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Implementing a tracking and ventilation control system at Barrick Goldstrike's underground division

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ABSTRACT: Underground mining accidents in the USA in recent times have prompted the Mine Safety and Health Administration (MSHA) to review emergency and tracking systems for underground mines. Several communication and tracking systems are available on the market and various systems have been installed in mines around the world. In addition, MSHA's standard on Diesel Particulate Matter (DPM) requires mines to comply with the final PEL of 160μg/m^3 by May 20, 2008. Barrick Goldstrike Mines Inc., Underground Division, has been in operation since 1995 and an extensive control and monitoring network, and a leaky feeder voice network is in place. Enhancements to the communication and control system are currently being implemented to include a PED emergency notification system, wireless LAN with tracking of personnel and equipment in the mine, and a ventilation control system that will use the tracking information and ventilation data to automate much of the mine ventilation system. Expected benefits from such a system would be enhanced communication with miners, emergency notification, location of miners and equipment, energy savings, improved ventilation control, and improved atmospheric conditions in the mine including reduction of diesel particulate matter (DPM).

1 Introduction

Barrick Gold's Goldstrike Mine is located on the Carlin Trend in North East Nevada, USA. The Underground Division has been in production since 1996 and covers a footprint measuring 1850 m by 125 m, located directly to the north of the Betze-Post open pit.

The Underground Division is made up of several mining zones including Meikle, Rodeo, Griffin and others. There are two major haulage drifts connecting Meikle and Rodeo through the Griffin zone. Ramp systems connect all mining levels. The mine has two ventilation intake shafts, one at Meikle- and one at Rodeo Mine, and three exhaust shafts, two at Meikle- and one at Rodeo Mine. A decline haulage drift from the Betze-Post pit enters the Rodeo mine from the south and acts as another fresh air intake. The lowest mining level is currently 610 m below surface at an elevation of 1097 m (3600 ft) above sea level.

The mine produces about 5000 tonnes a day, 4000 of which is ore, using a production fleet of approximately 70 pieces of rubber tired, diesel powered equipment. Because of high rock temperatures, of the order of 60°C (145°F), the mine has a 10 MW cooling facility. Furthermore, gases such as carbon dioxide and sulphur dioxide are liberated at various areas in the mine, thus requiring a large volume of air to be moved through the mine to ventilate workings.

From the outset, a mine control network was installed, initially for the mine refrigeration system and then, as the underground was developed, to allow remote control of underground auxiliary fans. As the mine has grown, all fixed plant have been added to the control and monitoring system. Now, with tighter control on diesel exhaust emissions, and the need for tracking the whereabouts of miners, the next generation of communication and control systems is required in the mine. These systems lend themselves to implementing a Ventilation-on-demand (VOD) system in the mine with obvious benefits.

2 The Mine Ventilation System

The mine ventilation and cooling system has been described in several papers, including Mutama and Meyer (2006).

Meikle Mine has one fresh air intake shaft with Bulk Air Cooler (cooling in summer and heating in winter) and Rodeo Mine has a similar intake shaft and Bulk Air Cooler. A third fresh air intake is the Betze Drift from the Betze-Post pit to the Rodeo 4100 level.

The total amount of air exhausted out of the mine is 1080 m^3/s (2.1 million cfm). Meikle Mine has two 2.74 m 1300 kW centrifugal exhaust fans on the main exhaust shaft and a 1.93 m 520 kW centrifugal fan on a borehole (or vent raise) which together pull 517 m^3/s. Rodeo Mine, about 1.6 km to the south, has two 2.74 m 1120 kW 1200 rpm variable speed axi-vane fans on an exhaust shaft pulling 564 m^3/s.

In addition to the surface main fans there are numerous axi-vane booster fans located throughout underground ranging from 75 to 375 kW. Fan sizes vary from 1067 to 2134 mm. The booster fans are essential in distributing airflow to the various levels and zones of the mine where the required quantity dictates the size of the fan.

Vent raises exist on almost every level where some of these fans are located to move airflow on the main haulage or footwall drifts. Air flow per level can vary from 38 to 190 m^3/s or more. Variable air flow quantity demand on some levels is achieved by using controllable pitch fans and/or variable flow regulators.

