Guidance Note QGN 26

Electrical propulsion systems used in self-powered earth moving machinery

Coal Mining Safety and Health Act 1999

Mining and Quarrying Safety and Health Act 1999

June 2017

Queensland Government

Reference is made to the following legislation as applicable to a Mine or Quarry in Queensland:

- *Coal Mining Safety and Health Act 1999*
- Coal Mining Safety and Health Regulation 2001
- *Mining and Quarrying Safety and Health Act 1999*
- Mining and Quarrying Safety and Health Regulation 2001

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To ensure you have the latest version, check the DNRM website: https://www.business.qld.gov.au/industry/mining/safety-health/mining-safety-health/legislation-standards-guidelines or contact your local Inspector of Mines.

North Region - Townsville PO Box 1752 MC Townsville Q 4810 P (07) 4447 9248 Fax (07) 4447 9280 tsvmines@dnrm.qld.gov.au	**North Region – Mount Isa** PO Box 334 Mount Isa Q 4825 P (07) 4747 2158 Fax (07) 4743 7165 isamines@dnrm.qld.gov.au	**North Region - Atherton** PO Box 210 Atherton Q 4883 P (07) 4095 7023 Fax (07) 4095 7044 tsvmines@dnrm.qld.gov.au
South Region PO Box 1475 Coorparoo Q 4151 P (07) 3330 4272 Fax (07) 3405 5345 sthmines@dnrm.qld.gov.au	**Central Region - Rockhampton** PO Box 3679 Red Hill Q 4701 P (07) 4936 0184 Fax (07) 4936 4805 rockyminesinsp@dnrm.qld.gov.au	**Central Region - Mackay** PO Box 1801 Mackay Q 4740 P (07) 4999 8512 Fax (07) 4999 8519 minesmackay@dnrm.qld.gov.au

This publication has been compiled by Electrical Inspectors of Mines of Mine Safety and Health, Department Natural Resources and Mines.

Summary

This Guidance Note was developed in consultation with representatives from the mining industry, mines inspectorate and original equipment manufacturers (OEMs).

The reason for developing this Guidance Note was first brought about by concerns in relation to accessing high voltage conductors fitted to diesel-electric earth moving equipment and how to comply with the Queensland legislative requirements that if work is to be carried out on high voltage conductors they must be ‘earthed’.

After consultation with industry and OEMs, it was further identified that this Guidance Note should be developed to address this matter and other concerns associated with the electrical installations on these types of machines. In consultation with the mining industry, OEM’s and the mines inspectorate, it was agreed that the guidance note should also include electrical hazards and associated minimum safety requirements.

At the time of drafting this guidance note there was no Australian Standard covering the desired safety outcomes for these machines. An International Standard was being drafted but did not include some of the safety concerns that were raised by the group which have been covered in this guidance note.

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1 Purpose

This guidance note (QGN 26) is to provide practical guidance to mine operators, Site Senior Executives (SSEs), Electrical Engineering Managers (EEMs) and Persons to Control Electrical Work (PCEWs) of the requirements for safe electrical design and maintenance of electrical propulsion systems used in self-powered earth moving machinery.

The content of QGN 26 is to be considered in addition to any Australian or International Standards that may be applicable for this type of equipment.

2 Scope

This document applies to:

- all Queensland coal mining operations, defined under the *Coal Mining Safety and Health Act 1999* (CMSHA)
- all Queensland metalliferous mining operations, defined under the *Mining and Quarrying Safety and Health Act 1999* (MQSHA).

It covers electrical hazards, and associated safety requirements, with the use of systems in self-powered diesel-electric earth moving machinery such as dozers, trucks and front end loaders.

It does not include the control function aspects of autonomous machines.

3 Application

3.1 General

The coal mining safety and health regulations and the mining and quarrying safety and health regulations require that if work is to be carried out on high voltage conductors they must be ‘earthed’.

This means that there must be “a conducting connection between an electric circuit or equipment and the ground or some similar large conducting body”.

