

# An Overview of Remote Isolation Systems Applied in Process Industries

David B. Durocher, *Senior Member, IEEE*, and Mike Lane, *Member, IEEE*

**Abstract**—This paper describes the application of remote isolation applied in mining industry conveyance systems. Remote isolation removes personnel from potentially dangerous electrical lockout tasks by removing the element of human error. Safe verified isolation of electrical systems has proved to increase production output by reducing the required time to electrically isolate industrial systems where zero energy is required prior to performing work. Time saved to both isolate and de-isolate is converted to production time and increased manufacturing throughput. This paper describes the application of remote isolation systems, discusses implementation of enhanced safety systems and the necessary engagement with local regulating authorities. Finally, a case study of an actual installation discusses specific details where these systems have been installed.

**Index Terms**—Integral motorized circuit-breaker racking, personnel safety, remote isolation, safety integrity level (SIL) verification.

## I. INTRODUCTION

IN THE recession of 2009, the trading commodities of many mining companies were struck hard. In order to maintain a viable business, many large miners demanded that their key equipment suppliers help to identify ways to reduce operating costs and/or improve production. A newly developed concept was introduced and identified as a remote isolation system (RIS). This offering included retrofit of an existing system that would enable nonelectrical personnel to isolate the plant electrical loads while not requiring entry into dangerous substations. Mining producers required that isolation had to be done quickly and safely, while also reducing the time required to isolate. Implementation of RIS throughout multiple sites and countries has delivered promising results in both increased safety for personnel and additional available production time.

## II. CONVENTIONAL ISOLATION

Conventional isolation practice has historically relied on a robust user defined process to assure a zero energy state prior

to any work being performed. To demonstrate as an example, Fig. 1 shows a typical block diagram of an electrically driven conveyor fed from an electrical switchroom. A field conveyor mounted metal detector is typically applied to sense foreign materials on the belt prior to mineral processing. When a nonore material is detected, the conveyor motor control center (MCC) receives a control signal from the metal detector to de-energize the system so that the foreign material can be safely removed before conveyor restart. Before personnel can safely remove the foreign object, safe work practices required that a zero-energy state must first be established for the conveyor system. Historically, this has required that an electrician travel to the substation, then suit-up with appropriate arc flash clothing and operate the isolators manually prior to placing their personal isolation locks and danger tags on the isolation lock out points. Often these isolations are required in more than one substation and usually a significant distance apart. Once this process was complete, nonelectrical personnel are then authorized to enter the substation and place their personal isolation locks and tags on the lock out points before commencing work on the breakdown or shutdown. The total time taken to safety isolate can be hours.

Some of the undesired events experienced during this process include significant delays to production due to time spent waiting for isolation and de-isolation of the plant, delays to production due to availability of electrical personnel, incorrect isolators operated and locked out, incorrect sequence of switching, damage to isolators, and arc flash events injuring personnel during switching.

In recent years, the dangers of arc flash hazards have become better understood and updated consensus safety standards including [1] and [2] focused on quantifying arc flash heat energy are now in force. Labeling equipment with the available energy measured in calories/centimeter-squared, along with defining necessary personal protection equipment before performing energized work is now compulsory in many mining countries across the globe.

Performing energized work requiring isolation via opening a medium-voltage (MV) switchgear circuit-breaker and then manually racking the breaker off the energized bus in equipment that is perhaps 30–40 years old becomes a unique challenge. How the equipment has been historically serviced and end of life issues of both the air or vacuum interrupting device and operating mechanism makes operation while standing in front of the switchgear a significant hazard. Fig. 2 shows an actual image of a mine site electrician performing isolation on a vintage switchgear line-up. Obviously the intent is to stand out of harm's

Manuscript received August 1, 2016; revised December 29, 2016; accepted February 21, 2017. Date of publication March 23, 2017; date of current version July 15, 2017. Paper 2016-MIC-0755.R1, presented at the 2016 IEEE Industry Applications Society Annual Meeting, Portland, OR, USA, Oct. 2–5, and approved for publication in the IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS by the Mining Committee of the IEEE Industry Applications Society.

D. B. Durocher is with Eaton Corporation, Wilsonville, OR 97070 USA (e-mail: DavidBDurocher@eaton.com).

M. Lane is with REMSAFE, Balcatta, WA 6021, Australia (e-mail: Michael.Lane@remsafe.com.au).

Color versions of one or more of the figures in this paper are available online at <http://ieeexplore.ieee.org>.