3 The Mine Monitoring and Control System

The mine ventilation monitoring system was described in detail by Mutama and Meyer (2006).

The ventilation system is very dynamic in that changes in conditions in one area affect other parts of the mine, thus requiring a carefully balanced system to maintain safe working conditions throughout the mine in real time.

A ventilation monitoring system was installed to monitor various gas concentrations, and to detect the presence of high carbon monoxide, such as in the event of a fire. In addition, air flow and air temperature measuring devices were installed to provide real time ventilation information in critical areas.

3.1 Existing Control System

Several control networks have been installed in the mine since 1995. An extensive fiber optic network has been installed from surface and throughout the underground to all main levels of the mine. Several copper or twisted pair networks are also installed with media converters, routers, etc. to interface the local devices with the fiber optic network as needed.

The main mine control network is based on a combination of Ethernet, Allen-Bradley Data Highway Plus (DH+) and DeviceNet which interfaces to numerous Programmable Logic Controllers (PLCs) throughout the mine. Fixed plant such as shotcrete plants, backfill plants, loading pockets and crushers, motor control centers (MCCs), mine hoists, exhaust fans, refrigeration plant, air compressors, etc. are all controlled by PLCs on this control network. All booster and auxiliary fans are powered from motor control centers (MCCs) or from mobile load centers (MLCs), and can be remotely controlled.

3.2 Ventilation Monitoring System

The ventilation monitoring system of choice is the MSA Ultima Gas Monitor which uses the LonWorks digital communication network. Configuration of this network is undertaken using LonMaker Turbo with Microsoft Visio.

Numerous gas monitors have been installed in the mine in recent years. The system's primary purpose is fire detection, to detect high levels of carbon monoxide. In several areas in the mine other pollutants occur, requiring installation of additional monitors such as carbon dioxide (from ground water), sulphur dioxide (from sulphide ore), nitrous oxide and ammonia (from blasting and refrigeration plant). In addition, oxygen sensors and air temperature monitors (wet bulb and dry bulb) were installed at various locations and in refuge chambers.

Ultrasonic type air flow monitors have been installed on several levels, ramps and main intersections. Where air flow can reverse direction, the air flow monitor was configured to give a bi-directional flow reading.

Several remotely adjustable air flow regulators are installed at main vent raises. The regulator actuators are connected to the LonWorks network to allow remote control of the actuators.

3.3 Supervisory Monitoring and Control System

The supervisory monitoring system, also referred to as SCADA or HMI, is based on a software package known at the mine as CIMPLICITY (GE Fanuc Automation, Proficy CIMPLICITY HMI) which monitors all aspects of mine services, both surface and underground.

Servers on the Local Area Network (LAN) gather the real time information from the PLCs on the DH+ and Ethernet networks, from the LonWorks database using an OPC server, and from the Process PI database, also using an OPC server. This data is displayed on the users' desktop computer (viewer), logged to an SQL database, and used for trending, alarming and reporting. Furthermore, a Web-based viewer called WebView is also available for remote monitoring across the company intranet.

4 The Mine Communication Systems

The mine communication systems consist of land line telephones, push-to-talk mine page phones, and a leaky feeder radio system currently configured for voice only.

Land line telephones are installed underground at fixed locations such as shaft stations, refuge chambers, motor control centers or substations, and workshops and offices.

Mine page phones are also located at the same locations as well as in the mining areas, drifts and headings.

The leaky feeder radio system was originally based on El-Equip equipment (VHF), but now has only El-Equip head end equipment and Mine Site Technologies (MST) and Tunnel Radio amplifiers. Five voice channels are configured, one for Rodeo Mine, one for Meikle Mine, one for Backfill operations, one for Electrical personnel (primarily used for commissioning and troubleshooting), and a fifth for Safety/Emergency. The latter channel also interfaces with the surface Emergency channel.

5 Communication and Tracking Enhancements

As a result of the mining accidents in the USA in 2006 and 2007, the need was identified to locate miners underground in the event of an accident. Several communication and tracking options are available on the market, or have recently become available.

