Reducing High Frequency Ground Currents to Zero Enhances Mine Safety

BY ROBERT HOPKINS

Technology and the electrical/electronics industry have changed at a dizzying pace. Among these many changes is the growing uses of adjustable speed drives (ASDs) or variable frequency drives (VFDs) with motors. An unforeseen consequence of using VFDs with motors is the production of high frequency ground currents. Circulating ground currents can cause sparks, shocks and arcing.

These ground currents can, and often do affect sensitive devices. Any electrical/electronic device in a mine that is grounded to "physical earth" is subject to high frequency ground currents (electrical noise and transients). In mines specifically, environmental sensors used in mine-wide monitoring systems (MWMS) are likely to be affected. These types of occurrences in ASD/VFD mining applications usually result in costly unplanned downtime. When these problems arise, typically technicians often take a trial-and-error approach, such as installing line and/or load reactors or EMI filters. Too often, these attempts prove ineffective and overly costly in terms of both time and dollars wasted.

ANALYZING THE PROBLEM

VFD technology today relies on very fast switching power semiconductor devices. Manufacturers have turned to insulated-gate bipolar transistors (IGBTs) as the semiconductor of choice. This preference arises from characteristics of IGBTs including cooler operating components, smaller footprints, quieter operating systems, and increased control of motors—all of which add up to major dollar savings by end users.

The IGBT generates the rapid turn-on and turn-off time needed to create the Pulse Width Modulated (PWM) waveform to control the motor. Specifically, a nuisance transient voltage occurs at the juncture of the turn-on/turn-off point. The faster the IGBT switches and the higher the DC bus voltage, the greater the sum effect of the nuisance high frequency transients. These high frequency transients (ground currents) often stray into other systems and devices—card readers, amplifiers, proximity sensors, communication hubs, robotic controls, wireless communications, and low voltage control wiring (0-1 mA, 4-20 mA, 0-10 Vdc, etc.). Other vulnerable equipment includes machine control protocols (Devicenet, Profibus, Modbus), video/security systems, machine vision systems, flow sensors, etc.

THE TRADITIONAL APPROACH AND ITS LIMITS

Grounding is probably the source of confusion in the understanding of electrical power distribution. The conventional wisdom and standard practice of grounding electrical circuits to "physical earth" for safety (per the National Electrical Safety Code) began more than 100 years ago. The past few decades have brought technological innovations in ASD/VFDs, servos, and other computer-controlled systems that typically generate high frequency ground currents, which when grounded to "physical earth" can and will affect other sensitive electrical/electronic equipment (See Figure 1). These troublesome high frequency ground currents must be dealt with since they cannot be eliminated.

THE NEW APPROACH AND ITS BENEFITS

Still, these high frequency ground currents can be contained, directed, and controlled. A new system solution, Zero Ground, provides a more effective grounding method that reduces high frequency ground currents to zero, while reducing motor bearing currents which extends motor life, and minimizes crosstalk between adjacent cables. This new

