Challenges for Successful Ground Fault Protection of VFD's used in Underground Coal Mining

LONGWALL USA Exhibition & Conference
June 13, 2013

Power, Automation, and Process Systems

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Over 100 Years of Combined Industry Experience

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Abstract

This presentation will discuss the issues one should consider when installing variable frequency drives in underground mining applications, including:

- *Ground fault protection performance when applied with a VFD operating at various speeds.*
- *Successful testing and documentation to simulate the real world application.*
- *Regulatory agency requirements and recommendations.*
  - *MSHA/A&CC*
  - *PA-BDMS*

Introduction

VFD's have been successfully installed in underground mining operations in the U.S. for many years; conveyor belts, fans, etc….

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Introduction

Until recent years the application of VFD's within systems that must be approved, operated, maintained as "permissible" as defined by MSHA or CFR 30 have not been commonplace; Emulsion pumps, water pumps, etc…

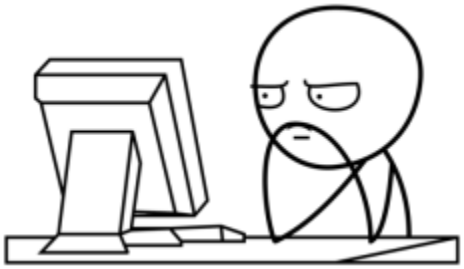
Introduction

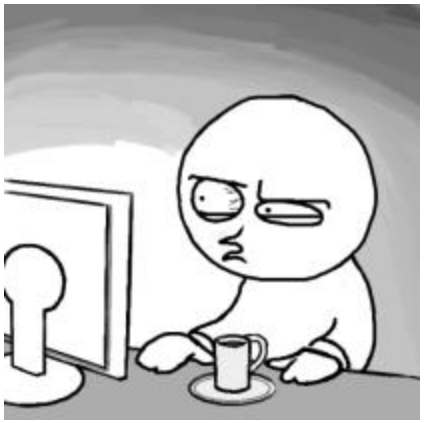
The introduction of VFD's in permissible applications has given rise to the involvement of governmental organizations; MSHA AC&C and PA-BDMS. These organizations have developed approval procedures and test criteria to ensure equipment is manufactured, tested and proven to operate safely when installed and put into service.

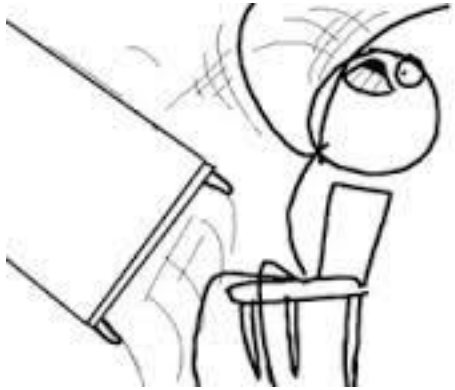
Best Practices/Limitations/Cautions

Confirm the Latest and Greatest

We at IE are aware of the benefit to the mining community of this information. We also understand that revisions to the information we will discuss may continuously occur in the future as this presentation is reproduced. Therefore we recommend that before any design work is initiated a request should be made to for the latest criteria produced by each approving agency.



