic components required to implement a condition monitoring system is shown in Figure 2 below.

![Figure 2: Generic components needed for condition monitoring](image)

The configuration of the basic components shown in Figure 2 is not specific, and similar configurations can also be used. A user interface is required to view current or historic data, which can be done either locally or remotely. Additionally, a notification system is required to notify personnel of undesired circumstances and a database is needed to store historical data for future reference and reporting. This layout makes a condition monitoring system look rather simple, but the compatibility of software packages poses several challenges poses several challenges.
The condition monitoring systems from various mines can be linked by centralising the condition monitoring data. Instead of linking the condition monitoring systems of such mines directly to each other and solving compatibility problems from different SCADA systems, it is simpler to utilise a centralised system that can receive data from these different systems as different formats and process it to be archived as one database.

Data transfer between applications from different developers, can already make this troublesome for computers on the same network. This communication problem only becomes more complicated when the data needs to be communicated between remote computers on different networks. Even though SCADA systems can do condition monitoring, due to inter-application compatibility problems, it would be simpler to implement a system that can obtain data from various SCADA systems on different gold mines and archive it centrally. This can be attributed to the fact that the active SCADA systems on the different gold mines are not necessarily from the same software company. These companies don’t provide easy integration of SCADA systems from their competitors as part of a marketing strategy. This system however needs to be implemented and configured in the same way for all condition monitoring sites to ensure consistent data quality. This generic implementation process will be discussed in the following section.

2. METHODOLOGY

2.1 Overview

This process will be developed and tested for the implementation of a condition monitoring system on the MSS’s of South African gold mines. An overview of this process is given in Figure 3 below.

![Figure 3: Implementation process overview](image)

This implementation process consists of four parts as shown in Figure 3. The investigation step focuses on determining the scope of the machines to be monitored and documenting the available machine parameters that need to be monitored. The second step consists of configuring the logging of the monitored parameters and sending the recorded data, at regular intervals, to a centralised server to be processed and archived. The following step in the process is to configure a visual representation of the monitored parameters and to verify the data quality. The fourth and final step in the implementation process is to configure the condition monitoring system feedback or outputs in terms of alarm notifications and automated reports. These steps will be discussed in more detail in the following sections.

2.2 Investigation

Before starting the implementation of a condition monitoring system, it is important to determine the scope of the machines that will be monitored. It is recommended to start by implementing the condition monitoring system on the most important systems of the mine. In the case of South African gold mines, this would be the five mine support systems, since they are essential for the effective and uninterrupted operation of gold mines. The primary deciding factors in which MSS’s are to be monitored, are the availability of instrumentation and the overall system availability. It is thus important to determine which machines in each system will be monitored and what parameters will be used.

For the purpose of this study, only machines with existing monitoring infrastructure will be included in an effort to minimise the implementation of a remote condition monitoring system. The SCADA computer can thus be used to determine the scope of the condition monitoring system by checking which machines are currently monitored and what parameters are available for each. All this information needs to be documented for future reference. The document created to contain this information is referred to as a commissioning sheet.

The commissioning sheet should also contain the parameters’ measurement locations and types in addition to their corresponding machines and MSS’s. The tag names used on the SCADA computer to monitor these systems need to be recorded for future reference. The commissioning sheet should be updated as new information becomes available.
parameters must be documented as well as the parameter logging interval. It is important to note that obtaining data directly from PLC’s can add unnecessary traffic on the control network and might influence its reliability negatively. Since tag naming conventions vary significantly from mine-to-mine and even for different dates of creation, it is recommended that a unique naming convention is used to record parameter values. This will make it easier to identify parameters from their names irrespective of their original tag names or origin. An example of the commissioning sheet for two mine ventilation fans is used to illustrate the resulting layout of the commissioning sheet. This is shown in Figure 4 below. (DE - Drive End, NDE - Non-Drive End)

