NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Technical Reference
Electrical Engineering Safety
EES011

NSW DPI Technical Reference
Technical Principles for the Design of Electrical Systems at NSW Mines (Coal and Metals) and Extractives Operations

Coal Mine Health and Safety Act 2002
Coal Mine Health and Safety Regulation 2006
Mines Health and Safety Act 2004
Mines Inspection Act 1901
General Rule 2000

March 2007 (version 1)

Disclaimer

The compilation of information contained in this document relies upon material and data derived from a number of third party sources and is intended as a guide only in devising risk and safety management systems for the working of mines. It is not designed to replace or be used instead of an appropriately designed safety management plan for each individual mine. Users should rely on their own advice, skills and experience in applying risk and safety management systems in individual workplaces.

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This publication contains information regarding occupational health, safety, injury management and workers compensation. It includes some of your obligations under the various workers compensation and occupational health and safety legislation that NSW Department of Primary Industries administers. To ensure you comply with your legal obligations you must refer to the appropriate legislation.

This publication may refer to NSW legislation that has been amended or repealed. When reading this publication you should always refer to the latest laws. Information on the latest laws can be checked at www.legislation.nsw.gov.au or contact (02) 4931 6666.

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FOREWORD

Coal Mines and Metalliferous Mines legislation allow mines to develop occupational health and safety management systems that will:

- Be appropriate for that organisation,
- Be integrated with other systems and core functions of the organisation,
- Improve the organisations overall safety performance,
- Assist the organisation to meet its legal responsibilities, and
- Improve the performance of a site or the industry by a range of actions.

Specific NSW Department of Primary Industries (NSW DPI) targets for electrical engineering safety within the mining industry are:

- Zero electrocutions.
- Zero deaths as a result of electric shock (eg falls because of receiving an electric shock).
- Zero permanent disabling injuries as a result of electric shock.
- Zero incurable burns from electricity.
- Zero gas/dust explosions with electricity as an ignition source.
- Zero fires that result in injury, death or evacuation of a mine or part of a mine, caused by the malfunction of electrical equipment.
- Zero injury or death from unintended operation of electrically powered or controlled equipment.
- Zero injury or death from failure to stop of electrically powered or controlled equipment.
- Zero injury or death from the failure to operate of electrically powered or controlled equipment.

The Technical Principles for Electrical Engineering Safety identifies the risk controls that should be designed into electrical systems used at mines to achieve the above targets. It does not go into specific detail.

Mine Safety operations electrical engineering staff will use this document as a minimum expectation for electrical systems and equipment installed at all types of mining operations.

Consultants, designers and mine personnel should incorporate these requirements as a minimum. Where these requirements are not implemented alternative engineering risk controls must be applied and analysed to ensure that the alternative risk controls provide for a risk less than if the principles were applied in total.

This Technical Reference can also be used by mine operators to assess the effectiveness of their present arrangements for the design of electrical engineering safety into their electrical systems and equipment.

This Technical Reference will assist employers, self-employed persons, employees, contractors and other parties involved with practices of designing and life-cycle management of electrical systems and equipment.

John Francis Waudby

Senior Inspector of Electrical Engineering

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Chapter 1 Establishment

1.1 Title

This is the NSW DPI Electrical Engineering Safety Technical Reference – Technical Principles for the Design of Electrical Systems at NSW Mines (Coal and Metals) and Extractives Operations.

1.2 Purpose

This Technical Reference is intended to provide a framework for NSW DPI officers to assess electrical system and equipment designs for use at mining operations. When mines or designers of electrical systems contact the NSW DPI for advice, this document will provide the principles expected to be used by mines and designers in delivering safe electrical systems and equipment.

It can also be used by mine operators and designers as guidance material for implementing, managing or reviewing their design requirements for electrical systems and equipment.

This Technical Reference specifies minimum expectations for:

- The design features for electrical systems and equipment.
- The design process.

