Using Gas Monitoring and Personnel/Vehicle Tracking to Maximize the Benefits of Ventilation-On-Demand in Underground Mining Operations

By Tanveer Jahir, Mohamed Mohamed

Conspec Controls Limited

With increasing energy costs and mounting government pressure to adopt low emission, green sources of energy, it has become imperative to develop long-term sustainable underground infrastructures that exhibit low power consumption. Underground mining environments are mandated to have ventilation systems in place to replace polluted air with clean air. Continuously running air ventilation systems have proven to be an expensive solution for this requirement. Ventilation-on-demand (VOD) is a cost effective method for not only reducing energy consumption and greenhouse gasses, but also ensuring the safety and well-being of the miners beneath the surface. VOD is achieved by monitoring the air quality in target areas of the mine, and based on variables such as the number of personnel in the area, the number of emission-emitting vehicles, the air leakage around doors and entrances, dust levels, and other key environmental details, the speed and angles of the fan blades are adjusted to increase or decrease the volume of air flow. For over 40 years, Conspec Controls has been developing systems capable of VOD through the use of controllers, gas monitors and personnel/vehicle tracking equipment, providing inexpensive, reliable solutions for underground ventilation.

Key Words: Ventilation-On-Demand, Toxic Gases, Mining, Instrumentation, SCADA, Conspec Controls

Nomenclature

VOD: Ventilation-On-Demand
MSHA: Mining Safety and Health Administration
SCADA: Supervisory Control and Data Acquisition
AMS: Atmospheric Monitoring System
UVW: University of West Virginia
MTU: Michigan Technological University
DPM: Diesel Particulate Matter

1. Introduction to Ventilation-On-Demand

Over the years the cost of mining operations has increased significantly, in part due to the rising cost of electrical power. A significant portion of a mine's operating cost is devoted to electrical power, with ventilation systems being major consumers. Ventilation can account for 35-50% of an underground mine's energy consumption, translating into as much as $ 20-30 million per year [2].

With mines all over the world looking to be more cost effective, one method of ventilation, the VOD system, has shown promise as a method for curtailing cost. The essential premise of the VOD system is simple; supply ventilation only to those locations where work is actually in progress, and not into areas that are vacant.

Mines utilize heavy machinery to dig and haul raw materials. This machinery, in conjunction with the blast work that goes on in a mine produce air contaminants such as dust, diesel particles, carbon dioxide, methane and a number of other gases, which mix with air that is brought into the mine. Ventilation systems draw this contaminated air out, and pump fresh air into the mine from the surface, making it possible to provide a non-hazardous underground working environment [1]. According to current Mining Safety and Health Administration (MSHA) standards on Diesel Particulate Matter (DPM), mines are required to comply with the final PEL of 160µg/m3 by May 20, 2008 [4].

Typical ventilation systems consist of primary and secondary ventilation systems. The primary system transports air to and from the mine and is made up of shafts, ventilation walls and primary fan stations. The secondary system usually consists of fans and ducts that distribute air to specific areas of the mine [1].

In non-VOD systems most fans controlling the input and output of air have variable speeds that can be adjusted to increase or decrease the air flow. These fans typically operate continuously and provide air and ventilation into all areas of the mine, including areas that are unoccupied. In a VOD system, these fans can be controlled on demand so that only occupied underground work areas would be ventilated.

To achieve the optimal goals of a VOD system, a number of criteria must be met. First of all a "true" VOD system should be able to track equipment and personnel in real time to ensure on-demand ventilation and also adjust air flow and heat as is needed [2]. The system should also be able to monitor airflow, air quality, and on/off status of all equipment. It should also be able to dynamically track and analyze patterns of usage, to simulate and create models for further design [2]. Most importantly the system should be able to control ventilation to achieve optimal air flow and quality at lowest cost [2].

Having an existing Atmospheric Monitoring System (AMS) is the first logical step in moving towards a VOD system. Most mines currently implement some form of AMS, but recent tragedies have demonstrated the need for the adoption of stricter safety rules and more capable atmospheric monitoring systems.