Digital Object Identifier 10.1109/TIA.2017.2686799

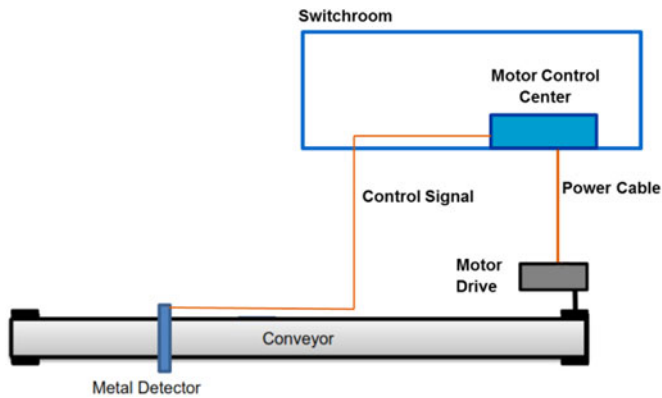


Fig. 1. Conventional Isolation requires a zero energy state to be established prior to commencing work following an equipment shutdown.



Fig. 2. Performance of circuit breaker operation during isolation for this vintage switchgear presents a significant risk to personnel.

way while the device is operated. In many cases, a frequent requirement of manual isolations becomes both dangerous and impractical.

### III. SAFETY REQUIREMENTS

The industry directive was to reduce the time taken to isolate the plant, without compromising safety. Global mining operators are faced with many hazards. Published papers including [3] demonstrate that machine and equipment safety are of paramount importance in mining applications. In process industry applications, improved understanding of arc flash hazards while operators perform routine maintenance activities as outlined in [4] has assisted in moving toward a safer workplace. Many industry standards are focused on assuring operator safety. By industry standards [4]–[8], functional safety performance is measured by the safety integrity level (SIL). For an RIS to meet a certain SIL, verification of the hardware components used, such as relays and also assemblies, such as low-voltage (LV) or MV switchgear is required. There is also a requirement for SIL verification of software. Finally, in most cases, a functional safety assessment for the entire system is required to confirm that the

implemented system meets the applicable industry standards. In particular, IEC Standard 61508 [4] defines requirements that ensure systems are designed, implemented, operated, and maintained to provide an acceptable safety integrity level. The standard defines various levels of SIL, with SIL 1 being the least stringent. SIL 4 is the most stringent level, reserved primarily for critical applications including the nuclear industry. The SIL required is determined by performing a risk assessment. Risk assessments have been conducted for various types of applications that include conveyors, crushers, and pump systems. Energy sources are identified such as electricity, gravitational, and pressure. These together have been assessed, allowing the system to be designed to mitigate the hazards.

Specifically, the parameters for the RIS are as follows.

- 1) To comply with SIL requirements through the following standards:
  - a) IEC 62061 Safety Machinery – functional safety of safety related electrical electronic/electronic programmable electronic systems [6];
  - b) IEC 61511 Functional safety – Safety instrumented systems for the process industry sector [7];
  - c) IEC 60204 Machine Safety Conveyors [8];
  - d) IEC 61508 Functional safety of electrical/ electronic/ programmable electronic safety devices [5];
  - e) AS 1755-2000 Conveyor Safety [9].
- 2) To have a modular and expandable topology.
- 3) To have the ability to isolate by remotely operating multiple isolators in multiple locations (substations) simultaneously in less than 5 min, regardless of energy type.
- 4) To have a single lock out point for multiple isolations.
- 5) To provide a full current isolation (isolate the power circuit directly).
- 6) To continually monitor the status of the isolation system while in use, detecting the presence of any changing or dangerous conditions.
- 7) To have the ability to take the system out of service if a critical system fault occurs in the RIS, allowing production to continue while not creating a dangerous situation to personnel.
- 8) To operate under “high demand”, which is defined in the safety standards as more than one operation per year.

### IV. INDUSTRY INPUT

An organization called the Remote Isolation Technology Association (RITA) was formed that called for industry participation to develop a failsafe compliant RIS. Over an 18-month period, RITA engaged the expertise and consulted with over 450 industry-experienced personnel with safety, electrical, and mechanical engineering and trades experience in the mining and resource sectors from Australia and South Africa. Users from the global mining industry were called upon to assist and guide system development to ensure the RIS would comply with the relevant International and Australian Standards, Mines Department Regulations, and site specifications.