The outcomes sought to be achieved by this Technical Reference are:

- To protect people and property from the risks associated with the use of electricity in mining operations including:
    - Electrocution
    - Electric Shock
    - Electrical burn injuries
    - Arc blast injuries
    - Injuries sustained through operation of the equipment
    - Unintended operation of the equipment
    - Ignitions of flammable mixtures of gas or dust
    - Fire
- To protect people and property from electrical and non-electrical hazards by the provision of electrical safeguards with an appropriate safety integrity level.

1.3 Scope

This Technical Reference extends to all mining and extractives operations in New South Wales. The range of equipment that should be considered includes mains supplied, generator supplied and battery supplied systems. It encompasses all electrical circuits at all voltage levels, and commences at the point of connection to the supply; for mains this is generally the metering point, for generators this is generally the output terminals of the generator, and for batteries the battery terminals.

1.4 Authority

This is an Electrical Engineering Safety Technical Reference and is recommended by the Department of Primary Industries.

1.5 Definitions

Arc blast is the force of plasma and fire from an electric arc.

Circuit means an electrical network providing one or more closed paths.

Competent person for any task means a person who has acquired through training, qualification, experience, or a combination of these, the knowledge and skills to carry out the task.

Earth continuity monitoring system is a form of monitoring normally provided to confirm the integrity of the earthing conductor(s) in cables supplying equipment. It operates when the earth-loop resistance exceeds a predetermined value, or when the resistance value between pilot and earth falls below a predetermined value. *

Earth-leakage protection detects earth-leakage current and isolates the electrical supply from any fault zone.*

Electric arc is a flow of current between two electrodes through ionized gases and vapours. It is started by flashover or the introduction of some conducting material between energized parts.

Electrical equipment means electrical apparatus, appliance, machine, fitting, or cable in which conductors are used to transmit and utilise electricity.

Electrical protection is a form of protection normally provided to confirm the integrity of the earth conductors in the cables supplying equipment. It operates when the earth loop resistance exceeds a predetermined value, or when the resistance value between pilot and earth falls below a predetermined value.

Licensed electrician means a person who is the holder of a Qualified Supervisor Certificate – Electrician as defined under the Home Building Act 1989.

Lockout earth-fault protection prevents a circuit being energised if the insulation resistance to earth of one or more of the conductors is below a predetermined level. *

Mains means conductors or cables connecting mains switch-gear with an electrical power distribution or load centre.

Mains switch gear means power circuit switching or interrupting devices in combination with associated control, instrumentation, metering, protective and regulating devices, or assemblies of any such devices and associated inter-connections, accessories and supporting structures used primarily in the transmission, distribution and conversion of electric power.

Plant includes machinery, equipment or appliance.

Plasma is a collection of charged particles that exhibits some properties of a gas but differs from a gas in being a good conductor of electricity and in being affected by a magnetic field.

Portable apparatus means electrical apparatus capable of being carried manually while it is being used but does not include a caplamp. It covers such items as hand-held portable or transportable welders, portable power tools, appliances and flexible extension cords.

PPE (Personal Protective Equipment) means clothing and equipment designed to mitigate the effects of hazards to which workers might be exposed.

Risk assessment means the qualitative and quantative evaluation of the risk posed to human health and / or the environment by the undertaking of an activity that has an associated and identifiable hazard.

Voltage:

Extra low voltage – Not exceeding 50V AC or 120V ripple free DC

Low voltage – Exceeding extra low voltage, but not exceeding 1000V AC or 1500V DC

High voltage – Exceeding low voltage.

Information Note - For underground mining applications voltages of 1000 V AC and 1100 V AC have been commonly used in a similar manner to voltages of 415 V AC and 550 V AC (low voltage). Previous legislation required that voltages exceeding 1200 V AC not be applied to certain types of apparatus (explosion protected, mobile, portable, or motors smaller than 15Kilowatts). From this there is a common and accepted practice of considering high voltage to be greater than 1200 V AC in underground mining applications and associated surface applications. Where a coal operation chooses to not use accepted (mining and non-mining industry) high voltage practices on circuits whose nominal voltage exceeds 1000 V and is less than 1200V, this must be supported by a risk assessment and nominated controls, including specific procedures to prevent electric shock, arcing and failure of explosion protection. It is not acceptable to plug and unplug restrained plugs at voltages exceeding ELV whilst relying solely on pilot or earth continuity control circuitry for isolation.