<table>
<thead>
<tr>
<th>Machine</th>
<th>Measurement Type</th>
<th>Measurement Location</th>
<th>SCADA Tag Name</th>
<th>Condition Monitoring Tag Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation Fan 1</td>
<td>Vibration (mm/s)</td>
<td>Motor DE</td>
<td>fan1_mot_de_vibration.value</td>
<td>Gauteng Gold Mine B Ventilation Fan1 Motor DE Bearing Vb V</td>
</tr>
<tr>
<td>Ventilation Fan 1</td>
<td>Vibration (mm/s)</td>
<td>Motor NDE</td>
<td>fan1_mot_nde_vibration.value</td>
<td>Gauteng Gold Mine B Ventilation Fan1 Motor NDE Bearing Vb V</td>
</tr>
<tr>
<td>Ventilation Fan 1</td>
<td>Temperature (°C)</td>
<td>Fan DE</td>
<td>fan1_fan_de_vibration.value</td>
<td>Gauteng Gold Mine B Ventilation Fan1 Fan DE Bearing Vb V</td>
</tr>
<tr>
<td>Ventilation Fan 1</td>
<td>Temperature (°C)</td>
<td>Fan NDE</td>
<td>fan1_fan_nde_vibration.value</td>
<td>Gauteng Gold Mine B Ventilation Fan1 Fan NDE Bearing Vb V</td>
</tr>
<tr>
<td>Ventilation Fan 1</td>
<td>Status (-)</td>
<td>Motor DE</td>
<td>fan1_mot_de_temp.value</td>
<td>Gauteng Gold Mine B Ventilation Fan1 Motor DE Temp T</td>
</tr>
<tr>
<td>Ventilation Fan 1</td>
<td>Status (-)</td>
<td>Motor NDE</td>
<td>fan1_mot_nde_temp.value</td>
<td>Gauteng Gold Mine B Ventilation Fan1 Motor NDE Temp T</td>
</tr>
<tr>
<td>Ventilation Fan 1</td>
<td>Current (A)</td>
<td>Motor</td>
<td>fan1_mot_current.value</td>
<td>Gauteng Gold Mine B Ventilation Fan1 Current I</td>
</tr>
<tr>
<td>Ventilation Fan 1</td>
<td>Energy (W)</td>
<td>Motor</td>
<td>fan1_total_active_power.value</td>
<td>Gauteng Gold Mine B Ventilation Fan1 Total Active Power J</td>
</tr>
<tr>
<td>Ventilation Fan 2</td>
<td>Vibration (mm/s)</td>
<td>Motor NDE</td>
<td>fan2_mot_nde_vibration.value</td>
<td>Gauteng Gold Mine B Ventilation Fan2 Motor NDE Bearing Vb V</td>
</tr>
<tr>
<td>Ventilation Fan 2</td>
<td>Temperature (°C)</td>
<td>Fan DE</td>
<td>fan2_fan_de_vibration.value</td>
<td>Gauteng Gold Mine B Ventilation Fan2 Fan DE Bearing Vb V</td>
</tr>
<tr>
<td>Ventilation Fan 2</td>
<td>Temperature (°C)</td>
<td>Fan NDE</td>
<td>fan2_fan_nde_vibration.value</td>
<td>Gauteng Gold Mine B Ventilation Fan2 Fan NDE Bearing Vb V</td>
</tr>
<tr>
<td>Ventilation Fan 2</td>
<td>Status (-)</td>
<td>Motor DE</td>
<td>fan2_mot_de_temp.value</td>
<td>Gauteng Gold Mine B Ventilation Fan2 Motor DE Temp T</td>
</tr>
<tr>
<td>Ventilation Fan 2</td>
<td>Status (-)</td>
<td>Motor NDE</td>
<td>fan2_mot_nde_temp.value</td>
<td>Gauteng Gold Mine B Ventilation Fan2 Motor NDE Temp T</td>
</tr>
<tr>
<td>Ventilation Fan 2</td>
<td>Current (A)</td>
<td>Motor</td>
<td>fan2_mot_current.value</td>
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</tr>
<tr>
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<td>Energy (W)</td>
<td>Motor</td>
<td>fan2_total_active_power.value</td>
<td>Gauteng Gold Mine B Ventilation Fan2 Total Active Power J</td>
</tr>
</tbody>
</table>