Information workshops, incident research, risk assessments, and technical discussions were conducted with the advisory

group to gather data on applications, scope and requirement, compliance, risk, and functionality.

A Generation 1 system and an associated implementation process was developed and proof of concept trial systems were installed on fixed plant mine sites in Western Australia. Over a period of 12 months, functionality and performance of the RIS was refined through a continuous improvement process that became the basis of design for Generation 2 systems. In October 2013, the Federal Government of Australia provided an AUD \$2 million grant for the commercialization of the product. Later, a Generation 3 RIS was developed and taken to industry through RITA. This demonstrated improved functional safety compliance and improved features based on industry feedback. Further improvements resulted in a Generation 4 system that is produced at half the cost of the Generation 2 system, is modular, expandable, installed quickly and easily over one shut-down while continuing to provide many additional operational features and options.

## V. SYSTEM ENGINEERING

IEC 61508 [5] describes the safety lifecycle. Each RIS must follow this in order to properly fulfill the requirements of functional safety. One of the major phases of the lifecycle is hazard and risk analysis. Each hazard is evaluated by a quantitative risk assessment. If it is determined that after adjusting for all existing risk controls a significant hazard remains, then a risk reduction is required. This risk reduction is described by the ratio between the probability of the existing risk and the acceptable risk – “risk reduction factor” (RRF). Each hazard that has a RRF greater than 1 needs to be controlled; if it is greater or equal to 10, then a safety function is required to control it. These functions are described in the Safety Requirements Specification. The SIL for each safety function is determined by the RRF for the controlled hazard. While this process must be followed for each installation, the consistency of the application across multiple installations allows risk assessment of new systems to be completed and commissioned quickly. This also allows the safety functions for the RIS to be made as simple and as modular as possible, so that the individual functions remain the same, regardless of the number of times they are used.

The system has been developed with common off-the-shelf hardware and software by major manufacturers of switchgear and motor control assemblies that often have performed the required tests and SIL certification for these applications.

The RIS can be installed into new or existing installations by using safety rated power and control hardware installed and wired in a free-standing electrical enclosure called a safety rated controller or failsafe instrument cubicle, located in the same substation as the isolators it is to remotely isolate. The failsafe instrument cubicle also accommodates the safety logic solver, its associated I/O, safety relays and safety contactors, and network communication equipment.

The RIS is able to operate any automated MV or LV isolator and can also isolate LV drives either through existing isolators or independently through the addition of inline power components located in the failsafe instrument cubicles.

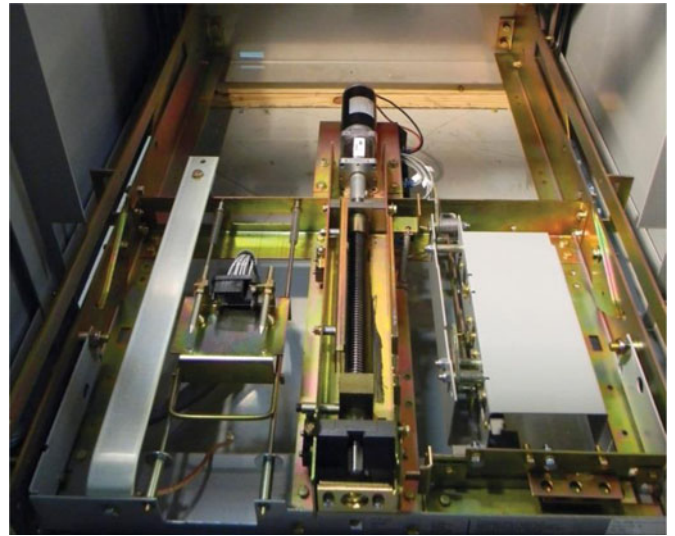


Fig. 3. Newer designs of MV MCCs include an integral motor operator as a part of the cell compartment, enabling integral racking from a remote location.

The field isolation station (FIS), failsafe instrument cubicle, system programmable logic controller (PLC) and supervisory control and data acquisition (SCADA) system are linked via an Ethernet-based safety protocol on a redundant communication ring.

Although the system is available for both retrofit and new or Greenfield installations, significant savings can be achieved for Greenfield projects. System purchase and installation costs are reduced by integrating the RIS hardware into the MV MCCs and LV/MV switchgear at the time of panel installation. The process is nonintrusive and complementary to the overall safety integrity of the engineered switchgear assemblies.