Underground coal operations use mining machinery powered at 3.3 kV. High voltage practices and procedures must be used on these circuits, it is not acceptable to plug and unplug restrained plugs at 3.3kV, without effecting “whole current” isolation.

For high voltage distribution systems a “permit to work” system must be used and records kept.

** Definitions as per AS2081.1:2002.*

1.6 Applicable Legislation

The Occupational Health and Safety Act 2000

The Occupational Health and Safety Regulation 2001

The *Coal Mine Health and Safety Act 2002*

The *Coal Mine Health and Safety Regulation 2006*

The *Mine Health and Safety Act 2004*

The *Mines Inspection Act 1901*

The *General Rule 2000*

1.7 Referenced Gazette Notices

N/A

1.8 Referenced Standards and Guidelines

AS/NZS 3000 - Electrical installations (known as the Australian/New Zealand Wiring Rules)

AS 3007 Series - Electrical installations - Surface mines and associated processing plant

AS 4024.1 - Series - Safety of machinery

AS/NZS 4801 - Occupational health and safety management systems - Specification with guidance for use

AS 61511 - Functional – Safety instrumented systems for the process industry sector

AS 61508 Series - Functional safety of electrical/electronic/programmable electronic safety-related systems

AS 62061 - Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems

HB187 (Australian Standards Handbook) Guide to selecting a safe multimeter

NSW Minerals Industry Safety Handbook

EES002 NSW DPI Technical Reference - Control and Supervision of Electrical Work

EES003 NSW DPI Technical Reference - Practices for the Life-Cycle Management of Explosion Protected Equipment

EES004 NSW DPI Technical Reference - Practices for Portable Electrical Apparatus

EES005 NSW DPI Technical Reference - Electrical Protection and Earthing

EES006 NSW DPI Technical Reference - Removal and Restoration of Power

MDG15 Guideline for Mobile and Transportable Equipment for Use in Mines

MDG25 Guideline for Safe Cutting and Welding at Mines

MDG 40 Guideline for Hazardous Energy Control (Isolation or Treatment)

WTIA TN07 (Welding Technology Institute of Australia) Health and Safety in Welding