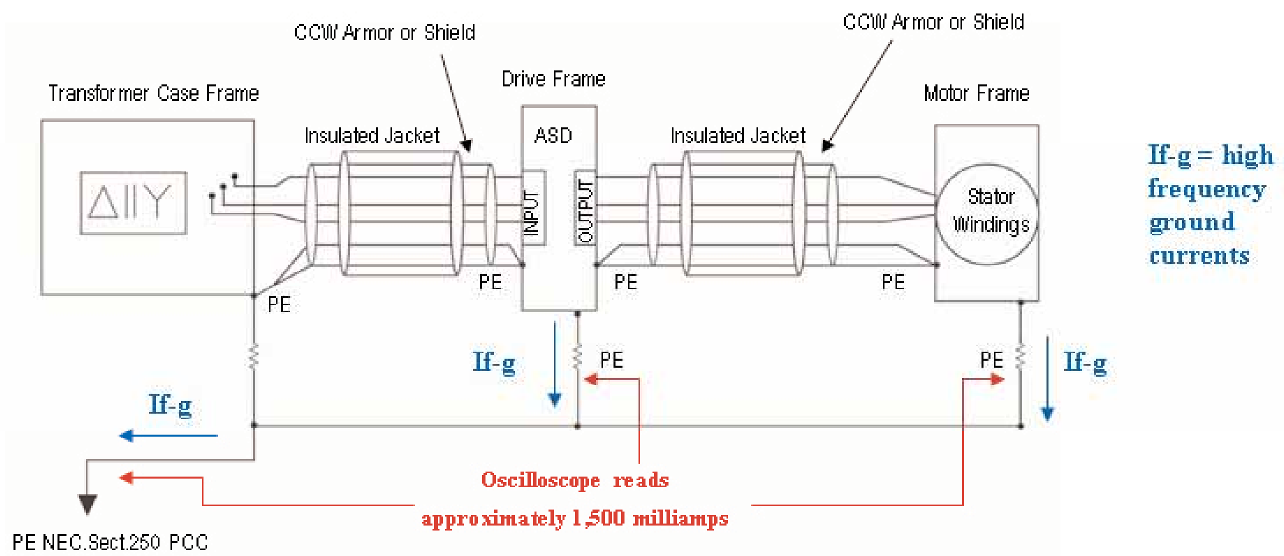


Figure 1: A typical, traditional wired ASD/VFD system with ground currents.

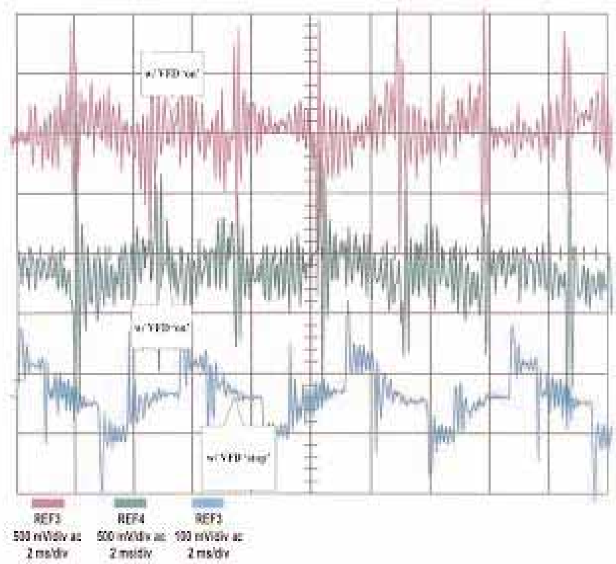


Figure 2: "Electrical Noise" measured *before* Zero Ground System Solution (Note: "before" graph vertical divisions are 500 mA).

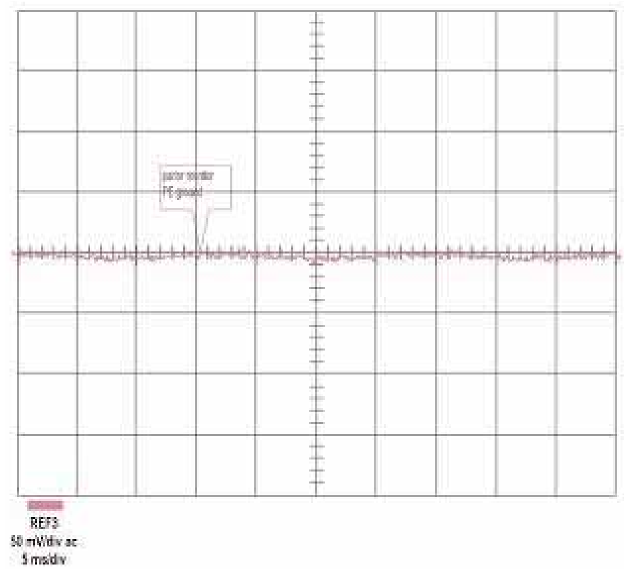
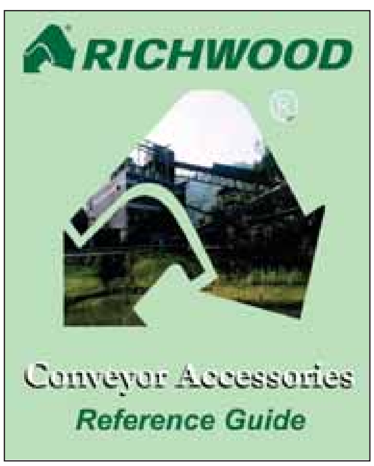