In 2005, Barrick Goldstrike Underground Division started looking at tracking vehicles to monitor location and payload information. As a result of the 2006 accidents, this project quickly escalated to tracking personnel in the mine.

5.1 Selection of Systems

A basic project scope was developed, listing the requirements of a communication and tracking system. Firstly, an emergency notification system was required to send a message to miners in the event of a mine emergency, and secondly, a tracking system was required to track and locate miners in the mine.

Several options were reviewed, and very quickly, the benefits of these systems were realized. Vehicles could be tracked in the mine. Engine performance information could be logged and uploaded. Payload information could be gathered. Ventilation could be controlled according to vehicle and miner location or mining activity.

In order to use onboard data loggers (computers) and move a large amount of data, a wireless Ethernet network would be required. Thus, the tagging system should also use Wi-Fi tags. Since Ethernet was already available in the mine, it would lend itself to extending into the mining zones using wireless access points to create “hot spots”.

Several other requirements for the system were also identified. It would need some redundancy built in to it to make it more robust in the event of cable damage or power failure. Any associated software had to be open to allow system integration between the existing and the new systems.

Mine Site Technologies (MST) was selected as the primary equipment supplier, since it met the basic requirements for the communication and tracking system.

5.2 Emergency Notification System

The MST PED Emergency Notification System is a one-way, through-the-earth communication system, capable of sending a text message to a wearer of a PED receiver. The PED system transmits the message via ultra-low frequency (ULF) signal that propagates through the rock strata to the receiver.

The Barrick Goldstrike PED head end panel was installed at Meikle main administration building. The antenna is a continuous loop that was laid out partly on surface and partly underground, from Meikle to Rodeo Mine, down Rodeo Intake shaft, up to Meikle through Griffin, and up Meikle Production shaft. This route was chosen primarily because of limited surface real estate.

The MST Integrated Communications Cap Lamp (ICCL) was selected to replace existing cap lamps. The ICCL houses a PED Receiver and an 802.11b Wi-Fi tag (made by AeroScout, refer to Figure 4). The lamp is light weight, has a Lithium Ion battery and a Koehler-Wheat focusable headpiece.

Figure 1. MST Integrated Communications Cap Lamp

5.3 Wireless Local Area Network

In order to track Wi-Fi tags in the mine, and to allow wireless access to the mine LAN, Wireless Access Points (WAPs) would need to be located at major intersections, plant locations, refuge chambers, PM bays and workshops, and shaft stations.

Additional single mode (SM) fiber was installed in the Meikle and Rodeo intake shafts, between all levels and between the two mines in both main haulage drifts. New Cisco Ethernet switches were installed on all main levels in the mine on the SM fiber to create a 1 Gigabit/second Ethernet backbone. Switches were inter-connected to provide redundancy.

MST ImPact Wireless Access Points (WAPs) were installed at each shaft collar and all shaft stations. Additional WAPs are being installed in the mine in workshops, refuge chambers, major intersections and footwall drifts. The WAPs are connected together using a hybrid fiber/copper cable with two or four multimode (MM) fibers for signal, and two copper conductors for the 24 VDC power. The WAP consists of a fiber switch motherboard, which communicates at 100 Megabit/second and provides wired LAN connectivity, and a wireless access card (WAC) supporting 802.11 standards.

Figure 2. MST ImPact Access Point

Several Virtual LANs (VLANs) were created to subdivide the mine into five specific zones, and to provide the IP addressing of devices as required.

In areas where congestion occurs, one WAP will detect tags from multiple directions. In order to better distinguish exact locations, exciters are required to be installed at these locations. The exciter will modify the information on the tag to provide the location of the exciter. Figure 3 below shows a typical level where this occurs. A WAP installed at a four-way intersection will not be able to distinguish between the four areas, for example, powder magazine to the west, shotcrete plant to the east, footwall to the north and shaft access to the south. Using an exciter at the shotcrete plant, and another at the powder magazine, will at least identify tags at these two locations.

The tracking software used is the AeroScout Engine with MobileView.