WorkCover Publication 1394 – Work Near Overhead Power Lines: Code of Practice

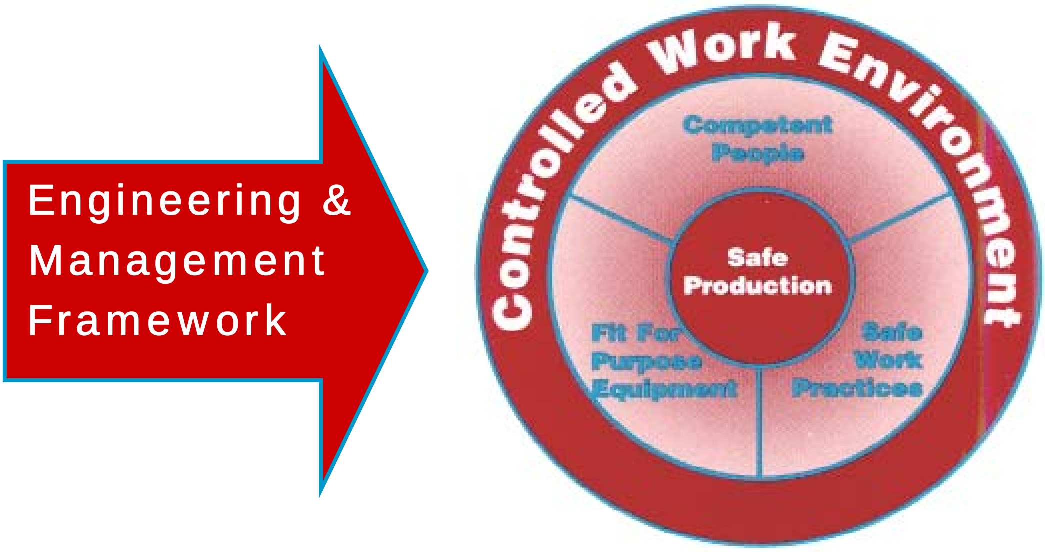
1.9 Acronyms

AS	– Australian Standard
AS / NZS	– Australian New Zealand Standard
E/L	– Earth leakage
Ex	– Explosion protected
FFP	– Fit for purpose
NSW DPI	– NSW Department of Primary Industries
OHL	– Overhead lines
PLC	– Programmable Logic Controller
SIL	– Safety Integrity Level

Chapter 2 Overview of the Mining Industry and Electrical Engineering Safety

2.1 Introduction

Electrical engineering decisions are critical to attaining safe production at mine sites. To achieve safety, these decisions must be of the highest quality. A model for making these quality decisions is the Minerals Industry Risk Management (MIRM) Model (refer: www.mishc.uq.edu.au). The MIRM Model has two main elements; these are the management system and the work process factors. The management system incorporates the management and engineering framework for the design and operation of the site. As such, it supplies the inputs to the daily work processes to achieve safe production within a controlled work environment, by, competent people, fit for purpose equipment and safe work practices. This is expressed in the diagram below.



The quality of the decision depends on the quality of the engineering and management process that designs, purchases, installs, commissions, operates, maintains (including repair and overhaul), modifies, trains, standardises and otherwise defines the nature of the day-to-day work process. To do this the management system has to be defined and formally documented so that the quality of key decisions is not left to chance. (Refer to Australian/New Zealand Standard AS/NZS 4801:2001 *Occupational health and safety management systems—specification with guidance for use).*

All of the above must be present and effective at every stage of the equipment and mine's life cycle, and must be effectively supported by the organisational culture. If any element is deficient, or, there is ineffective support from the organisational culture – safe production is left to chance.

2.2 Electrical Engineering Safety

Electrical engineering safety encompasses:

- Prevention of electric shock and burns, (electrocution, death or injury as a result of a shock, radiation burns, flash burns, burning particles and plasma),
- Prevention of electrical arcing and surface temperatures that have sufficient energy to ignite gas and/or dust,
- Prevention of fires caused by the malfunction of electrical equipment,
- Prevention of injury and death from unintended operation, failure to stop or failure to operate of electrically powered and electrically controlled equipment, and
- Use of electrical technology to provide safe-guards and monitoring with a safety integrity level appropriate for the risk for non-electrical hazards and electrical hazards.

2.3 Key Risk Controls for Electrical Engineering Safety

The elements required as a minimum to safely manage the use of electricity. These elements were identified via a risk assessment conducted and regularly reviewed by Mine Safety Operations electrical engineering staff.

Note: Where mines do not have hazardous zones or hazardous areas (open cut mines, quarries etc) then it can be considered that the risk of explosions from hazardous areas is adequately managed.

- Electrical technology management systems incorporating incident investigation
- Competency (of people engaged in electrical equipment and systems throughout the life cycle).
- Fit for purpose (FFP) electrical equipment.
  - High energy electrical systems
  - Electrical protection
  - Earthing and lightning protection
  - Electrical equipment (cables and apparatus) in non hazardous areas
  - Machine Control circuits
  - Electrical apparatus in a hazardous zone (includes gas monitoring)
  - Cables in a hazardous zone
  - Signage
- Safe Procedures
  - Hazardous zone classification and identification
  - Removal/restoration of power procedures
  - Isolation procedures
  - Electrical testing procedures
  - Electric welding procedures
  - Electric shock and burn protocols
  - Use of portable apparatus U/G (underground)
  - Use of remote controlled equipment
  - High voltage procedures
  - Work near overhead lines

Chapter 3 Technical Principles for Electrical Engineering Safety

These guiding principles are for use by NSW DPI electrical engineering officers as a starting point for any discussions with stakeholders. These principles can be applied in the vast majority of situations, where they can not be applied the electrical engineering officers must be satisfied that alternative arrangements provide for an equivalent or lesser risk.