Due to the presence of methane gas and heavy coal dust concentrations, the potential for gas explosions is typically thought to be of concern only for coal mines, but statistical research has shown that both hard rock and coal mines require a capable AMS to prevent explosive events. In a recent study conducted by South African Department of Minerals and Energy: "According to the South African Department of Minerals and Energy's (DME) database, flammable gas accidents accounted for 7.3% of fatalities in the South African mining industry between 1998 and 2001. Nearly 97% of these accidents occurred in mines other than collieries. Most research in South Africa over the past decade has focused on collieries, but five of the last six devastating flammable gas-related events (four or more deaths) occurred in hard rock mines." [3]

This demonstrates an obvious need for AMS which is a highly recommended prerequisite to VOD.

2. The Costs and Benefits

As many studies have shown, the benefits of VOD are numerous. Most notably, implementation of a VOD system has shown to provide a 20-50% reduction in ventilation energy costs [2], as unnecessary ventilation of areas without personnel or equipment is reduced. Studies and tests have also shown that VOD systems improve overall mine productivity, reduce overextension of skilled labour, lower carbon emissions and improve mine safety [2].

Despite the benefits, implementation of VOD is not without challenges. To begin, most mines planning to install a VOD system have a pre-existing ventilation system which will need to be retrofitted with new technology requiring initial capital costs. To ensure that the system operates smoothly, personnel would need to be trained in the use and maintenance of the new system and equipment [4]. Finally equipment, instruments, networks and cable would require regular maintenance, calibration and repair [4]. However, these drawbacks are relatively minor in comparison to the benefits. And in comparison to existing ventilation systems VOD is clearly the better choice.

Not implementing a VOD system can have serious monetary and efficiency repercussions. According to the Luossavaara-Kiirunavaara Aktiebolag (LKAB) study, a system they already had in place was inefficient in circulating air, causing the movement of excessive volumes of air and high energy costs [1]. Despite the expense, air quality and working conditions remained poor. "The result ... was that all the fans were running at maximum capacity, large volumes of fresh air were being heated yet still insufficient air volume of insufficient quality were reaching the areas where it was needed. Airing and extraction of explosion products, diesel gases and dust were also insufficient for attaining acceptable levels for accessing production areas (within acceptable time scales)" [1]. Other mines have shown similar problems with existing ventilations systems. On the other hand implementing a VOD system by extending a pre-existing AMS may be a more viable solution.

3. Software That Can Be Used to Determine Cost Savings

There are many software solutions available to assist in determining whether a VOD system would be a viable investment for a mine. These software systems use variables such as location, size of the mine, what is being mined, the type of heating system, the number of fans, the number of monitors, etc., to determine a relatively accurate indicator as to start-up costs of a VOD system, and the number of years before the VOD system becomes profitable.

One such software is the RETScreen Clean Energy Project Analysis Software. "The RETScreen Clean Energy Project Analysis Software is a unique decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software can be used worldwide to evaluate the energy production/ savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). The software also includes product, project, hydrology and climate databases, a detailed user manual, and a case study based college/university-level training course, including an engineering e-textbook." [5]

"Since RETScreen International is managed under the leadership and ongoing financial support of the CanmetENERGY research centre of Natural Resources Canada's (NRCan), it provides trustable references and reliable platform for our customers to assess and evaluate their potential projects, not only on the technically prospect, but also in financial point of view." [5]

Using an example to demonstrate the power of the software, there are few assumptions that need to be made while setting up the RETScreen platform. Assuming that the customer is a small mine in Sudbury; it can be said that an electric heating system is being used as the main heating source; there are two main ventilation fans for the mine; it can also be assumed that after the VOD system is installed, the requirement for the flesh air will be reduced by half. After running the simulation, it was determined that the initial cost of this project is predicted at $100,000 per unit fan ($200,000 in total) and an annual maintenance cost of $20,000.