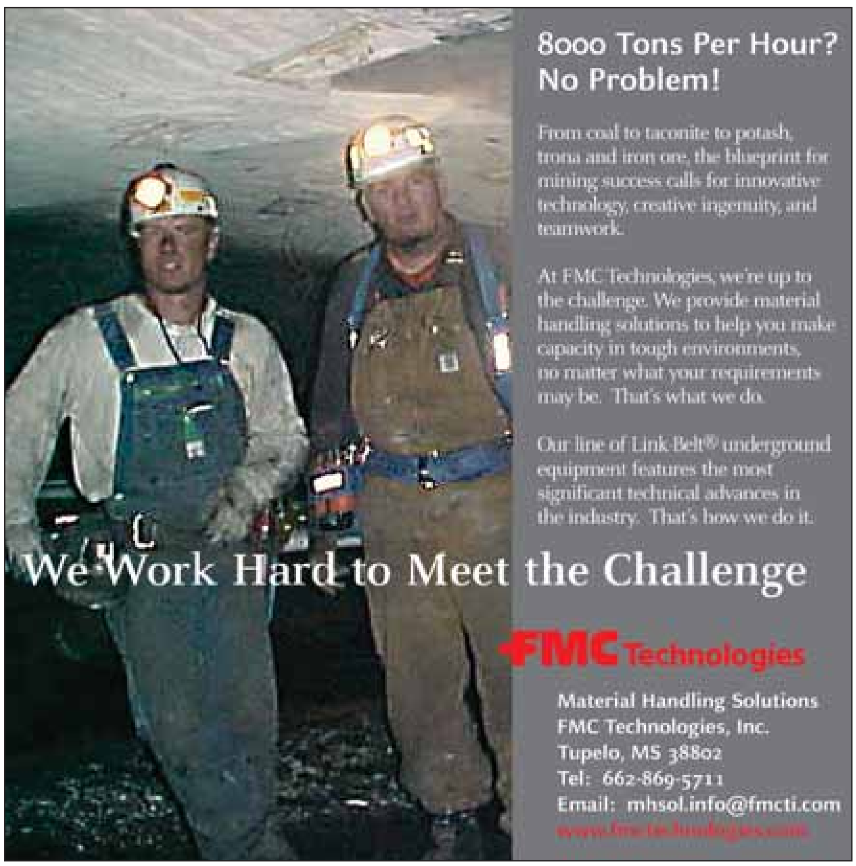
Figure 3: "Electrical Noise" measured *after* Zero Ground System Solution (Note: "after" graph vertical divisions are magnified 10X to 50 mA).

approach is designed to contain stray capacitance and inductively coupled energy, while directing fault currents away from hazardous locations, eliminating both motor-to-frame and ASD/VFD-to-frame voltage to ground. This highly effective grounding method, in turn, reduces unplanned downtime, lost production and increases the mean-time-between-failure (MTBF) ratio.

Zero Ground allows traditional grounding methods to "catch up" to the recent changes in today's high-speed electronic systems. For example, by replacing a standard wiring system in an ASD/VFD cell, the new system reduced 1,538 milliamps to zero. Zero is defined as five places to the right of the decimal point (See Figures 2 and 3).

This system provides unsurpassed performance in reducing EMI/RFI caused by PWM or high frequency power supplies. The system solution has been engineered





and designed as a complete wiring system to be installed between a source and an adjustable speed drive controller and an electric motor, or in any wiring scheme in which high frequency voltages might stray. Patented cable/conduit components, coupled with a patented installation method, create a very low impedance return path for the high frequency ground current energy.

Unlike conventional ASD/VFD wiring systems that are grounded to earth, Zero Ground assures grounding and safety in a very different manner. The system solution provides grounding via the cabling system, not the components. No filters are needed to reduce ground currents to zero. Most drive manufacturers recommend that cable lengths should not exceed 50 ft. This grounding system solution has been successfully tested with cable lengths exceeding 300 ft. Zero Ground system solution does meet NEC 250 grounding requirements. Most conventional VFD wiring systems are used on the drive "output" only. The Zero Ground system solution is rated, and used on both the "input" and "output" of the drive. In addition, most VFD wiring systems are designed to keep any outside interference (noise) from getting "into" the cables. The Zero Ground system solution is designed to keep what is inside the system "in" and all outside interference "out."