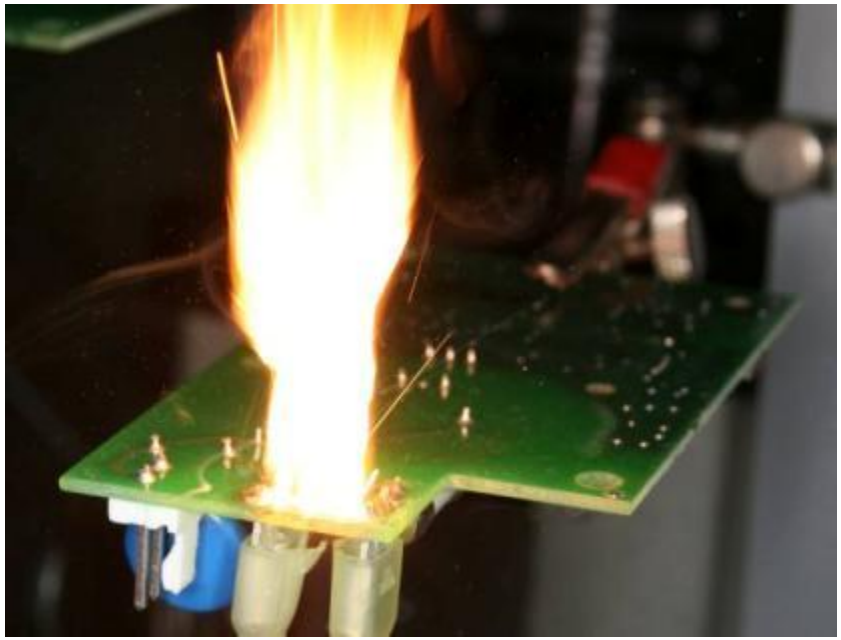




Best Practices/Limitations/Cautions

When Performing Electrical Testing Remember to

- ***Consult the Component Manufacturer's***
- ***Read the Instructions!!***



Best Practices/Limitations/Cautions

When Performing Electrical Testing Remember to

- *Determine Potential Hazards*
- *Determine Required Safety Precautions/Procedures*
- *Determine Required PPE*

Application/General Requirements

Common Systems above 1000Vac

- *4160Vac phase to phase voltage*
- *Max available ground fault current 500mA*
- *Ground fault current protection set point 125mA*

Common Systems at 1000Vac or Less

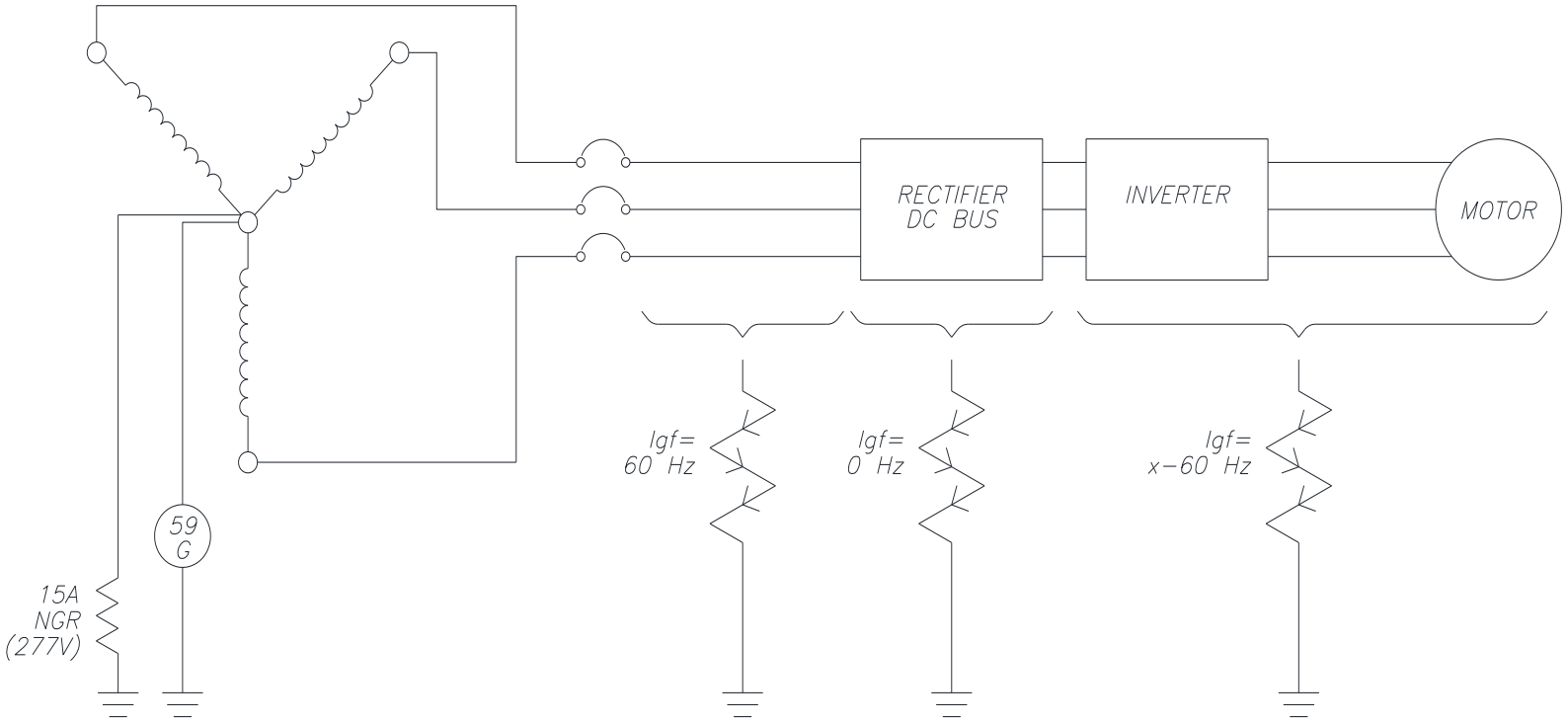
- *480Vac phase to phase voltage*
- *Max available ground fault current is 15A or less*
- *Ground fault current protection set point 7.5A max*