Designers of electrical systems and equipment should use this document as a basis for their design work.

The detail about these principles can be found in legislation, standards, guidelines and codes of practice.

3.1 General

- Electrical plant must be compliant to the Plant Safety requirements of the Occupational Health and Safety Regulation 2001 (Chapter 5).
- Compliance with Australian or International Standards for electrical equipment.
- Compliance with Australian or International Standards for electrically powered or electrically controlled machinery.
- Access to electrical plant for diagnostic purposes does not expose workers to increased risk of injury.

3.2 Electrical Distribution Systems

- All surface installations to comply with AS/NZS3000 & AS3007.
- IT systems for:
  - Mine operated HV circuits, where there is a transformer at the point of supply (eg 33kV incoming supply transformed down to 11kV for mine site distribution – earth fault limitation is required at the 11kV neutral point),
  - Mobile equipment, and
  - Underground mine distribution.
- Electricity Supply Authority installations on mine sites to comply with mining legislation – AS3007.
- No automatic reclose after a fault trip.
- Overhead lines (OHL).
  - No work near OHL's where there is a foreseeable possibility of contact with the lines.
  - No storage of material or equipment under OHL's.

3.3 Provision of Isolation

- Every part of an electrical system under the control of a mine has provision for isolation.
- Electrical distribution systems have isolation points on every sub-circuit.
- For circuits above 240 V each individual load item (motor) has its own isolation point.

- Isolation is provided by suitably rated switches or circuit breakers.
- Isolation devices have provision to be padlocked in the open position.
- Isolation by the use of contactors is not acceptable.

Note: Where there is a group of final load items, such as two motors on one drive, then the isolation supplied can isolate both motors.

3.4 Electrical Protection

Note: To put the need for electrical protection in context it is instructive to quote from the paper *"Electric Arcing Burn Hazards"* by Stokes and Sweeting[1].

"Modern electric fuses are marvelous devices for protecting life and equipment from the potential power of uncontrolled electricity. Since the coming of electricity in the 1870's, they have been in the front line of electrical defence. Indeed, it is fair to say that without the virtually fail-safe protection of the electric fuse, there would be no modern electrical industry. Electricity would be regarded as far too dangerous for widespread use…"

- Short circuit protection on all circuits and sub-circuits.
- Earth-leakage protection on all circuits and sub-circuits.
- Earth continuity monitoring system on trailing cable circuits.
- Lockout earth-fault protection on trailing cable circuits.
- The first level of earth-leakage protection to have no intentional delay in operating.
- High voltage distribution tripping circuits to be fail safe, or have redundancy with no common modes of failure, or be designed to an appropriate SIL level.

3.5 Hazardous Areas / Zones

- Electrical equipment in underground coal mine hazardous zones to be explosion protected and satisfy gazetted criteria.
- Hazardous area equipment to be certified.
- Exceptions are for:
    - Portable apparatus used in accordance with gazetted criteria.
    - Where mines require non-Ex equipment in hazardous zones an exemption is required. Where exemption is granted a condition must be to automatically remove all power to non-Ex equipment if the gas level exceeds 0.5%.

3.6 Control Circuits & Electrical Safeguards

- Extra low voltage for control circuits.
- Electrical safeguards (risk controls, interlocks etc) to be designed to an allocated SIL.
- Where PLC's are used for safety related purposes, they should be safety PLC's.
- A functional safety approach is used for machinery control and safeguards.

[1] Stokes, DA., Sweeting, DK. *"Electric Arcing Burn Hazards"*, IEEE Transactions on Industry Applications, page 134, Vol. 42, No.1, January/February 2006

3.7 Electrical Work

- All electrical installations to be designed by a qualified electrical engineer.
- All electrical work to be done by qualified electrical engineers or licensed electricians.
- No live line work.
- Test before you touch.
- Application of working earths.
- Electricity supply authorities are responsible for their work on their assets.
- Mines are responsible for their work on their assets.
- Professional medical treatment for all victims of electric shock.