The following are a few screen shots from the RETScreen software for this project:

Figure 1 – The General Project Setup

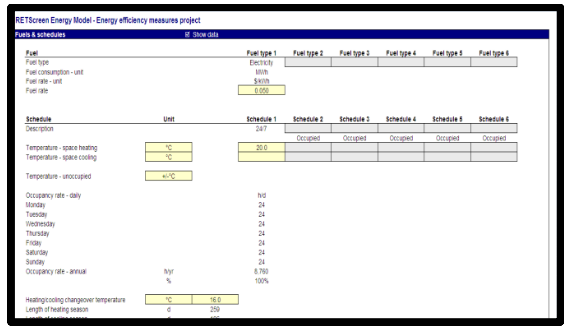

Figure 2 – The Fuel Type and Schedule Setup

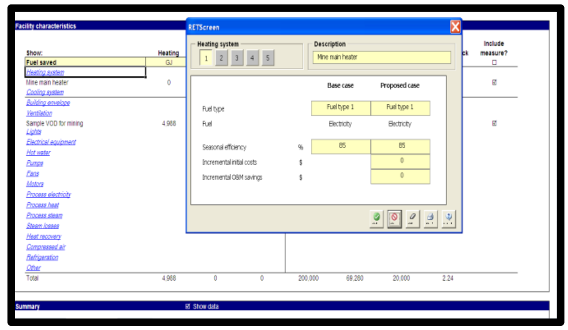

Figure 3 – The Heating System Setup

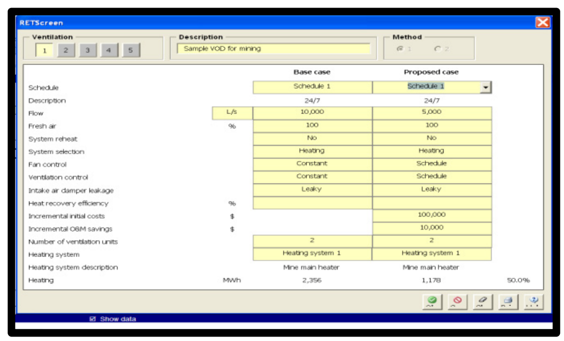

Figure 4 – The Ventilation System Setup

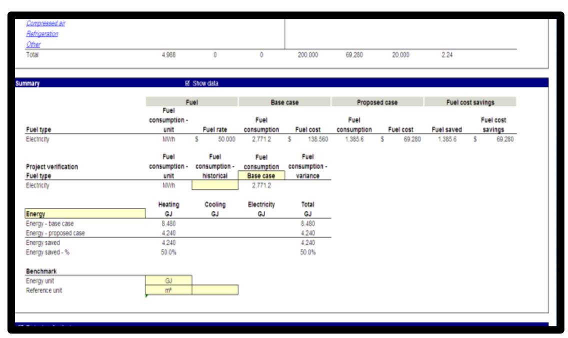

Figure 5 – The Project Summary

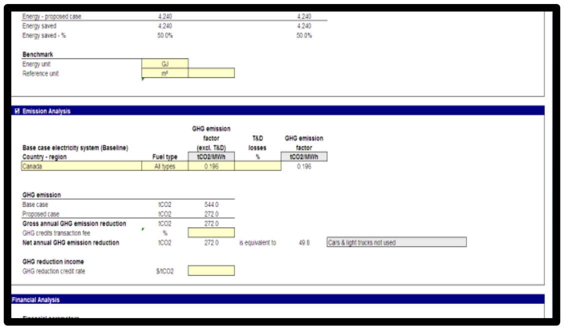

Figure 6 – The Emission Analysis

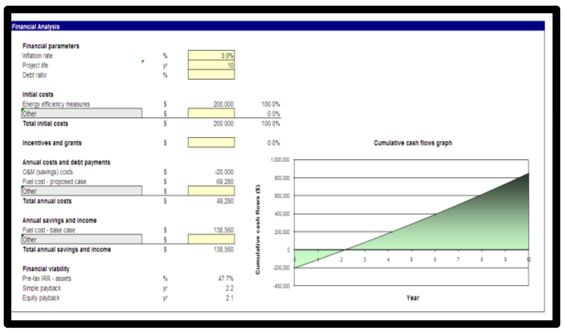

Figure 7 – The Financial Analysis

As shown above, it would only take approximately 2 years for the example mine to recover the expense of the VOD system.