Common Electrical Output/Utilization Circuit

- *Wye (or Derived Wye) Transformer Configuration*
- *Wye "Center" Point Grounded through NGR*

Application/General Requirements

Typical Circuit illustrates that a ground fault condition may be different based on location in the circuit and/or a component failure.



Approval Criteria/Testing Methods

Mine Health and Safety Administration (A&CC)

- *Documentation on the system planned for installation*
  - *VFD*
    - *Manufacturer/Ratings*
    - *Operating Mode Range (speed/frequency)*
  - *Neutral Ground Resistor*
    - *Rating*
  - *Ground Fault Protection Device*
    - *Manufacturer and Model Number*
    - *Include any sensors/accessories required for testing*
  - *Testing Data*
    - *Test Equipment Devices*

Approval Criteria/Testing Methods

When determining test requirements remember to consider A&CC requires testing of all equipment being used as part of a larger system approval, Therefore,

- ***Alternate VFD Manufacturers and /or Models by the same Manufacturer***
- ***Alternate VFD Models (same Manufacturer)***
- ***Alternate Ground Fault Relay Manufacturers***
- ***Alternate GFR Models (same Manufacturer)***

Any and all combinations of the scenarios above must be tested as part of the approval of the system. So depending on which items listed above apply be aware that this could significantly increase the quantities of tests to be performed.

Approval Criteria/Testing Methods

System Operational Range

- *The operational range which the VFD will be operating in must be declared.*
- *Not the operating range of the VFD, but the operating range required by the application.*

NGR Rating

- *The neutral ground resistor rating must be documented.*
- *The ground fault protection relay will be required to be tested at the following settings based on the NGR rating*
    - *The max value of current limited by the NGR*
    - *The "safety" value of ½ the rating of the NGR (which will be the max set point of the GFR).*

Approval Criteria/Testing Methods

Best Practice when Testing

Depending on the resources available, the test procedure can be simplified by installing 2ea separate neutral ground resistors (of the same make, model, manufacturer) in series with the wye connection point of the transformer and the equipment ground bus. A bypass switch rated for the system voltage and current is installed in parallel with one of the neutral ground resistors.

Approval Criteria/Testing Methods

With respect to the Ground Fault Relay used in the system being tested for approval, it too must be documented including:

- ***Manufacturer***
- ***Model Number***
- ***Sensors/CT's used as part of the apparatus under test***

The protection device must be able to detect a variable frequency at or below the maximum allowed ground fault current set point and operate appropriately.

Approval Criteria/Testing Methods

Commonwealth of Pennsylvania BDMS

Available Support Documentation

- ***Document entitled "Variable Frequency Drive (VFD) Performance Standards"***
  Written and approved by a task force/group of industry and Pennsylvania BDMS Staff.
- ***Draft Test Criteria***
  Document can be obtained at the offices in Uniontown, PA.