Figure 4: Commissioning sheet layout example

Literature has shown that nearly half of all machine failures can be accredited to bearing failures [15]. One of the popular methods of condition monitoring in bearings is vibration monitoring. There are also well-accepted standards like ISO 10816 available for vibration monitoring. Bearing temperature monitoring can be seen as the traditional method of condition monitoring and can provide vital information about machine and bearing conditions [15]. Therefore, the initial measurement types for condition monitoring will be vibration and temperature, but this can be expanded once the condition monitoring system has been implemented. However, for the purposes of this article, only these two measurement types will be used. The measurement locations must also be system specific to ensure that similar machines are monitored similarly. Once the parameters have been documented the parameters must be recorded and processed, which will be discussed in the data gathering section.

2.3 Data Gathering

In the development of this process, software data loggers have been used to record parameter values. Individual data loggers should be used for the different MSS’s. This will ease the maintainability of the data loggers in the future. A logging interval of thirty minutes has been chosen for data logging, which should still enable the identification of deteriorating machine conditions. The average parameter value for every thirty-minute interval is calculated and logged to provide a more accurate indication of parameter values.

Even though vibration monitoring is being done at much higher frequencies, an increasing vibration will still be detectable at these logging intervals. This will minimise the amount of data that needs to be processed and stored without significantly compromising the data quality. The logged parameter values are sent as e-mail attachments to a remote server for processing and to be archived every thirty minutes. This means that the processing server will receive forty-eight e-mails daily from each condition monitoring site. It is important to note that machine conditions are monitored in real-time for alarm notification purposes, but data is only being logged at thirty-minute intervals for reporting. This means that when a parameter exceeds its limit, an alarm notification will be triggered on the condition monitoring server without the need for processing by the centralised server. This is illustrated in Figure 5 for one parameter being logged by the software data logger.
This processing server extracts the parameter values and sorts them accordingly before they are archived in a database for reporting purposes. It is also important to note that data accuracy is not as important for condition monitoring as for performance monitoring and data reliability should be prioritised above accuracy. This means that it is more important to be able to replicate measurements that it is to get accurate measurements. Centralising the condition monitoring data from different remote sites, makes it easier to access and to use for reporting on the condition monitoring of these remote sites. One of the reporting methods are to present the parameter values visually on a web-based user interface. This will be discussed as part of the data interpretation process in the next section.

2.4 Data Interpretation

Presenting parameter values visually, will help simplify the interpretation of logged parameter values. Parameter values can be presented as line graphs, which provide a simple indication of its recent behaviour. The limit for each parameter is also indicated on these line graphs so that the user can evaluate its condition. These parameter limits may also be used to quantify the machine and MSS conditions in terms of the distance between the parameters and their limits.

It is important to verify that the values being logged for each parameter are correct. There are a couple of easy ways to identify suspicious parameter values. The first is static parameter values, which means that the value of the parameter does not change significantly irrespective of the state of its machine. This is also valid for a parameter value that is constantly "0" even when the machine is running. Another example is parameter values that are unreasonably low or high, like a bearing temperature that is negative or an excessive vibration. In cases of incorrect data being monitored, the configuration of the parameter logging and processing is verified and followed by an inspection of the relevant instrumentation if necessary. Once the parameter data are correctly being recorded and visualised, it should be used to provide feedback on the condition of the monitored machines and MSS’s. This will be discussed in the next section.

