GAS VENTILATION AND CONTROL SYSTEM: A CASE STUDY

White Paper

Regulations and customer requirements surrounding the operation and maintenance of gas and ventilation monitoring and control systems in underground coal mines in Australia and across the world, have become more arduous in recent years. With these systems now interfaced directly to the power reticulation systems, availability is key.

Introduction

When approached recently to design and supply a mine wide system, Ampcontrol considered new design concepts incorporating the latest available certified technology. Safety, reliability and efficiency would form the pillars of the design philosophy.

Collaboration with the client was an essential part of the project. The client provided clear functional and operational expectations which included providing an integrated, fail safe, easy to use and deploy system which;

- Monitored carbon monoxide, methane, carbon dioxide, oxygen and differential pressure at ventilation splits throughout the coal mine,
- Monitored carbon monoxide around conveyor drive heads and loop take up areas,
- Monitored carbon monoxide at the boot end of conveyor belts,
- Monitored methane and provided visual indication of healthy, warning and alarm conditions at zone boundaries throughout the coal mine with the ability to individually isolate sensors at each sensors' location for maintenance and calibration purposes,
- Interfaced with the high tension power reticulation system for automatic tripping of the feeders in a gas detection event,
- Interfaced with conveyor belt starters,
- Included low smoke, zero halogen cable suitable for Zone 0 installation,
- Provided better than 99.99% system availability,
- Was suitable for a 20 year plus life of mine,
- Incorporated end to end system lengths of up to 15,000 metres,
- Provided a minimum of 24 hour operation without mains power,
- Was Intrinsically Safe Group I Ex ia,
- Complied with all statutory and legislative requirements for Queensland mines.

During the design phase, with the recognition that this system is vital and must be maintained for mine operations, a request was made to have the gas communications network perform additional functions. With the system already interfacing with the HV distribution network and with HV cable systems not incorporating pilot cores, the client requested that the system have upstream tripping capability for downstream switchgear faults.

Statutory and legislative requirements

The system was installed in a recently developed coal mine in Central Queensland. As such the design incorporates the requirements of the Queensland Coal Mining Safety and Health Regulation 2001 including zone boundaries and the inter-tripping of power systems.

This regulation divides zone boundaries into Explosive Risk Zones (ERZ) and Negligible Explosive Risk Zone (NERZ) these are defined as:

- ERZ0 (Explosive Risk Zone) is "an underground mine, or any part of it, where the general body concentration of methane is known to be or is identified by a risk assessment as likely to be, greater than 2%" . These areas are typically sealed off and inaccessible areas with no ventilation.
- ERZ1 is "an underground mine, or any part of it, where the general body concentration of methane is known to range, or is shown by a risk assessment as likely to range from 0.5% to 2%" . These areas are typically face or coal cutting areas and return airways.
- NERZ is "an underground mine, or any part of it, where the general body concentration of methane is known to be, or identified by a risk assessment as likely to be, less than 0.5%"1. These areas are typically fresh air intakes and referred to as Zone 2 in IECEx certified systems.
- These boundaries are typically only valid while the mines ventilation system is operational. When no ventilation is present the whole mine is considered to be an ERZ0.

In a NERZ-NERZ and NERZ-ERZ gas and ventilation monitoring and control system methane gas sensors are installed in all fresh air intakes forming zone boundaries and provide local visual indication of:

- Healthy when the methane level is below 0.25%,
- Warning when the methane level is between 0.25% and 0.49%,
- Alarm when the methane level is above 0.49%,

These boundaries can be an interface between NERZ and ERZ1 zones or an interface between NERZ and NERZ zones. When a methane level of above 0.49% is detected the system must automatically remove power from the area being monitored back to an adjacent zone boundary. An example of a NERZ-NERZ and NERZ-ERZ system architecture is shown in figure 2.