Approval Criteria/Testing Methods

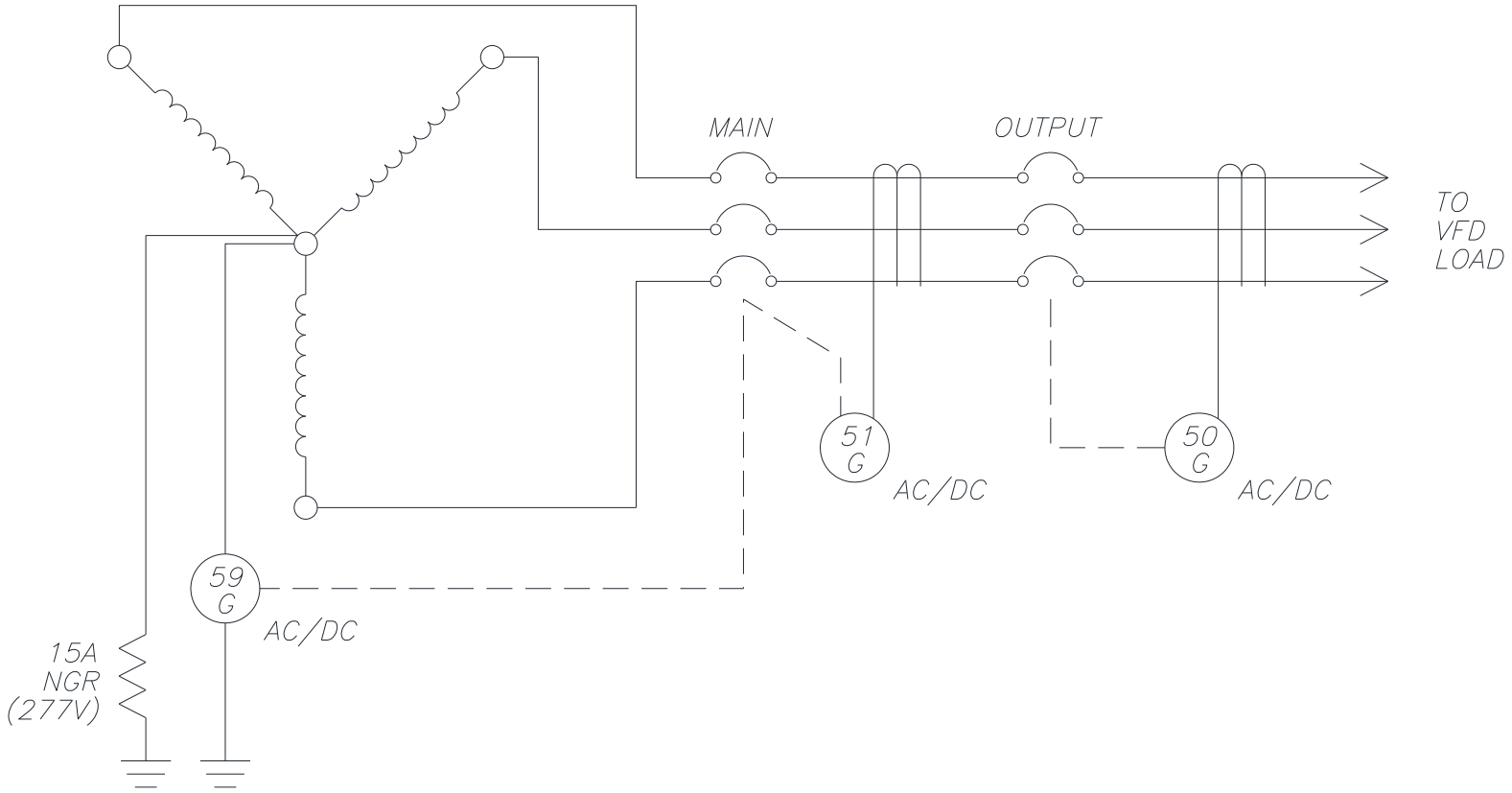
Many aspects of the testing required by PA-BDMS are the same as required by the A&CC. The criteria and testing must be witnessed by an inspector for the agency. There are two significant differences in the testing required by A&CC and PA-BDMS and they are:

1. ***PA-BDMS requires a voltage relay across the neutral ground resistor.***
    - ***The relay must detect and operate on AC/DC voltages that would be present across the NGR when a ground fault is present.***
    - ***This applies to systems operating at 600Vac or less.***
    - ***The voltage relay must operate at no more than 50% of the line to neutral voltage across the NGR at the minimum operating speed during a ground fault.***

2. ***PA-BDMS requires a total of three detection devices that will operate to independent circuit interrupting devices***
    - ***Detection devices will typically comprise of 2ea – AC/DC current based devices and 1ea – AC/DC voltage based device***