4. Implementation of Ventilation-On-Demand

According to ABB and Simsmart, a VOD system can be implemented in three phases [6]. In the preliminary phase, a mine undergoes a feasibility study where the results are reviewed and a decision is made whether a VOD system can be implemented using the current infrastructure [6]. Once a mine has passed through the first phase, phase two is implemented, whereby a detailed mine-specific model based on a 5-10 year plan for the mine is created. If the model proves to be feasible and cost effective, plans are made to move on to the third phase wherein the site implementation of all the physical devices of the VOD system begins [6].

The components required to achieve a VOD system can be easily broken down into two categories: hardware and software. Some of the hardware components needed to achieve a VOD system are dedicated computer hardware, variable frequency drives on ventilation fans, airflow and gas sensors, a vehicle and personnel tagging/tracking system, an underground inter-device communications network that also connects to Supervisory Control and Data Acquisition (SCADA) computers on the surface, among many other hardware devices.

The software requirements for a VOD system are demanding. The software will essentially require a physical model of the mine indicating which areas require more ventilation and which areas require less. This will be based on many factors, such as gas readings in those areas as well as vehicles and personnel in the area. The software will also have output control of the fans in the mine, and the potential to not only control which fans are turned on and off, but also the speed of the fans as well as the blade angles of the fans. This would allow for more control of the volume and speed of the airflow.

Predictive software and mathematical models are important aspects in having successful VOD software. These variables are extremely unique to each individual mine; based on these factors, as well as the different atmospheric and tracking information provided by the sensors within the mine, the software recognizes and responds dynamically to the environment and reacts by controlling the various output nodes such as the doors and fans.

In order to achieve a true VOD system that is extremely accurate and responsive, it is important to utilize hardware that is best able to represent the current conditions in the mine, and software that considers as many variables as possible to perform calculations, make predictions and thus develop an extremely detailed mine model.

5. Hardware Infrastructure

When upgrading an existing AMS system to a VOD system, one of the most critical aspects to be considered is the existing hardware infrastructure, and the changes that need to be made to that infrastructure. The hardware infrastructure can be broken down into a several classifications:

1. Front-End
2. Communications Backbone
3. Gas Monitoring Instrumentation
4. Input/Output Controls

It is imperative that the existing system incorporates the above general structure. The front end computers can easily be upgraded with the correct predictive software to allow for a true VOD system. The use of a strong communications backbone will simplify the deployment of additional devices and control systems to ensure that sufficient data gathering and output controls are in place to implement VOD. Depending on the intricacy of the existing system, it may be necessary to relocate gas monitoring instrumentation in order to improve the accuracy of readings and allow for better coverage through the mines. The input/output controls would be used to control doorways and selected fans and thus redirect ventilation to specific parts of the mine as required.

Having an existing hardware system in place, similar to the model shown above allows for a more practical upgrade to a true VOD system.

6. Vehicle and Personnel Tracking

Vehicle and Personnel Tracking is another key requirement for achieving true VOD. It allows the control software to take into account the number of passing vehicles and personnel in different sections of the mine when determining whether it is safe or not for workers to enter that area. The use of O2 monitoring and instrumentation is also crucial in the effective usage of vehicle and personnel tracking.

The atmospheric conditions in a mine are dynamic, and involve not just ambient gases but also the diesel emissions given off by machinery and vehicles in operation. This activity drastically adds to the CO and CO2 levels in the atmosphere, reducing the amount of O2, thus creating an unsafe, toxic environment.

One operable solution for Vehicle and Personnel Tracking is an underground traffic flow system, working similarly to street traffic lights. Sections of the mines are equipped with traffic lights, gas monitors and small ventilation fans which are connected to larger ones. As vehicles and personnel approach these areas, a red light will direct them to stop and wait while readings for different gasses (O2, CO, CO2, etc.) are taken. The control software uses these readings to calculate the effective load that this vehicle (or person(s)) will add to the atmosphere within the area being entered. Using these results, the software will determine whether the entry of that vehicle will be sufficient to trigger an alarm level reading for any of those gases. If this is the case, the ventilation system will expunge the air, or turn on the fans to accommodate for the vehicle. Once the readings reach an amount which is sufficient to support the vehicle or personnel, the traffic light will show green, indicating safe entry.