1. John Kabel, Inspector of Mines, Electrical, Department of Employment, Economic Development and Innovation, 2010, Explosion Risk Zones in QLD Underground Coal Mines www.resources.nsw.gov.au/_data/assets/pdf_file/0004368752/john_kabel_explosion_risk_zones.pdf

Equipment selection

Intrinsically Safe Sensors

Ampcontrol Gasguard Gas Sensors and Emerson Rosemount Differential Pressure Sensors were selected for this project.

The sensing technologies used include infra-red, catalytic and electrochemical for the detection of carbon monoxide, methane, carbon dioxide and oxygen.

The robustness and reliability of the Gasguard gas sensors, manufactured from cast stainless steel with ingress protection levels of IP66, including gas inlet ports, was considered paramount in order to achieve the required system availability of better than 99.99%.

Ampcontrol engineers identified a potential issue with the integration of the differential pressure sensors early in the project, with the sensors having a 1 Watt Intrinsically Safe power input limitation and the system Intrinsically Safe power supplies having an output of 22.65 Watts. This issue was addressed with the creation and subsequent Ex ia certification of a new product to limit the available power at the differential pressure sensor to less than 1 Watt. The new product designated a Field Interface Module has since been deployed in numerous applications.

Intrinsically Safe Power Supplies

Ampcontrol Intrinsically Safe Power Supplies with integrated battery back-up were selected to meet the functional requirements of the project. The selected units incorporate an Intrinsically Safe output of 15.1 Volts DC at 1.5 Amps with a universal input voltage of 90 to 250 Volts AC and a 300 Watt Hour battery capacity.

The battery backed Intrinsically Safe power supplies feature stainless steel construction with an ingress protection level of IP66 and an RS-485 communication port allowing connection to the monitoring system. The monitored parameters include battery voltage, battery temperature, AC input voltage, DC output current and DC output voltage.

The system design utilising these Intrinsically Safe power supplies in conjunction with the cable design (described below) allowed for possible installation distances between the Intrinsically Safe power supplies and Gasguard methane gas sensors to be in excess of 4000 metres, maintaining complete functionality and intrinsic safety.

A battery back-up time of more than 72 hours was achieved with a standard return gas monitoring station comprising of carbon monoxide, methane, carbon dioxide, oxygen and differential pressure sensors.

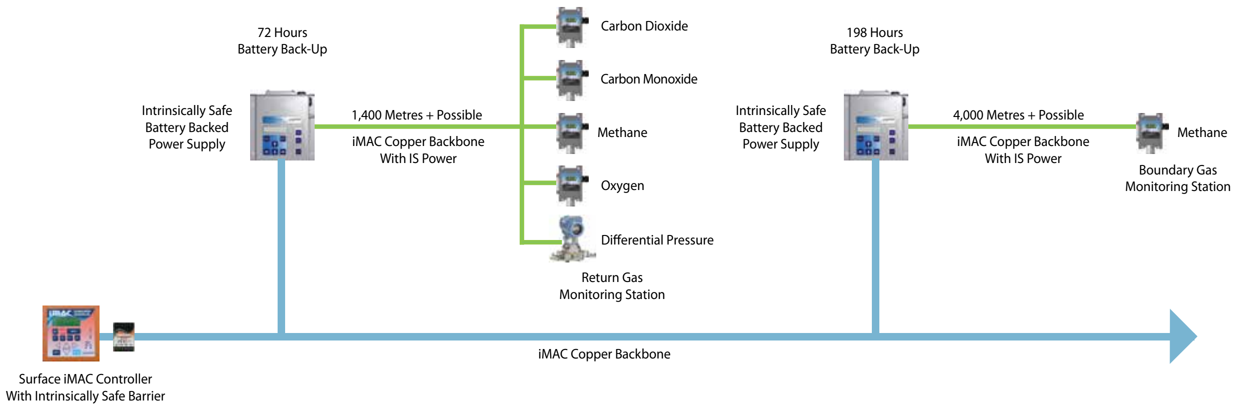

Figure 1: Examples of Intrinsically Safe power supply deployment

Intrinsically Safe Monitoring and Control

The use of an Ampcontrol iMAC pulse width modulated copper backbone system made it possible to achieve the required system end to end lengths. It also provided infrastructure that was easy to maintain with a small number of system components. These included;