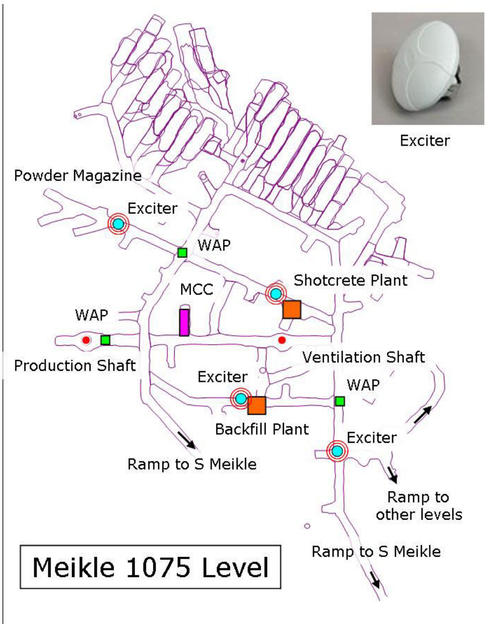

Figure 3. Typical mine level showing location of WAPs and Exciters.

5.4 Tracking System

AeroScout Wi-Fi tags are installed on mobile equipment and in all cap lamps (see Figure 4 below).

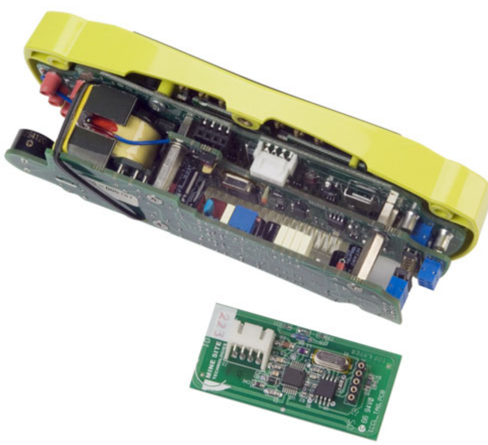

Figure 4. AeroScout Wi-Fi Tag plugs into the PED Receiver unit of the ICCL.

The tags (Active RFID Wi-Fi 2.4 GHz) are detected by Wireless Access Points as the tags move past the WAPs. The Access Point passes the information on to a central server (AeroScout Engine), or if communication to the server is not available, the Access Point will cache the data until the server becomes available.

The AeroScout Engine processes the information received from the AeroScout Wi-Fi tags and other standard wireless devices. The AeroScout Engine calculates the tag position and passes this data to AeroScout MobileView. MobileView records the location information to a database. MobileView is a Web-based tool that allows locating and viewing tag position in real-time from any computer on the company intranet.

5.5 Energy Management System

Another important component of the overall Mine Control System is an energy management system. Bestech's NRG-1 Web-based Control System was chosen to enable real-time control, time-of-day scheduling and event-based control of assets in the mine, such as ventilation fans, primarily the auxiliary fans.

The total installed horsepower for underground fans at Meikle Mine and Rodeo Mine is 22000 HP, or 16.4 MW. Normal power consumption for all of underground at mid-shift is about 5-6 MW at Rodeo and 5.5-6.5 MW at Meikle. With purely manual control of these fans, many run when not required and should be turned off. Thus an energy management system such as NRG-1 was ideally suited to managing the fans, with obvious energy savings.

NRG-1 interfaces seamlessly with the existing control network using an OPC server to communicate with the PLCs controlling the fans. NRG-1 will also interface with the tag tracking database as well as the ventilation data.

The NRG-1 Suite consists of three modules: Time-of-Day Scheduling, Event-Based module and Real-Time module. Each module can be used to enhance the existing mine ventilation control system.

Time-of-Day Scheduling was implemented first to stop all auxiliary fans at the end of each shift. This tedious task was performed by the Dispatch Operators before the blast could be initiated at the end of each shift, at 7:00 AM and 7:00 PM daily.

The Event-Based module will be used, once the tracking system is fully in place, to detect the presence of tags in an area and make ventilation adjustments accordingly (see Ventilation-on-Demand). When tags leave an area, fans can be shut down or ventilation reduced. Likewise, the presence of high CO after a blast could initiate a ventilation change, such as restarting the auxiliary fans in the area.