For many large-scale overland conveyance systems, multiple MV motors are applied. In this case, when new MV MCCs are used, a single point of isolation is possible for multiple system motors. This is accomplished via the addition of an integral motorized racking device for the circuit breaker or contactor as shown in Fig. 3.

These newer design motor control and switchgear assemblies include the capability to remotely isolate the circuit breaker or contactor from the energized bus. Designs are available for internal arc classified assemblies compliant with IEC 62271-200 [10] installed and applied predominantly in Europe, Middle East, and Africa along with the Asia Pacific Region. Integral contactor and circuit breaker racking designs are also available for assemblies applied across North America. These are manufactured to comply with ANSI/IEEE Standard C37.20.2-1999 [11] and their arc classified-tested counterpart assemblies, compliant with ANSI/IEEE Standard C37.20.7 [12]. The new MCCs and switchgear with integral racking functionality allows assurance of zero energy from the FIS, enabling the operator to remotely perform lock, tag, and try.

## VI. RESULT

Following successful design of the remote isolation system, several global users now have systems installed and operating.



Systems have been in use for over three years. In recent months, the Generation 4 system was released with 12 systems installed and several others are now in various stages of design, installation, and commissioning.

The load applications are wide and varied. They include, but are not limited to fixed plant such as mills, train unloaders, conveyors, stackers, bucket wheel reclaimers, and ship loaders; rail applications such as track switches, locomotives, overhead power lines, and powered track systems; and process plant such as pump sets and production lines.

The system can isolate various energy sources such as electrical, hydraulic, pneumatic, radiation, gravitational, mechanical, and kinetic. Remote isolation systems monitor the isolation condition during the isolation to alert the operator if a dangerous situation exists. Functionality includes a built-in alarm log which records system events and time-stamped alarms.

The RIS is operated by an FIS as shown in Fig. 4. These are typically located at a close proximity to the equipment requiring work while isolated. The FIS is operated by the person carrying out the task on the plant. As shown in Fig. 5, the FIS has a user interface panel with an isolator lockout switch, which provides a point for isolation lockout using a hasp and personal isolation padlocks.

The RIS is designed to work on call only. If the system is in “standby” it does not affect the normal operation of the conveyor and associated drives. If the system needs to be temporarily bypassed, a key exchange system is used to place it out of service and allow the plant to run without compromising safety of personnel.



Fig. 4. Typical FIS.

#### A. Isolation

Referring to Fig. 5, the steps required to establish a safe isolation are as follows.

Step 1: When the plant is stopped and all additional preconditions are correct, an “available” lamp on the RIS is lit. The operator can then press the “request” push-button.

Step 2: The “requested” indicator lights will flash indicating that a request to isolate message has been sent to the control room operator. The operator will see this on a local SCADA screen with the option to approve or deny the request. Once the request is approved, the “requested” lamp will be lit continuously to indicate the “approved” state. The energy release for the plant is then executed—for a conveyor this is performed by releasing and applying the brake until the belt stops. The conveyor state is monitored via an encoder on the belt. The isolation sequence will then be executed to bring the plant to an isolated state.

Step 3: The indicator lights in “checking” will flash during the isolation sequence. Before HV isolators start operating, audible and visual warnings in the substation are activated. Once the plant is isolated the “checking” lamps will be lit continuously to indicate the “proceed” state.

Step 4: The isolator lockout switch is normally locked in the “normal” position to prevent inadvertent operation of



Fig. 5. FIS user interface panel with isolator lockout switch and hasp for personal isolation padlock(s).

the switch, which would result in equipment downtime. Once all the switchgear is confirmed to be in the isolated state, the solenoid that locks the isolator lockout switch is energized. This allows the operator to rotate the switch to the “isolate” position.

Step 5: On the isolator lockout switch there is a flap which, when rotated to the upper position, allows the

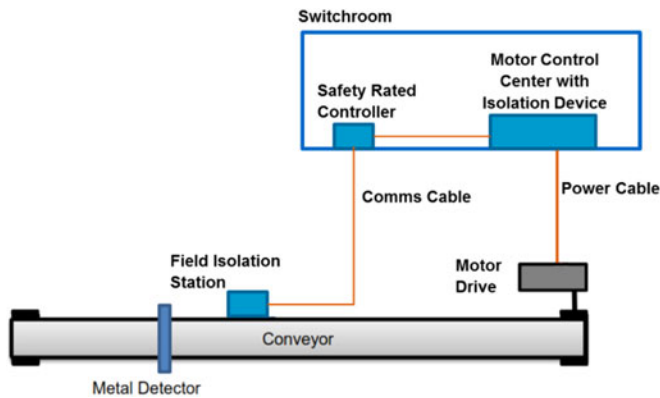


Fig. 6. Diagram of conveyor with RIS installed.