2.5 Reporting

One of the simplest ways of providing feedback is by sending notification alarms to relevant maintenance personnel when a parameter exceeds its limit. This can be done either via SMS or e-mail and ensures that personnel can be instantly notified of parameter limit violations and take corrective action. The notification system should be configured so that personnel are notified timeously but not be annoyed by these notifications. The notifications should also be able to accommodate parameter fluctuations, so it is important to define a set of conditions that needs to be satisfied before an alarm notification is triggered.

An example of such conditions is that the machine must be running, the parameter must exceed its respective limit for five consecutive minutes and a notification for this violation must not have been sent during the past twenty-four hours. It has been found that the preferred notification channel by mine personnel is by SMS, which makes it easier for them to get notifications no matter where they are or what time it is. Automated condition monitoring reports should also be configured for the different condition monitoring sites.

Reports must be configured to be generated automatically and sent to mine personnel daily. This can be seen as official notifications to mine personnel about faulty machines. It can also be used to plan scheduled maintenance and provide feedback on problems that were corrected. These daily reports include a list of machine parameters that exceeded their limits during the previous day as well as a list of machine parameters that got close to their parameter limits. Line graphs are also included in the report for the machine parameters that exceeded their limits to give personnel a quick overview of the parameter’s recent behaviour. In an effort...
to optimise the implementation process, it was implemented on the four MSS’s of a South African gold mine as a pilot study.

3. CASE STUDY

3.1 Pilot Study

The monitored systems were mine dewatering-, mine ventilation, refrigeration and compressed air systems.

3.1.1 CM System Layout

The condition monitoring system that was implemented, had a very unique layout. This layout is shown in Figure 6 below.

As shown in Figure 6, machine parameter values are measured by sensors and communicated to Programmable Logic Controllers (PLC’s). These PLC’s are all connected to the SCADA computer of the mine, which is used to monitor and control mine operations from a central location (Control Room). The CM server uses a secure mobile network to send alarm notifications via e-mail or SMS to mine personnel when machine parameters exceed their specified limits. This GSM router is also used to send the recorded parameter values obtained from the SCADA computer as e-mail attachments to a central server to be processed and archived.

The database server extracts the logged parameter values, sorts and archives them in a database for further use. The database server also transmits the sorted parameter values to a web server, which is used to present the parameter values visually on a central web interface.

3.2 Group implementation

The condition monitoring system implementation process was optimised from experience gained on the pilot study gold mine and deployed on the MSS machines of additional gold mines within the same South African mining group. The following sections will discuss the implementation process on all the condition monitoring sites by using Gold Mine B as an example.

3.2.1 Investigation

Investigations indicated that Gold Mine B had four mine support systems that needed to be included in the condition monitoring system. The ventilation system consisted of four ventilation fans, the dewatering system...
consisted of nineteen water pumps, the compressed air system consisted of five compressors and the refrigeration system consisted of thirteen fridge plants. The number of parameters monitored under each MSS is shown in Figure 7 below.

![MONITORED PARAMETERS](image)

**Figure 7: Parameters included in condition monitoring system**

These parameters were all included in the commissioning sheet and assigned new parameter names by using a naming convention. If the monitored parameter’s tag name is changed on the mine’s control system for some reason, the data loggers needs to be updated to take this into account. This commissioning sheet was then used to configure a data logging platform. The investigation process was the same for all the mines in the mining group.

### 3.2.2 Data Gathering

Parameters were grouped and logged separately according to their MSS. The half-hourly average value of all the monitored parameters were recorded for six different gold mines and sent to a central server for processing. This resulted in a total of 1.2 million parameter values being processed monthly, while around 800 parameters where compared to their individual parameter limits every half hour.

### 3.2.3 Data Interpretation

The data quality of the logged parameters was evaluated, and the parameter values were configured to be displayed on a web-based user interface. An overview of the visual presentation of the MSS conditions is shown in Figure 8 below.