- iMAC Controllers for surface control & tripping,
- iMAC Intrinsically Safe Barriers for surface control & tripping,
- iMAC Analogue Input Modules for sensor inputs,
- iMAC Digital Input Modules for isolation inputs & upstream tripping,
- iMAC Serial Interface Modules for power supply monitoring,
- iMAC Relay Output Modules for upstream tripping.

Cable

Due to the end to end system length design of up to 15,000 metres, as well as the requirement for low smoke zero halogen sheath materials and Zone 0 installation requirements, Ampcontrol worked closely with cable manufacturers to design a system cable that was both electrically suitable with low capacitance and inductance and also mechanically suitable. The cable was copper screened replacing the typical aluminium screening making the cable suitable for Zone 0 installation without need for further consideration or mechanical protection.

System description

The system utilises standard sensors with 4-20mA DC analogue output connected to iMAC Analogue Input Modules. Each iMAC Analogue Input Module reports, via a pulse width modulated signal on a single twisted pair cable, to the iMAC Controller located on the surface of the mine. Information from each module includes sensor value, alarm status, sensor voltage and cable resistance. Zone boundary sensors also have a retained key switch connected to an iMAC Digital Input Module, used for local isolation of the tripping functionally allowing for maintenance and calibration and a tri-colour LED strobe.

The surface iMAC Controller is interlocked with the underground power feeds and interfaced with the mine PLC - SCADA system for completely integrated monitoring and control.

iMAC Controllers are also installed in the 11kV underground switchboard and in each 11kV section circuit breaker. These controllers are user configurable and able to monitor any sensor or combination of sensors connected to the network automatically initiating a power trip at the required set points. The controllers also monitor the status of the outlet to be tripped. If the outlet does not trip, an upstream trip of the underground power feed is automatically initiated. The surface iMAC Controller communicates with and monitors the additional iMAC Controllers connected to the network allowing local configurations to be confirmed and monitored.

The design of the system is fail safe and any damage to the system hardware or cabling is treated in the same fashion as a gas initiated event. For increased robustness, each production panel was allocated an isolated iMAC network ensuring any system or cable damage in a production panel only affected the production panel involved.