Another method for implementing Vehicle and Personnel Tracking involves the use of RFID tags indicating the precise locations of all vehicles and personnel within the mine. Each vehicle would be associated with an emissions footprint determined by regular calibration and testing. The main computer could then determine which areas of the mine are heavily affected by the presence of vehicles and personnel, and based on those calculations, control which parts of the mine require more or less ventilation. Ideally, each vehicle would also contain on-board sensors and monitors so that its emissions footprint could be calculated in real time. However, this would require more sophisticated wireless technologies.

There are many other ways and methodologies for implementing Vehicle and Personnel Tracking, but it is imperative to have for all VOD systems in place to achieve true VOD.

7. Conspec Controls Ltd and Ventilation-On-Demand

In the mid 1970's, the Can-Met Uranium mine located northeast of Elliot Lake contacted Conspec Controls regarding their high costs in ventilation. Conspec engineers determined the best course of action was to measure and monitor the airflow underground, and utilize the ventilation system only when there was inadequate airflow.

Once the groundwork and cabling had been laid, it quickly became apparent that the mine could easily benefit from Conspec's Atmospheric Monitoring System (AMS). The existing Conspec infrastructure was ideal for the upgrade to the AMS. In the late 1970's, MSHA was made aware of the ongoing VOD project at Can-Met, and were tremendously impressed by the system Conspec has set in place. This essentially persuaded MSHA to work exclusively with Conspec Controls in developing VOD systems.

The early 80s saw a tremendous increase in research and development for Conspec and MSHA in the field of VOD. MSHA made the decision to subcontract their development of the Conspec system to the University of West Virginia (UVW) and Michigan Technological University (MTU). Duane Abbata, a doctoral candidate at MTU, was the professor in charge of the study on the Conspec system. He worked exclusively with Conspec in doing analysis of the system, finding mean times between failures and suggesting overall improvements and design ideas. Eventually, this led to the development of the ventilation monitoring and graphics system.

The main theory behind the ventilation monitoring and graphics system was to use the Conspec infrastructure to monitor the atmospheric conditions, quality of air and air flow to determine which areas of the mine required more ventilation and for how long. Through the control of opening and closing air ways via doors, increasing and decreasing the fan speeds of certain sections of the mine, and using predictive software, a very primitive implementation of VOD was hoped to accomplish.

After further study, it was ultimately determined that the technology and computing power available was not yet up to par as required by the software to successfully and accurately allow for VOD. Engineers at Conspec Controls decided to temporarily shelve their VOD system, and concentrate on their atmospheric monitoring system instead.

8. What Conspec Controls Ltd Currently Offers

The last 30 years have shown significant growth for Conspec Controls in developing and perfecting hardware for underground mining environments. Conspec's existing underground AMS and SCADA systems are currently being used in over 6 countries and over one hundred mines in both hard rock as well as coal. Conspec's equipment has consistently shown promise and has established itself as a robust, easy to use and maintain system.

Conspec's SCADA/AMS system can be broken up into two areas: above and below ground. The above ground components include two computers (a Primary, and a Server/Client), a trunk driver drawer, and portal protectors for any portion of the Conspec Blue Hose cable that is exposed. The Primary computer is used to continuously communicate with all the devices, and receives real time data and status from each device. Based on those readings, the Primary determines whether abnormal conditions exist that require corresponding actions. The primary computer utilizes an extremely reliable real time operating system. This is a key requirement because the Primary computer runs continuously and must never shut down. The Primary computer also has the capacity to run user written scripts and sequence programs, that allow for the user to implement certain command and output procedures based on the user requirements.

The Server/Client computer is used to set up the graphic views of the AMS and to distribute data being collected by the Primary to the client programs. The Server/Client and Primary systems are directly connected. The Trunk Driver Drawer provides the main communications interface between the Primary computer and the underground devices.

Below ground, the system consists mostly of Accessor Devices, Trunk Extenders and the Conspec Blue Hose cable. The Accessor Devices are monitoring and field control components that provide digital inputs, digital outputs, analog inputs and analog output devices. These devices are read and controlled via the Primary Computer. The Trunk Extenders are very similar to Trunk Drivers. They are used to add power and pulse shape the data travelling through the trunk cable. Finally, the Conspec Trunk cable is the communication link between the Primary Computer and the Accessor Devices. Due to the nature of the Trunk cable and the driver/receiver hardware, there is no need for special breakout circuitry; devices can easily be added or removed at any point along the trunk, without the use of splitters. The Trunk Cable can have a cumulative length of 8000ft (depending on the number and type of Accessors along the cable) before the need for a Trunk Extender.