![Legend](image)

**Legend:**

- Red: Compressed Air
- Green: Refrigeration
- Blue: Dewatering
- Orange: Pumps
- Yellow: Fans
- Date: 2018-02-03

**Figure 8: Condition monitoring overview of mines**

The colour for each MSS is determined by the status of the machine parameter within the MSS that has the highest value. The different colours indicate different parameter states. A blue colour as shown in Figure 8,
indicates that no parameter limit has been defined for the machines within the MSS, while the green colour indicates that all the machine parameters within the MSS are well below their respective limits. If the system is represented by a red colour, it means that one or more of the parameters has exceeded its defined limit, while an orange colour means that one or more of the parameters are getting close to their defined limits.

These recorded parameters are visually presented on a web-based interface, which gives mine personnel quick and easy access to historical parameter data.

### 3.2.4 Reporting

The condition monitoring system’s function can be observed in an incident where a compressor’s bearing started failing. This triggered an alarm notification, which resulted in maintenance being done on the compressor. The problem was solved by replacing the bearing, which resulted in a decreased vibration reading. This is illustrated by the parameter trend in Figure 9 below.

![Figure 9: Example of condition monitoring system function](image)

The data in Figure 9 represents two vibration limits, although only one is visible. The is because they are identical and the line representing one limit is covering the line representing the other. Each time a recorded parameter exceeds the specified limit, it is referred to as a parameter violation. The purpose of this is to quantify a machine condition, and there is no need to classify a machine as faulty more than once a day. These violations are limited to one occurrence per day for each parameter. The total monthly parameter violations for the MSS’s of each mine was recorded and are shown in Figure 10 below.
The changes shown in Figure 10 can be quantified in terms of a monthly parameter violation count and a total reduction in the number of monthly parameter violations during the illustrated period.

Although there was an initial increase in the total number of violations, this might be due to the condition monitoring systems becoming fully operational. Some mines even had an overall increase in monthly critical exceptions. This might be attributed to the fact that the condition monitoring system can only notify mine personnel about faulty machines but cannot force maintenance to be done more timeously. These mines might belong to the same mining group, but it is important to note that each mine has its own maintenance team, which is responsible for maintenance of machines and systems. The maintenance teams on these mines would also differ in terms of resources, since the maintenance requirements of each mine is unique.

The data represented in Figure 10 can be broken into more detail to show the condition of individual systems in terms of monthly parameter violations per system. The condition monitoring system can be used to track system specific improvements in a mine’s maintenance strategy. An example of such an improvement is shown in Figure 11 below.
From the data in Figure 11, even though there was an initial increase in parameter violations after the implementation of the condition monitoring system, the monthly parameter violations decreased to almost none. The dotted line represents the total monthly parameter violations for all the systems during each month. This can be attributed to persistent and sufficient maintenance actions. Another reason for this is that due to an infrastructure change on the mine, its support systems became more efficient and had a reduced workload.

Unfortunately, the number of parameter violations can also increase on a month-to-month basis for individual systems due to a failing maintenance strategy. This is indicated in Figure 12 below.

The data in Figure 12 shows that the number of parameter violations by the ventilation system stayed relatively constant, while the parameter violations caused by the fridge plants increased significantly after an initial
decrease. This has caused the overall MSS machines’ operating conditions to deteriorate and might indicate a deteriorating interest in proper maintenance by mining personnel. Since each mine has its own maintenance responsibilities, this can be seen as a sign of inadequate management, or the need for a more structured approach to maintenance strategies to ensure consistency on different mines.

A general decline in parameter violations, as shown in Figure 11, indicates that maintenance personnel on mines started doing more preventative maintenance and thus avoiding machine parameters exceeding their predetermined limits. This indicates that there has been a definite impact on the overall condition of MSS machines and their maintenance strategies by the condition monitoring system. There were however also some obstacles that were encountered during the implementation of this condition monitoring system. The most significant obstacles will be briefly discussed in the next section.

4. PROBLEMS FACED DURING IMPLEMENTATION

4.1 Investigation

A small group of people were initially tasked with implementing the condition monitoring system on these gold mines to speed up the process and distribute the workload. Since there was no defined naming convention for parameters being logged for condition monitoring, some parameters were poorly named, or the names were not descriptive enough. This kind of problem can be addressed and prevented by following a generic naming convention for all the parameters monitored by the data loggers.