In relation to electric self-powered earth moving machinery, the connecting of electrical conductors to the general body mass of the machine would be considered ‘earthing’ these conductors. Industry representative also consider this an appropriate definition.

3.2 Glossary

Earthing: protective earthing, or protective equipotential bonding to chassis in the case of self-powered earth moving machines.

Engine On: Machine engine running.

Extra low voltage (ELV): a nominal voltage of 50V or less AC RMS; or 120V or less ripple-free DC.

Low voltage (LV): a nominal voltage greater than extra low voltage, but not more than 1200V AC RMS; or 1500V ripple-free DC.

High voltage (HV): a nominal voltage greater than low voltage (i.e. >1200V AC or >1500V DC).

Nominal voltage: the typical RMS voltage that the machine experiences during normal operation.

Decommissioned: to remove equipment from service by physically disconnecting machinery so that energy cannot be restored through a switching process. For example, physical disconnection, removal of conductors, engine, or other apparatus.

Motivator: a separate, external electrical power source used to temporarily provide energy to the machine. These have been used to assist in relocating machines following engine or alternator failures.

OEM: Original Equipment Manufacturer.

3.3 Legal requirements

Mining legislation requires for risk to a person from operations to be at an acceptable level, the operations must be carried out so that the level of risk from the operations is—

a) within acceptable limits; and

b) as low as reasonably achievable.

To decide whether risk is within acceptable limits and as low as reasonably achievable regard must be had to—

a) the likelihood of injury or illness to a person arising out of the risk; and

b) the severity of the injury or illness.

4 Guidance

4.1 Isolation guideline – General Requirements

- Isolating devices shall be provided with a means of locking in the OFF position so that neither remote, nor local, nor inadvertent closing is possible.
- Any isolators shall be fit for the intended purpose, appropriately placed, readily identifiable and should break all current carrying conductors from the source of supply, and shall not be lockable in the ON position.
- Isolating devices should have a breaking capacity sufficient to interrupt the current of the largest total load. Where an isolating device is not capable of interrupting the largest load, measures need to be taken to prevent it operating while carrying current.

Such measures may include interlocking or, where the device will only be operated by authorized persons, suitable warning notices will be in place.

- It is recommended that all routine tasks to be undertaken on the machine be identified and that an isolation matrix be developed and be readily available.
- Tasks to be carried out under the isolation must be identified to ensure that correct areas are isolated. Before tasks are undertaken, the persons carrying out the task need to be familiarised and authorised with the isolation matrix and what areas have been isolated.
- The machine isolation process needs to ensure that stored energy components are fully discharged prior to access. For stored energy components, such as capacitors, information supplied by the OEM can provide a method for verifying that all components with residual voltages have been discharged prior to accessing the machinery.
- Checks need to be carried out to confirm the integrity of the isolation. This might include attempting to start the machine; or using the visual voltage control indication.

- Isolation procedures and task instructions shall consider inadvertent contact with energised electrical parts.
- Tools and test equipment required as part of the isolation process shall be appropriately designed, fit for purpose and readily available.

4.1.1 Isolation guideline for electrical access – All voltages

These isolation criteria are for access to electrical equipment and conductors and not for mechanical isolation purposes.

- Tasks to be carried out under the isolation must be identified to ensure that correct areas are isolated.
- A multi-pole isolator, breaking all current carrying conductors from the source of supply, should be used.
- If a multi-pole isolator is not installed, the primary isolation device shall prevent the engine from starting/turning. For example, isolating the drive motor for the alternator (positively isolating the engine).

Engine isolation is comparable to isolating upstream in a typical electrical distribution system.

- Up to date electrical schematics need to be readily available.
- An arc flash hazard assessment needs to be readily available
- (This is not required for ELV).
- Allow adequate discharge time for capacitive type devices before accessing. Where capacitors may be accessed, it is recommended the following systems be used:
  - timed-captured key or similar systems
  - visual indicators on individual capacitor segments
  - audible alarm for failure to discharge when machine is shut down.
- Testing for zero potential shall occur (test for dead) before the isolation process can be completed.
- Revalidating isolation testing when the machine sits unattended for a period of time, should be included as part of the site isolation procedures.

