

SAFETY BULLETIN

Electrical hazards associated with variable speed drives and earth fault current limited systems

BACKGROUND

Variable Speed Drives (VSDs), also known as Variable Voltage Variable Frequency (VVVF) drives, often cause relatively large capacitively coupled currents to flow in the earthing systems of the associated drive motors, plant and machinery during normal operation. These capacitive currents are associated with the switching frequencies of the output of the VVVF drives.

These high frequency currents are a source of electro-magnetic interference (EMI or noise) that can cause unreliable and sporadic operation of electronic control equipment. To minimise the impact of this noise on surrounding plant and equipment, it is common practice to use filter circuits to localise the currents to a specific area of the electrical network.

However, the use of VSDs and associated EMI mitigation techniques may (in certain circumstances) have a detrimental impact on the effectiveness of the current limitation system as used in underground mines. This phenomenon appears to be amplified when two or more machines fitted with VSDs and EMI filters are supplied from the one substation/transformer which utilises a neutral earthing resistor (NER).

Recent incidents at an underground mine involving earth faults on motor cables fed from VSD drives have drawn this issue to the Department's notice. Investigations into these incidents have identified high frequency currents flowing to earth during these fault conditions which were significantly higher than the value of the current limitation of the NER for the supply system.

Computer modelling has indicated that when powered from a common supply, the combined effects of multiple VSDs and EMI filters during fault conditions on the load side of the VSD can excite resonances that cause large circulating currents to flow between the EMI filters. Elements of this modelling have been verified in actual tests of equipment presently in service. Modelling also suggests that currents of several times the maximum value of the limitation device can flow at the substation NER.

Therefore, during an earth fault on the output side of an operating VSD higher fault currents could also have the effect of generating higher than expected prospective touch potentials at machinery associated with the supply system, not just at the location of the earth fault.

There is also an increased risk of sparking between machines, if machines are in close proximity to each other at the time an earth fault occurs on the VSD supplied motor or cable.

Notes:

1. It should be noted, that the duration of these high current earth faults on the equipment tested so far is typically very short. Tests on this equipment have demonstrated clearance times of about of 1 mS, due to the operation of an EMI filter fuse utilised with this system. However, different variable speed drives should be modelled according to their unique fault level and/or clearance time characteristics, where interactions with other VSDs and their associated EMI filters is possible.
2. Where a machine is fitted with its own isolation transformer eg the VSD traction drives on a longwall shearer the EMI filter on these drives will not interact with any other VSD drives in the longwall panel.

RECOMMENDATIONS

Whilst the following recommendations are good engineering practice, additional emphasis should be placed on them until a permanent engineering solution(s) is provided.

1. The values for the earth continuity of machinery fed via reeling and trailing cables, where VSD drives are utilised, need to be maintained at a minimum value. This is the primary protection against excessive touch potentials and should also be considered best practice in normal mining environments.
Note: The normal value for tripping of earth continuity relays is 45Ω . This upper value of possible earth resistance, allowing for known pilot resistance of the cables, may result in potentially dangerous voltages appearing at a machine. Measures should be used to ensure that the machine cable's earthing resistance remains as low as practical rather than potentially operating at the upper limits of the pilot relay.
2. Equipment fed via reeling or trailing cables should be protected with earth leakage units set for no intentional time delay ie 'instantaneous' initiation of fault detection.
3. The length of all reeling and trailing cables, including those supplying DCBs and Distribution Boxes should be kept as short as possible. Relocation of transformers should be undertaken where possible, in preference to the use of extension cables to machinery.
4. Effective mechanical protection should be provided to all cables fed from a VSD drive to minimise the likelihood of damage to the cables.
5. Where possible rearrange the VSD operated machinery at the mine to minimise the number of VVVF drives and associated EMI filters with any single substation/transformer eg distribute VSD operated equipment evenly between underground panels where such equipment does not have its own onboard isolation transformer.

6. Where a mine utilises VSD drives supplied through trailing cables it is suggested that the operator of the mine consider having professional software modelling of their applications undertaken to determine the extent to which the safety at the mine may be affected by this issue and how the risks can be managed. This recommendation therefore extends beyond the face areas of a mine eg VSD operated conveyor drives and pumps whose drives are powered through trailing cables supplied from fault current limited supplies.
7. Reference should be made to the following documents for more information
 - a. VVVF Drives and Electrical Protection in the Mining Environment, presentation by Tim Wylie at the 2011 Electrical Engineering Safety Seminar at Sydney Olympic Park, Homebush.
<http://www.dpi.nsw.gov.au/minerals/safety/publications/seminar-presentations/2011-electrical-engineering-safety-seminar>
 - b. AS/NZS 4871.1:2010 Electrical equipment for mines and Quarries Appendix E Variable speed drive - guidance for identification of potential risks
 - c. AS/NZS 60479 Parts 1 & 2 Effects of current on human beings and livestock

NOTE: Please ensure all relevant people in your organisation receive a copy of this safety bulletin, and are informed of its content and recommendations. This safety bulletin should be processed in a systematic manner through the mine's information and communication process. It should also be placed on the mine's notice board.

Signed



**Rob Regan
DIRECTOR
MINE SAFETY OPERATIONS BRANCH
NSW TRADE & INVESTMENT**

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