The documentation process also led to new problems. Some personnel did not document additional parameters being logged or the defined parameter limits used for some notification alarms. Others did not update the required documentation after changes were made to the data logging platform. This is another indication that a structured implementation process can assist the management and optimisation of existing maintenance strategies. There was also no complete list of available machine parameters, which meant that the data logging platform had to be updated regularly to correct faulty configurations or add new machine parameters to be monitored.

One of the most important parts of the implementation process is obtaining a tag list or list of monitored parameters before starting any data gathering. This will be used to evaluate and identify parameters that are important for condition monitoring. It was thus found to be essential for everyone working on the data gathering to update the relevant documentation frequently and to distribute these documents to the relevant people.

4.2 Data Gathering

A lack of experience in some areas also led to data loggers being configured incorrectly or alarm notifications not functioning correctly. There were also problems on the condition monitoring server itself. Some unused parameters were logged to build a more complete database for future reference. This caused the data logging platform to stop responding (frozen computer application) and caused either static parameter values to be logged or no parameters being logged altogether. On some occasions, the connection to the SCADA computer was lost and because it was unmonitored, it led to further data losses. These issues can be minimised by having qualified people maintain both the software and hardware components of the condition monitoring system.

Furthermore, the condition monitoring server failed to start up correctly after a power failure, which meant that data was not being logged. Due to the server not starting up correctly, remote connectivity was also not available to identify the cause of data loss. This meant that the server had to be restarted locally before data logging could resume. There was also an incident where a hardware component on the condition monitoring server failed and prevented the server from starting up without manual intervention. This caused data loss on several occasions before the problem was identified. This can be prevented by using an uninterruptible power supply (UPS), which will prevent data loss during power failures and protect equipment from electrical power surges.

4.3 Data Interpretation

There were some instruments that became faulty and caused unrealistic values to be logged without being noticed immediately. This was easily identified on the visual data graphs and could be corrected. The user interface made it easy to track and identify data loss or poor data quality incidents. Problems like this emphasises the importance of checking data quality to identify faulty instrumentation or configuration errors.
4.4 Reporting

A GSM router with a prepaid sim card was used to send data via e-mail, alarm notifications via SMS and provide remote access to the condition monitoring server for troubleshooting and maintenance purposes. This led to some problems like the data bundle or SMS bundle getting depleted unexpectedly. The depletion of the SMS bundle prevented essential alarm notifications from being sent, while the depletion of the data bundle had more significant consequences. A depleted data bundle meant that half-hourly data could not be sent to the central server for processing and remote connectivity for troubleshooting was also not possible. Another common problem was that due to poor mobile signal, remote connections were very slow and data log file sizes were very limited. It is thus recommended that a reliable system is used to transmit data and alarm notifications.

The alarm notifications were also initially configured to trigger too frequently, which ended up annoying mine personnel more than being informative. There were other occasions where alarms were triggered for machine parameters while the machine was switched off. This was remedied by decreasing the minimum alarm frequency and developing a list of conditions that had to be satisfied before alarm notifications could be triggered, as discussed in the previous section.

5. CONCLUSION

In this paper we have seen that there are five essential MSS’s for deep level gold mining in South Africa and that each of them is driven by large motors. It was found in literature that unexpected maintenance can lead to significant operational costs and production losses. There is thus a need for active condition monitoring on the machines of MSS’s and real-time notifications of parameters with excessively high values.

A condition monitoring system implementation process was therefore developed and optimised on the MSS machines of various South African gold mines in order to monitor the condition of MSS machines and encourage preventative maintenance. Although the total number of parameter exceptions increased initially, there was a general decline since the implementation. This means that the condition monitoring on MSS machines resulted in more efficient maintenance strategies on South African gold mines.

6. REFERENCES