The Real-Time module can be used to stop or start fans, or to disable them from any programmed mode or schedule.

The benefits realized from this system should be obvious – reduced tedious operator tasks, enhanced ventilation control, and energy savings. It is anticipated that about 3 MW of power can be shed by implementing this type of control of the auxiliary fans. This translates to a daily saving of about US$5000 in energy costs (at $0.07/kWh).

5.6 Mine Dispatch System

Goldstrike Underground Division utilizes Micromine's PITRAM software to track, store, and report a variety of underground activities. There are three major components to the mine dispatch system - Data Acquisition (DA), Reporting functions, and Administrative Controls. The DA module captures and records the events as they occur and are reported during the shift. Typical events that are recorded include equipment states, equipment location, equipment movements, personnel, and measures such as feet drilled, number of bolts, number of scoops, etc.

Each crew at both Meikle Mine and Rodeo Mine has a Dispatcher. The dispatcher is responsible for logging the data into PITRAM that is called in via the Leaky Feeder radio system and/or mine page phone system. The dispatcher is also responsible for monitoring data and alarms via the CIMPLICITY HMI system.

The current version of PITRAM (2.1) utilizes a Microsoft Access database on each Data Acquisition computer to store the shift information. The Data Acquisition application is the central, single point of entry when recording shift events. At end of each shift, the dispatcher processes shift data which moves it to an off-node SQL server.

Micromine is currently working on upgrading the Goldstrike system to PITRAM version 3. This version will solely utilize Microsoft SQL Server, thus allowing multiple concurrent data acquisition. It will also allow information to be accessed between multiple clients and the central PITRAM Data Server.

A further enhancement to the system will be PITRAM Automation which utilizes onboard ruggedized computers with touch screens mounted on mobile equipment, particularly the production fleet. The PITRAM Mobile application allows the equipment operator to enter data via the touch screen and keypad – the same information as the Data Acquisition application. The PITRAM Mobile application will also interface with engine management systems to gather engine performance data.

As the vehicle comes in range of a WAP, the stored data will download to the PITRAM Data Server via the LAN/WLAN. The onboard computer MAC ID will be used for tracking the equipment as it moves through the mine.

The engine performance data will be used by the NRG-1 Energy Management System to adjust ventilation accordingly.

6 Ventilation-on-Demand (VOD)

Various control systems are now in place in the mine, or are being installed or upgraded, as described above. So, what still remains to be done to achieve Ventilation-on-demand at Barrick Goldstrike's Underground Division?

A mine wide monitoring and control system is in place. Air flow and pollutant levels are measured in many areas of the mine to ensure minimum air quantity and air quality standards are maintained. Real-time DPM monitoring devices are being developed and will be incorporated into the ventilation monitoring system as they become commercially available.

Auxiliary and booster fans do not have variable speed motors, and upgrading to variable speed drives (VSDs) would not be considered at this time. If this is necessary in the future, the booster fan starters on the fixed MCCs may be upgraded to VSDs.

A wireless network and tracking system is being installed in the mine. All personnel and most vehicles will carry Wi-Fi tags. Some vehicles, such as the production fleet (bolters, drills, trucks and loaders) will have onboard computers for data acquisition. The computer MAC IDs can be tracked. The onboard computers will interface with the engine management systems to provide engine performance data. Where possible, exhaust emission data will also be captured.

An energy management system (Bestech NRG-1) has been installed to provide time-of-day scheduling and event-based control. The tag information associated with a particular vehicle, and the vehicle engine performance or exhaust emission data, can be used to determine the ventilation change required. An event will be triggered to adjust the ventilation in the area, or to stop the vehicle from entering the area if the number of vehicles in the heading exceeds the available ventilation to support them. It should be noted that the ventilation changes will be limited to starting auxiliary fans that ventilate headings, or stopping auxiliary fans in the event of inactivity. Main air flow regulators can be adjusted to increase or decrease the amount of air on certain levels. Booster fans will run at all times. Main exhaust fans may be adjusted to match the overall required air flow through the mine. These main fan changes will only be undertaken with caution so as to not cause a major ventilation imbalance.