3.8 Provision of Information

- Compliance with legislation and Australian or International Standards.
- Encompasses the life-cycle.
- Includes ALL emergencies.

Chapter 4 Design approach

4.1 Risk Management

- If the risks are not recognized, the risks will not be properly managed.
- If the risks are ignored, the risks will not be properly managed.
- If the risks are not understood, the risks will not be properly managed.
- Engineering risk controls must be implemented and supervised at an engineering level.
- Controls for high risk require highly credible and independent verification. (Type 5 certification schemes, NATA test reports).

4.2 System Safety Engineering

Based on risk management, requiring fit for purpose equipment, competent people and processes / procedures, within a managed work environment all supported by management systems, throughout the life cycle of the mine. Through:

- Identifying the hazards in the system.
- Determining the underlying causes of the hazards.
- Developing engineering and management controls to eliminate the hazards or mitigate their consequences.
  - For plant using functional safety approach (**Note**: plant safety files are a key element of the functional safety approach).
  - For safety instrumented systems, such as gas detection and ventilation interlocks using functional safety approach.
- Verifying the risk controls are adequate and in place.
- Monitoring the system.

4.3 Hierarchy of Risk Controls

Legislation and system safety engineering require the application of a hierarchy of risk controls. This means that the first option considered is to eliminate the hazard, and only when this avenue is exhausted should the second option be considered. In reality, a combination of risk controls will need to be implemented to adequately manage risks and unless it can be clearly demonstrated that a single risk control is sufficiently reliable, then multiple risk controls should be adopted. In electrical engineering design there has been a long tradition of the use of multiple risk controls. The hierarchy of risk controls is defined as:

- Eliminate the hazard
- Substitute the hazard for one that gives a lesser risk
- Isolate the hazard from the person
- Engineering controls
- Procedures
- PPE

4.4 Risk Reduction Precedence

When designing electrical systems the most effective risk control is to design out the hazard. However the very nature of electricity is such that safety devices such as electrical protection have to be utilised. The risk reduction precedence is:

- Design out the hazard
- Safety devices that fail to safety
- Warning devices
- Special procedures and training

4.5 Functional Safety

When designing electrical systems that are used to alarm, trip off power or bring plant to a safe state then a functional safety approach must be taken, resulting in a safety requirements specification that contributes to achieving a tolerable risk level.

When designing electrical control systems for mining machines (miners, shuttlecars, longwall systems, loaders, automated loaders, remote control systems) a functional safety approach must be taken as an "out of control" machine is high risk in the confines of a mine or processing plant.

AS 61508, AS61511, AS62061 are critical standards.

For simple systems AS4024 may be used.

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Feedback Sheet

Your comments will be very helpful in reviewing and improving this document.

Please copy and complete the Feedback Sheet and return it to:

Senior Inspector Electrical Engineering
Mine Safety Operations
NSW Department of Primary Industries
PO Box 344
MAITLAND NSW 2310
Fax: (02) 4931 6790
Phone: (02) 4931 6641

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NSW DPI Contact Details

NSW DPI Mineral Resources offices located in coal mining regions

North East Area	South East Area
Maitland	**Lithgow**
516 High Street	Suite 1, 1st Floor, 184 Mort Street
Maitland NSW 2320	Lithgow NSW 2790
PO Box 344	Phone: (02) 6350 7888
Hunter Regional Mail Centre NSW 2310	Fax: (02) 6352 3876
Phone: (02) 4931 6666	
Fax: (02) 4931 6790	
Singleton	**Wollongong**
Level 1, 1 Civic Avenue	Level 3, Block F, 84 Crown Street
Singleton NSW 2330	Wollongong NSW 2500
PO Box 51	PO Box 674
Singleton NSW 2330	Wollongong NSW 2520
Phone: 02 6572 1899	Phone: (02) 4222 8333
Fax: 02 6572 1201	Fax: (02) 4226 3851