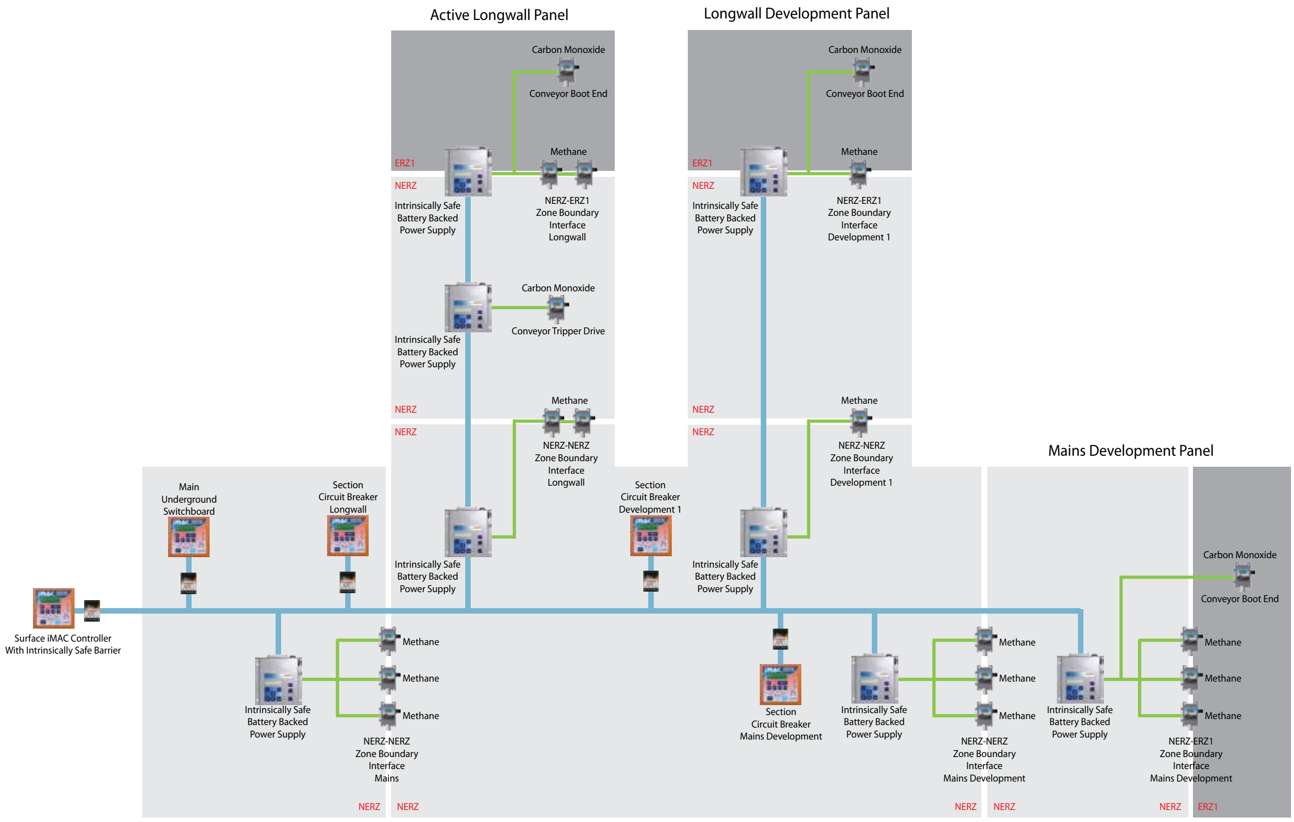

Figure 2: An example of the NERZ - NERZ and NERZ - ERZ system architecture

Upstream tripping

One of the unique features of the iMAC system is that relay output modules will automatically mirror the status of the digital input modules' inputs, if a relay output module is configured with the same address as a digital input module. This mirroring is automatic and requires no programming; this makes the upstream power tripping for non pilot protected electrical equipment relatively simple to achieve by deploying two iMAC modules in each piece of equipment, one module with 4 digital inputs and one module with 4 relay outputs. An example of this configuration is shown in figure 3.

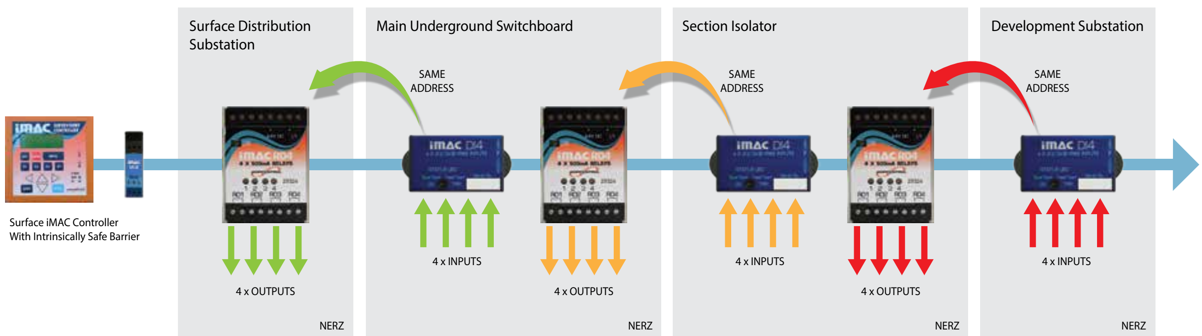

Figure 3: Upstream tripping