Conspec's SCADA/AMS system has been proven to be an inexpensive, versatile yet robust solution to the monitoring needs for many mines. One of the key technical points behind Conspec's systems is its abilities to function well in harsh noisy environments, and it's compliance with tough government regulations regarding underground mining equipment.

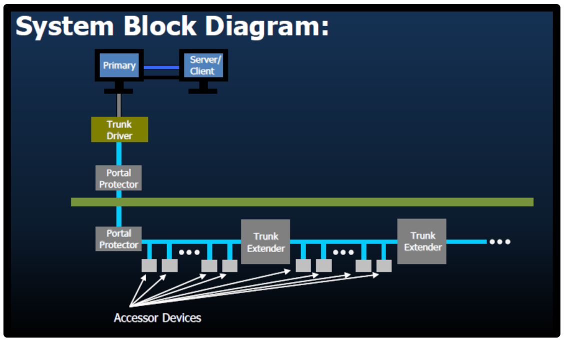

Figure 8 – The System Block Diagram

Currently, Conspec is developing a new generation of hardware including a new Primary system, multichannel gas monitors and sensors as well as new differential pressure monitors to determine airflow and wind direction (mini-weather stations) rated for under-ground usage. This demonstrates Conspec's commitment to the development of functionally superior equipment with exceptional potential for use as VOD hardware.

Although Conspec's existing SCADA/AMS cannot be considered as a complete VOD solution, due to the strength of the Conspec software and hardware devices, it would be fairly simple to incorporate the system into a VOD framework. The key to the existing Conspec system is the ease with which devices can be upgraded and ease of data access for use by 3rd party software. Conspec has laid down all the groundwork for a logical VOD upgrade.

By strategically placing certain gas monitors, airflow/direction sensors, fans/control to the fans, and deploying a third party dedicated VOD computer and software system, the Conspec SCADA/AMS can be utilized for VOD.

Conspec has recently shown their interest in expanding in the area of VOD by creating partnerships with instrumentation and wireless solution companies such as Newtrax. Newtrax has provided Conspec with the required wireless mainframe which would play an integral part in developing a strong VOD system. Conspec monitors in cooperation with Newtrax wireless communications provides a hybrid wired/wireless AMS which essentially opens a gateway towards achieving VOD.

9. The Future of Conspec Controls Ltd and Ventilation-On-Demand

Conspec Controls has laid the groundwork for a viable solution to VOD. It has already completed extensive research and development into building a strong SCADA/AMS system. With the existing framework, current mines utilizing Conspec's infrastructure can easily benefit from VOD via some relatively small changes. Conspec intends on further developing stronger and more dependable hardware and in cooperation with third party VOD software providers, Conspec will eventually be able to provide full VOD solutions for mining purposes.

Acknowledgments

A very special thank you to the entire Conspec Controls Ltd Engineering Team: Jian Zhao, Dave McCullough, Andy Di Cesare and Alex Kwan. This paper could not have been possible without your help and support. Also, I'd like to thank SB for all of your inspiration and support.

References

1. Nensen, P., and A. Lundkvist. "FROM 167 GWH TO 72 GWH – VENTILATION ON." Web.
2. "Newtrax." *Newtrax Technologies Inc. | MineTrax Helps You Tag out Safe and Healthy Every Day.* Web. 06 Apr. 2011. <http://www.newtrax.com/en/technologies>.
3. Van Zyl, F.J, J.J Dekker, and J. Haarhoff. "Early Detection of Flammable Gas Danger in Hard Rock Mines to Protect Miners." *CSIR*. Web.
4. Meyer, M.A. "Implementing a Tracking and Ventilation Control System at." *12th U.S./North American Mine Ventilation Symposium 2008*. Web.
5. "RETScreen International Home." *RETScreen International*. Web. 06 Apr. 2011. <http://www.retscreen.net/ang/home.php>.
6. "Optimising Ventilation." *International Mining*. Web.