4.1.2 Additional isolation guidelines for electrical access – High voltage

These isolation criteria are for access to electrical equipment and conductors and not for mechanical isolation purposes. These are also in addition to the requirements of clauses 4.1 and 4.1.1.

- Tasks to be carried out under the isolation must be identified to ensure that correct areas are isolated.
- In the case of high voltage access, ensure that the work task does not inadvertently disconnect the earth path. Where necessary to disconnect the earth path as part of the task, the risk assessment and procedure shall address this. For example, defining when the

equipment is deemed to be electrically decommissioned, or by using temporary earth connections.

- For high voltage applications, the supply disconnecting device and associated earthing switch should be combined in a functional unit. If a combined functional unit is used, interlocks shall exist to ensure that earthing of the live conductors is only possible when the disconnecting device is in the open position and closing the disconnecting device is only possible when the live conductors are not earthed.
- Dedicated machine fitted earth switching devices are recommended.
- If portable earthing equipment is utilised, then the use of these shall be to dedicated attachment points on the machine while maintaining clearance and approach distances. The location for these dedicated attachment points shall consider the tasks that may be required to be undertaken on the high voltage parts such as diode replacement on alternators.
- Switching and access procedures shall be developed and followed. Prewritten switching sheets for routine tasks shall be developed. Switching and earthing operations shall be conducted with a minimum of one appropriately trained, competent and authorised electrical person with an appropriately trained, competent and authorised person to assist.
- The isolation process followed by site personnel shall requires that the vehicles have the engine OFF and are positively isolated before high voltage switching, earthing and/or access is allowed.
- Earthing equipment must be rated for maximum potential fault current and voltage.
- Earthing is allowable through semi conductive devices provided that these devices provide electrical continuity and can withstand maximum potential fault current and voltage. Quantifiable evidence that semi-conductive devices are capable of withstanding maximum fault currents and voltages is to be provided, to ensure that the earth system is not compromised. It is preferable that this evidence be provided by the OEM. If this evidence is not available, then these semi-conductive devices shall not be relied upon as the primary earth path.
- Allow adequate discharge time for capacitive type devices before applying earths. Visual confirmation that these capacitors have discharged is preferred before they are accessed.
- Before applying earths, test to confirm that the circuit is de-energised.
- Each high voltage exposed part shall be earthed if access to these parts is required.

HV isolation earthing cannot be performed through fuses.

4.1.3 Guideline for non-electrical access – Engine on

This type of access could be for tasks such as, but not limited to, brake adjustments, brake bleeding, engine diagnostics, vibration analysis and thermography. Consideration should be given to the machine design and task allocation so that all tasks can be conducted without requiring the engine to be on.

- Physical barriers from potentially live parts above ELV shall be provided, to ensure safe approach distances are maintained.

- Machine design should eliminate the requirement to access areas in the vicinity of live electrical parts above ELV. For example, brake pressure testing from within wheel housing.
- If access to wheel motor vent area is required during engine ON testing, access to the inverter cabinets shall be prohibited to reduce the risk of arc flash or exposure to noxious gases in the event of inverter failure or flashover.
- For any Engine-ON testing, the inverters should be prevented from operating. This may be done by positively isolating the excitation circuit, or the isolation process should prevent voltages above ELV levels from supplying the inverters. The purpose of isolating the inverters is to reduce the electrical risk during the task. If this is not practicable however, alternative controls shall be determined by risk assessment.

4.1.4 Isolation guideline for non-electrical access—Engine OFF

- Isolate in accordance with standard operation procedure for isolation on the site.
- It is recommended that this isolation process be kept consistent with other mobile machines on the site.

4.1.5 Guideline for electrical access—Engine ON

This type of access could be for tasks such as, but not limited to, earth fault testing, fault finding and load box testing.