Approval Criteria/Testing Methods

Typical Requirements for PA-BDMS Approval



Further Reading

Intermountain Electronics Overcomes Underground Mining Space Constraints with Rockwell Automation

First-ever Horizontal Application of Allen-Bradley® PowerFlex® 755 Variable Frequency Drives

Challenge

- Design and install underground mining control system with variable frequency drives (VFDs) to fit in a small enclosure to meet end user requirements

Solutions

Intelligent Motor Control

- Allen-Bradley CENTERLINE® motor control centers integrate control and power in one centralized package
- Allen-Bradley PowerFlex 755 IP00 variable frequency drives (VFDs) regulate the speed of the mine's stage-loader conveyer motors, and dictate pressure levels for the mine's emulsion pumps and centrifugal water pumps

Results

Product Standardization and Space Savings

- Repackaged PowerFlex 755 IP00 VFDs offer an extended power range and the flexibility to mount horizontally
- Open chassis drive style eased the ability to engineer a drive cooling system while still fitting in the custom enclosures

Uptime Boost

- No unscheduled downtime after installation

The ControlLogix® automation controller and PanelView™ operator interface are mounted in the same control skid and communicate to the VFD's via Ethernet.

Background

When most people think of coal mining, they envision men in soot-covered clothes and hard hats digging at deposits in deep underground caverns. These mental images commonly include coal cars rumbling on rails as they emerge from the earth, filled to the brim with rocky ore.

The world of modern, long-wall coal mining is a far different place. Yes, it's underground, the miners still wear hard hats, and the environment is filled with soot. However, today's mining operations are carefully monitored and the entire process is highly automated.

Three miles underground, a sophisticated, high-powered mining machine moves steadily through a six-foot-high tunnel at an average speed of two miles per hour, carving out coal, then conveying it to a crusher and carrying it to the surface.

Instead of digging out the ore, a long-wall mining system slices it from the exposed tunnel face, using giant rotating shears. The shorn coal tumbles onto a conveyer below the shears, and is conveyed to the "stageloader" where it is crushed and dumped onto the main conveyer belt that eventually hauls it out of the mine.

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UNDERGROUND SAFETY EQUIPMENT

Safety Advances with Longwall Power Systems

VFDs become an accepted technology on the road to full automation

BY STEVE FISCOR, EDITOR-IN-CHIEF

If mines are to achieve automated longwall mining, advanced electrical systems will play a significant role.

A number of new longwall mines have started up in the Illinois Basin in the last few years. One aspect that distinguishes these longwall systems from others is the technological and design innovation of the electrical distribution systems. Another distinguishing characteristic is the company who manufactures these systems: Intermountain Electronics, Inc. (IE), a Utah-based company that is competing successfully in this space against traditional providers such as Line Power and SMC.

IE has been maintaining, rebuilding and upgrading longwall electrics for 20 years now. However, the Foresight Energy installations were the first systems wholly designed and manufactured by IE. The systems involved innovative uses of VFDs, ground faults and other devices, aimed at greatly improved safety and reliability. IE worked closely with the customer to meet its operating requirements while managing the certification and approval process with MSHA's Approval & Certification Center (A&CC) in Triadelphia, W.Va.

IE has assembled a team of 15 experts with hands-on experience in the area of longwall electrics. "We pride ourselves on our service capabilities," Phil Blackburn, IE's chief commercial officer, said. "Foresight Energy wanted help with electrical engineering and they also wanted the service and support after the sale. Once they learned about the depth of our team, they recognized that we could be a great asset to their longwall programs both before and after delivery."

Getting the Green Light

Foresight Energy first approached IE for the electrical system on its Deer Run longwall. The company's other operating longwall mine, Mach, also wanted a set of electrics—its second—to rotate in and out with its first set. "We received the purchase order for the Deer Run system first," Blackburn said. "The original plan was to deliver it by the end of 2011. The service aspect was a big issue for them." The second order, for the Mach mine, followed shortly. When Mach,one of the most productive mines in the U.S., surged ahead of its production plan on its existing longwall panel. IE was asked to bump its electrics ahead for a December 2011 delivery. Deer Run's system then followed in May. IE delivered two brand new systems in the first half of 2012. Deer Run has since ordered a second set from IE that will be delivered in the summer of 2013.

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Questions???

Thank You For Your Time and Participation!!

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