operator to attach their personal isolation lock. This lockout flap is held captive in the lowered position at this stage until the “try step” process is complete. When the “try step” pushbutton is pressed the RIS will instruct the conveyor control system to energize a start relay following isolation. Once it is confirmed that this action has failed to start the conveyor, the “complete” indicator lights will be lit continuously and the flap solenoid will release it. The operator can then rotate the flap to the upper position. The operator then attaches their personal lock, allowing them to then safely conduct work on the conveyor.

### B. Deisolation

The operator removes their personal lock, and then rotates the flap to the lower position. The final step is to rotate the isolation lockout switch back to the “normal” position. The operator does not have to interact with the RIS beyond this point—the de-isolation sequence commences, closing the circuits on all the conveyor drive switchgear. The conveyor can now resume operation.

Fig. 6 shows an updated block diagram of a typical conveyance system similar to Fig. 1, but updated to show the additional functional components required for remote isolation. Note that a single FIS is shown, but in most applications, multiple isolation stations will be network connected and installed along the entire overland conveyor system, allowing operators to perform lockout/tagout from several different locations as needed.

## VII. CASE STUDY INSTALLATION

A case study example of an RIS that was installed on a conveyor belt at an iron-ore site in Port Hedland located in Western Australia’s North West Pilbara Region is outlined in this section.

The conveyor is 2 kilometers (km) long and conveys iron ore from the mainland to an island for stockpiling and shipping. The conveyor runs under a harbor through an 8 meter diameter tunnel. The conveyor travels at 7 meters/second and has an average loading rate of 10 000 tons/hour.

Before the RIS was installed, whenever the conveyor stopped due to a fault that required an operator to isolate for repairs, an electrician was called upon to carry out the isolation. The distance by road is over 30 km from the electrical workshop on the mainland to the substation on the island. Once in the substation, the electrician was required based on site safety procedures to suit-up with the appropriate arc flash protection clothing and then isolate by manually racking the high-voltage switchgear trucks into the isolated position. There are four 6.6 kilovolt (kV) trucks and one 415 Volt isolator. Once isolation was confirmed, the electrician would place an isolation confirmation lock onto the isolator lockout points, and then permit the operator to enter the substation for them to place their personal isolation locks and danger tags on the isolator lockout points. The operator was then authorized to commence work on the conveyor often requiring them to drive back to the mainland end of the conveyor. This exercise took 90 minutes to isolate and the same time again to deisolate. Altogether, that represented 3 hours of lost production each time isolation was required. Additionally, each time site electricians operated the switchgear, they were subjected to the dangers of a potential of arc flash.

The RIS installed had to address specific risks around the application. One of these was when the conveyor was isolated, it had the potential to store gravitational energy and would often free run if the brake was inadvertently lifted. The conventional isolation procedure required the conveyor motors to be isolated then the brake would be cycled so that the conveyor could move to release the stored energy. When the conveyor was stationary, the brake would be applied and isolated, then locked out. This was a time consuming step in the procedure and was often inadvertently skipped by isolation personnel. Another step in the process causing concern was the electrician was to isolate, try to start the conveyor, confirm no-start, then lockout. The try start and subsequent confirmation were often not done correctly or not done at all. Another risk was the switchgear was old and outdated; this type had known incidents of arc flash events. While personnel were wary when operating the isolators, they still did not always adhere to the strict safe work procedures associated with isolating the switchgear. The RIS installed on the conveyor needed to mitigate these potential hazards, amongst others.

Application of the RIS installed on the conveyor included a completed risk assessment along with clear identification of the tasks to be performed using the RIS. The target SIL was determined to be SIL 2, which the RIS design accommodated. Automated isolation devices were fitted to the 6.6-kV switchgear and the LV brake isolator had safety isolation contactors installed into the existing MCC bucket, along with the necessary safety PLC I/O and safety relays. A failsafe instrument cubicle was also installed that housed the safety logic solver along with a touch screen for data logging and system diagnostics.