THE NEED FOR ADEQUATE GROUNDING

A once effective electrical system, often, is compromised by changes over time. The addition of new machinery with ASD/VFDs (switching power supplies), changes in electrical service, and utility power spikes/surges, will bring about issues to the in-house grid. Overall, there is a significant probability that electrical distribution systems installed a decade ago now harbor major inadequacies that are unable to accommodate today's new electrical/electronic components and other sensitive controls.

Meeting all requirements of National Electric Code Sec. 250 is not difficult. Unfortunately, many systems that were initially grounded correctly are no longer in compliance. Bonds, where two different types of metals join, corrode. Grounds can and will corrode over time. This system solution grounding system specifically targets mining applications in which three-phase and single-phase motors are used, and any application in which EMI/RFI problems are a concern. In mines, damaging leakage currents are unacceptable. They can affect environmental sensors used in MWMS, network communications, and wireless communications equipment.

In mines, Zero Ground addresses safety and interference (noise) issues by reducing high frequency ground currents, thus providing the elimination of potential electrical shocks, sparks, and arcing. In addition, the enhancement to continuous communication is immeasurable. There is also a significant impact on motor life. Eventually, these high frequency ground currents can lead to the degradation of dielectric insulation in motors and transformers, and in addition, motor bearing fluting. Bearing fluting is caused when an electrical discharge occurs between the bearing inner or outer races and the rotating balls. Bearing fluting reduces the life of the bearing, thereby reducing the life of the motor. Bearing fluting is not covered under warranty by any motor manufacturer. Recent industry testing on this system solution has verified a significant reduction in motor bearing currents, thus extending motor life. Since a minimum of 41% of motor failures are bearing related, using this system solution to reduce motor bearing currents could have a significant impact on efficiency and economy.

MSHA VALIDATE THE RESULTS

In October 2002, MSHA visited and tested several Zero Ground system solution installations to evaluate potential benefits. In January 2004, a report was issued by MSHA validating the safety claims of the Zero Ground system solution. In the report, it explains during an MSHA investigation of ground fault currents, "it was found that the design of some VFDs produces ground current flowing in the ground conductor between the VFD and the driven motor," which the Zero Ground system solution successfully addresses. MSHA also states, that "it is well known that many components used in mining produce some current that is circulated on the grounding conductor. As good as trailing cable designs are, current flow in phase conductors produces some amount of current flow in the grounding conductor which is unavoidable. This current can be reduced, but has not been demonstrated that it can be eliminated." The Zero Ground system solution contains, controls, and redirects these currents while reducing it to levels well within MSHA requirements.

In addition, the Zero Ground system solution is within MSHA requirements. MSHA has stated that variable frequency drives must provide certain features in complying with MSHA regulations, e.g. detecting grounded phase conditions and not producing frame potentials. For the systems which eliminate the stray voltages and currents, interference noises, etc. (i.e.: Zero Ground system solution) MSHA has not placed any foregoing conditions (except areas forward of the last open cross-cut).

Developed in 1998, this system solution was in testing and development, with multiple site installations, until its 2005 market introduction. Presently, there are system solutions offerings for low voltage (1,000 V) with ratings of (10 hp or less) 33 amps; (50 hp or less) 70 amps; (125 hp or less) 205 amps; (250 hp or less) 410 amps; and (500 hp or less) 820 amps. The initial Zero Ground system solution offering is in low voltage (1,000 V). Since this system solution has no voltage or frequency limits, when developed, a Zero Ground offering in medium voltage applications will provide exactly the same benefits.

This system solution has been used for the safe wiring of all input and output connections found in VFD (switching power supplies). All cables and conduits in the system solution are UL listed materials, and these systems meet all requirements of NEC 336 Power and Control Cable Type TC, NEC 350 Liquid Tight Flexible Metal Conduit Type LFMC, and NEC 250 grounding. The cables are rated for 2,000V AC RMS and are dielectric tested to12 kV–22 kV. Other than the cable/conduit, these systems use all standard off-the-shelf industry fittings and components. These systems are protected by U.S. patents for the components and installation method, respectively. International patents are pending.

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