- All diagnostics should be carried out in the operator's cabin or via remote communications.
- OEMs to provide comprehensive procedures for these tasks.
- Tasks to be carried out should not require access to energized compartments containing any voltage above ELV levels. For example, an external switch should be provided for relay operation during earth fault testing. Tasks to be carried out shall not encroach on safe approach limits to energized high voltage equipment.
- Remote communications should be installed to flag potential faults before they become a serious issue.

4.2 Operation under external motivator supply

- This is currently not recommended to be undertaken.
- A detailed change management process must be followed if considering this task. Incompatibility of protection systems and operation systems shall be considered.

4.3 Fault protection guideline

- Must limit prospective touch voltage, under fault conditions, to within acceptable limits.
- Electrical circuits shall be protected against overload, short circuit and earth fault under all operating conditions to effectively interrupt the electricity supply and isolate faults.

Modification of a machine's electrical protection should be done in consultation with the OEM to ensure hazards are not inadvertently introduced. Unearthed electrical circuits above ELV shall have earth fault detection and control. An insulation monitoring device, which provides

an alarm to the operator and where possible the vehicle monitoring system, is one way to accomplish this. This does not provide instantaneous protection, however, it does provide early 'first fault' warning.

- Electrical protection may allow for a managed stop of the vehicle before shutdown occurs.
- A fault protection study shall be provided by the OEM for all ELV, LV and HV electrical circuits. For ELV circuits the OEM is to provide confirmation that the circuit protection devices are adequate for the circuit they are protecting.

Historically it has been identified that circuit protection devices for ELV circuits have not cleared overload and short circuit faults adequately.

- It is recommended that current sensing devices be installed at the alternator to ensure shutdown under a fault condition. This is to provide fault protection for the alternator output.
- It is recommended that monitoring of the excitation and alternator voltage be installed. This monitoring is to allow a controlled shutdown of the machine when either voltages are out of specified limits.
- Remote/automated functional testing of earth fault protection systems should be provided. Testing of protection systems should be undertaken following the risk management process. Guidance from the OEM and relevant standards should be considered.
- Maintenance strategies will be developed to ensure that equipotential bonding remains effective and as per design.
- It is recommended that insulation monitoring be provided with insulation readings being made accessible.

4.4 Arc flash guideline

- An appropriate arc flash hazard assessment shall be undertaken for all low and high voltage electrical equipment. This assessment should consider engine running at idle, mid speed, normal speed, over-speed, engine not running (stored energy).
- Where personnel can be exposed, the design of the electrical installation shall provide arc flash energy levels as low as reasonably achievable. Appropriate signage shall identify incident energy levels and PPE requirements. Refer to IEEE1584 and ENA NENS-09 for more information.
- Electrical enclosures shall have adequate arc fault control ability and rating. For example, containment by enclosure design, explosion vents, high speed detection relays. Arc fault control shall form part of the equipment's maintenance strategy and be considered during design
- OEM to provide a copy of the studies to the mine.

4.5 Cable types and protection

- ELV electrical equipment shall comply with the relevant sections of AS 4242.
- Low voltage electrical equipment shall comply with the relevant sections of AS/NZS 3000.
- High voltage electrical equipment shall comply with the relevant sections of AS/NZS 2067.
- Conductors and cables shall be fit for purpose, with consideration given to:
  - voltage
  - current
  - grouping of cables
  - protection against electric shock
  - ambient temperature
  - moisture, water, or insulation-degrading substances
  - mechanical stresses, including installation stresses
  - risk of fire.
- The use of fire retardant cables should be considered through the risk assessment processes.
- Cables should be double insulated with additional mechanical protection where exposed to damage (people standing on cable, rock damage etc.). AS/NZS 4871.6 provides guidance for cable protection for diesel powered machines. The requirements of this standard should be considered. The use of split conduits are not recommended for cables above ELV due to the potential ingress of contaminants, and subsequent cable damage.
- The number of joints and terminations through cable runs should be minimised. Runs should be from terminal-to-terminal without splices or joints. Where a cable is damaged it should be replaced through its entire length.