Three FIS’s were installed: the first at the conveyor head end, the second on the tail end, and the third inside the tunnel. It was essential that these were located along the conveyor so there was no confusion as to what equipment operators would isolate. This principle also overcame the possibility of incidents that

occurred in the legacy system when the incorrect isolators were operated during manual isolations.

The system delivered a return on investment within the first week it was commissioned. After 12 months of use, a production gain of 1.2 million tons was received as a direct consequence of using the remote isolation system. The mine operator has since established this as their standard system for remote isolation of plant and equipment, embarking on a program to install several more within their operations.

### VIII. CONCLUSION

The task of lockout/tagout for complex systems applied in process industries has historically been the source of many challenges. Typical systems driven by electric motors can oftentimes be installed with the primary switching and protective device located several kilometers from the drive equipment. Emerging electrical workplace safety standards are driving increased emphasis on remote switching and racking of circuit breakers and contactors to establish zero energy prior to lockout. The latest RIS's have been successfully applied across multiple industries to address the industry challenges. Although the primary business justification for these systems has been based on improved productivity, a significant additional side benefit is that the workers are physically separated from electrical panels when switching and racking functions are required, eliminating the risk of dangerous arc flash. In addition, SIL-rated systems offer a demonstrated safeguard against possible human error.

### REFERENCES

- [1] IEEE Standard 1584-2002, Guide for Performing Arc Flash Hazard Calculations, 2002.
- [2] National Fire Protection Agency NFPA70E: Standard for Electrical Safety in the Workplace, 2015.
- [3] M. A. Reyes, G. W. King, and G. G. Miller, "Intelligent machine guard monitoring: A wireless system to improve miner safety," *IEEE Ind. Appl. Mag.*, vol. 20, no. 2, pp. 69–75, Mar./Apr. 2014.
- [4] D. J. Hill, L. W. Bruehler, and P. H. Chmura, "Designing, operating and maintenance strategies to limit arc flash energy exposure," in *Proc. IEEE IAS Petroleum Chem. Ind. Tech. Conf.*, 2004, pp. 339–349.
- [5] *Functional safety of electrical/electronic/programmable electronic safety devices (for SIL rating)*, IEC 61508, 2010.
- [6] *Safety Machinery – Functional Safety of safety – related electrical electronic/electronic programmable electronic systems*, IEC 62061, 2010.

- [7] *Functional safety – Safety instrumented systems for the process industry sector*, IEC 61511, 2016.
- [8] *Machine Safety Conveyors*, IEC 60204, 2016.
- [9] *Australian Standard for Conveyor Safety*, AS 1755, 2000.
- [10] *Medium-Voltage Metal Enclosed Switchgear and Controlgear*, IEC Standard 62271-200, 2011.
- [11] *IEEE Standard for Metal-Clad Switchgear*, ANSI/IEEE Standard C37.20.2, 2015.
- [12] *Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults*, ANSI/IEEE Standard C37.20.7, 2007.
- [13] D. B. Durocher and M. Lane, "An overview of remote isolation systems applied in process industries," in *Proc. IEEE Ind. Appl. Soc. Annu. Meeting*, Portland, OR, USA, 2016, pp. 1–5.



**David B. Durocher** (SBM'77–M'97–SM'99) received a B.S.E.E. degree in bachelor of science electrical engineering from Oregon State University, Corvallis, OR, USA, in 1978.

He serves as a Global Mining, Metals, and Minerals Industry Manager with Eaton Corporation, Wilsonville, OR. He has over 35 years of experience with Westinghouse and Eaton serving in a variety of product engineering, sales, and global marketing roles, authoring numerous technical papers that have been presented at conferences around the world and

published in the IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, *Plant Engineering*, and *EC&M Magazine*.

Mr. Durocher presently serves as a member of the IEEE Industry Applications Society (IAS) Mining Industry Committee, Cement Industry Committee, and Pulp and Paper Industry Committee, and also served as the President of the IEEE IAS 2015–2016.



**Mike Lane** (M'14) received an advanced degree in leadership and management (minerals and energy) from Hedland College, South Hedland, WA, Australia, in 1998.

He serves as a Managing Director with REM-SAFE, a business of Orbital Corporation Limited, Balcatta, Western Australia. He has more than 20 years of technical experience managing successful projects involving remote isolation systems in the mining and process industries in Western Australia. He has authored and presented technical papers at

Arc Flash Safety Conferences sponsored by IDC Technologies and others across Australia, and has extensive experience in business leadership.