Thus a basic version of Ventilation-on-Demand will be achieved for each mining level depending on activity in the area. The resulting benefits will be increased energy savings, reduced burden on the Dispatchers to control fans, and overall improved atmospheric conditions in the mine.

7 Summary and Conclusion

The mine communication and tracking system being implemented at Barrick Goldstrike Mine Underground Division provides not only emergency notification and personnel tracking capabilities in the event of a mine emergency, but also enhances the overall mine communication scheme to provide wireless hot spots and greater WLAN coverage. Upgrading to PITRAM 3 and employing an Energy Management System such as NRG-1 along with the existing mine wide control and monitoring system (CIMPLICITY), moves the mine to the next step in achieving a total mine control system. This system provides many benefits including enhanced communication, quicker emergency response, energy savings, better ventilation control, improved atmospheric conditions in the mine, and an overall mine control system (see Figure 5 below).

Challenges will still exist. Any sophisticated control and monitoring system will need a Control Engineer for design, programming and configuration, as well as highly skilled Electrical and Instrumentation technicians for the installation and maintenance of these systems. Instruments require regular calibration to provide the required accuracy and confidence in the system. Equipment, instruments, communication and control cables will get damaged and need repair. Challenges aside, the benefits are worth it.

Acknowledgements

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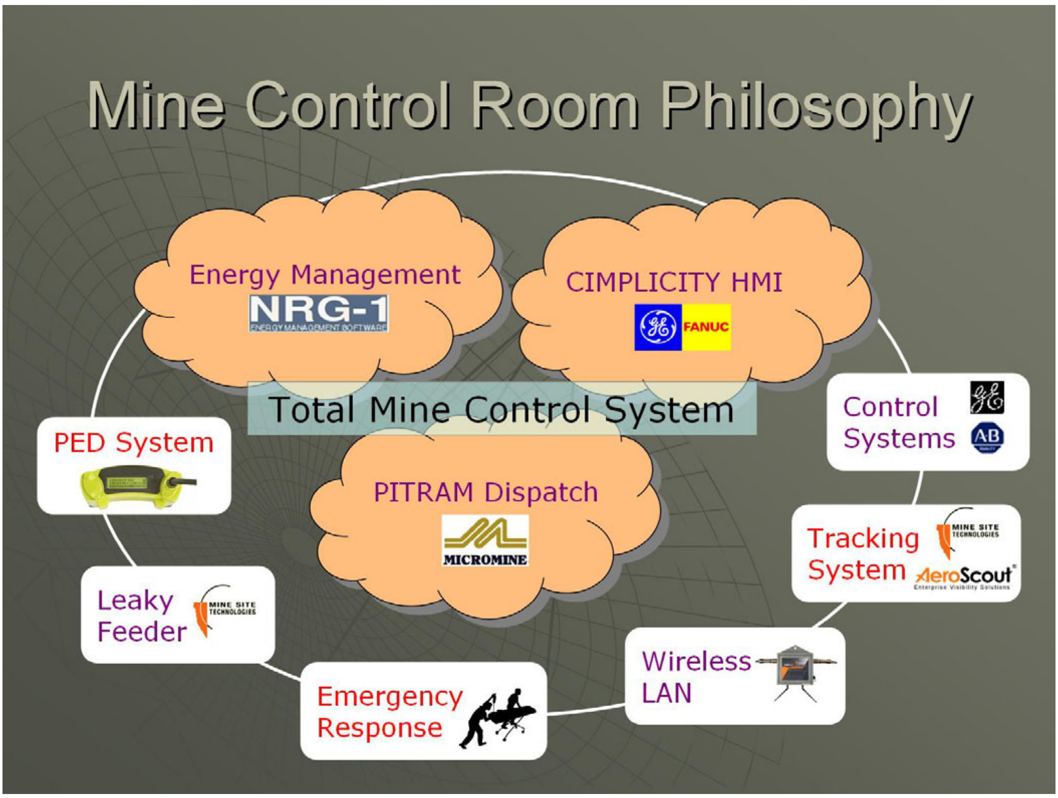

Figure 5. Schematic of the Total Mine Control System concept utilizing all installed technologies.