Appropriately designed and installed plug/socket combinations with suitable protection against accidental disconnection are not considered to be joints.

- Every conductor shall have a current-carrying capacity not less than the demand current to be carried by the conductor. For LV cables they shall be in accordance with the AS/NZS 3008.1 series.

Current-carrying capacities determined in accordance with the AS/NZS 3008.1 series do not take into account the effect of temperature rise on the terminals of electrical equipment that can result in the temperature limits of the insulation of cables in the vicinity of the terminals exceeding the limits specified. The equipment OEM may be able to provide advice on this point.

- Cable terminations shall be adequately supported to minimise mechanical stresses on the conductors and the vibration of normal operation. These supports shall be fit for purpose for an electrical installation.

- Conductors of circuits operating at different voltages shall be clearly delineated and separated by barriers or shall be insulated for the highest voltage to which any conductor insulation within the same duct is subjected.
- Cables of HV circuits and cables of LV or ELV circuits shall not be enclosed in the same wiring system. Separation distance / barriers shall consider induction.
- LV and ELV cables may be enclosed in the same wiring system if the LV cables are provided with the equivalent of double insulation.
- The cable sheath shall be resistant to normal wear and environmental contaminants such as oil, water, coolants, and abrasive dust.
- A space of at least 25 mm should be maintained between cables subject to movement and other moving parts. If that distance is not practicable, fixed barriers between the cables and the moving parts shall be provided.
- Cables shall not be in direct contact with fuel, brake, hydraulic lines without additional mechanical protection. Separation is the preferred method.
- Consideration is to be given to the detection and suppression of a fire associated with the wiring systems.

4.6 Electrical Enclosures

- Through the risk management process, fire suppression should be considered for electrical enclosures.
- Electrical enclosures should be designed, installed and maintained to ensure that the ingress protection is appropriate for the environment that the enclosure is subjected to. For example, inclement weather and hosing-down. Guidance for ingress protection is provided in AS 60529.
- For enclosures that contain voltages in excess of ELV, AS/NZS 3007 does not apply to earth moving machines covered by ISO 6165 however Section 15 of AS/NZS 3007 does provide detail on labels, signage, information requirements and colour coding of enclosures.
- Maintenance requirements for electrical enclosures should consider the use of thermography to locate electrical faults and subsequent heating. This maintenance technique can be utilised across the entire electrical installation.

It is recommended that infra-red (IR) viewing windows be installed and utilized to allow thermography to be conducted with enclosure doors closed. Also, it is recommended that a procedure be developed, to manage the risks inherent with thermography.

- Electrical enclosures above extra low voltage shall be interlocked or secured to provide access to electrical personnel only.

4.7 Software and control systems

- Software changes shall be conducted in accordance with the site's change management process. This includes changes to OEM firmware, machine control system code, and protection settings.
- The software change management process shall capture details of changes made at each update for each machine (what was changed, when, why and by whom), and changes shall be approved by an appropriate owner representative (EG EEM/PCEW) prior to implementation.
- Copies of previous versions should be kept onsite.

5 Legislation references for isolation

The Mining and Quarrying Safety and Health Regulation 2001 has the following specific requirements relevant to isolation procedures:

Part 4 – Electrical

Division 4 Control and protection for electrical equipment

26A Basic safety principle

(1) A person carrying out or preparing to carry out work on or near electrical equipment must treat each exposed electrical conductor as live until it is—

(a) isolated and proved to be de-energised; and

(b) if it is a high voltage conductor, earthed.

(2) In this section —
electrical equipment means an item used for generating, converting, transmitting, distributing or using electrical energy.

high voltage means a voltage of more than 1200V.

27 Isolation facilities

(1) The operator and site senior executive must ensure each item of electrical equipment used at the mine has a full current isolation facility in a location that is easily accessible by a person required to carry out the isolation.

(2) The operator and site senior executive must also ensure the isolator is –

(a) clearly marked or labelled as the isolator for the plant; and

(b) compatible with the mine's isolation and lock-out procedures.

Part 10 – Plant Generally

Division 1 Selection and design

103 Isolation facility

(1) If, having regard to the nature and level of risk from plant used at a mine, it is necessary for managing the risk, the site senior executive must ensure the plant has a facility for –

(a) preventing its operation;

(b) preventing or controlling the release of its stored energy; or

(c) isolating its energy supply.

(2) The site senior executive must ensure the facility is capable of being locked-out and tagged or otherwise secured.

Division 2 Other provisions about plant

106 Operating plant

A person who has an obligation under the Act to manage risk at a mine in relation to the operation of plant must ensure the plant is not operated –

(a) in a way that creates an unacceptable level of risk; or

(b) if inspections, tests or monitoring show the plant is unfit for use; or

(c) if the plant is locked-out and tagged. Isolating, locking-out and tagging plant

107 Isolating, locking-out and tagging plant

(1) A mine's safety and health management system must provide for the following–

(a) isolating plant, including effectively isolating plant to control the risk from a release of energy;

(b) taking plant out of service;

(c) testing plant or its energy source for zero potential;

(d) returning plant to service.

The Coal Mining Safety and Health Regulation 2001 has the following specific requirements relevant to isolation procedures:

Part 4 - Electrical activities, equipment and installations

Division 1 Electrical activities

Subdivision 2 Other provisions about electrical activities

21 Access to exposed electrical conductors

(1) A coal mine must have a standard operating procedure for safely accessing exposed electrical conductors at the mine.

(2) The procedure must provide for minimising the risk of energising exposed electrical conductors on which work is to be carried out, including, for example, by using personal locks or danger tags or both personal locks and danger tags.

(3) The procedure must also provide that before work is carried out on an exposed electrical conductor at above extra low voltage it must be—

(a) positively isolated from the electricity source; and

(b) tested for zero potential; and

(c) if it is a high voltage conductor, earthed.

(4) Subsection (5) applies only to a surface mine and only if—

(a) it is not practicable to positively isolate the conductor from the electricity source; and

(b) access to the conductor is required or work in close proximity to the conductor is required to be carried out.

(5) The procedure must also provide that—

(a) a risk assessment, including consideration of high fault currents, must be carried out before the work is carried out; and

(b) if the risk assessment shows an unacceptable level of risk in carrying out the work with the conductor energised, before the work is carried out, the conductor must be—

(i) positively isolated from the electricity source; and

(ii) tested for zero potential; and

(iii) if it is a high voltage conductor, earthed.

Division 2 Electrical equipment and installations

Subdivision 1 General

24 Isolators for equipment driven by electricity

(1) The electrical engineering manager must ensure the mine has a full current isolator for equipment driven by electricity at the mine.

(2) The electrical engineering manager must ensure—

(a) the isolator is—

(i) clearly identified as the isolator for the equipment; and

(ii) situated in a location that is easily accessible by a person working on the equipment; and

(b) the equipment is clearly identified as being supplied with electricity from the isolator.

Part 10 - Plant

Division 3 Miscellaneous

78 Isolating and tagging procedures

(1) A coal mine must have a standard operating procedure for the following—

(a) controlling the risk of an unplanned release of energy from plant, including positively isolating the energy source;

(b) if an electrical or mechanical energy source is positively isolated—testing for zero potential;

(c) taking plant out of service;

(d) returning plant to service.

(4) For subsection (1)(a), the method for positively isolating the energy source for plant provided for in the standard operating procedure must—

(a) for plant that is electrical equipment—be a manually initiated operation that—

(i) isolates all active power conductors of the plant being isolated from the electricity supply; and

(ii) prevents unintended re-energisation, including re-energisation through inadvertent operation of the plant or component failure; and

(b) for other plant—be the operation of a manually operated device that—

(i) is installed in the energy supply for the plant and, when operated, isolates the plant from its energy source; and

(ii) requires a manually initiated operation for the supply of energy to the plant to be resumed; and

(c) require that the isolation device be clearly marked as being the positive means of isolating the plant.