



**Industry &
Investment**

Investigation Report

Electric shock injury involving 3.3kV electrical equipment at the Liddell Coal Preparation Plant on 15 November 2007

Report prepared for the Director-General of the Department of Industry and Investment by the Investigation Unit, Thornton

Mine Safety Investigation Unit

Title: Investigation Report,
Electric shock injury involving 3.3kV electrical equipment at the
Liddell Coal Preparation Plant on
15 November 2007

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Disclaimer

The information contained in this publication is based on knowledge and understanding at the time of writing. However, because of advances in knowledge, users are reminded of the need to ensure that information on which they rely is up to date and to check the currency of the information with the appropriate officer of the Department of Industry and Investment or the user's independent advisor

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Overview

The incident On 15 November 2007 a preparation plant technician received an electric shock and burns when he touched a live high voltage electrical circuit when accessing an electrical cabinet. The electrical circuit was contained within a high voltage, 3300 volts, switchboard consisting of three cabinets located in a switch room. This switchboard supplied power to a motor which operated a conveyor for the transportation of coal.

The preparation plant

The operation The Liddell Coal Preparation Plant is a coal handling and preparation facility located in the north-western district of the New South Wales coalfields 25km northwest of Singleton.

Coal from the nearby Liddell Open Cut Mine is washed at the Liddell Coal Preparation Plant and almost all of the products are railed off site and exported as thermal or semi-soft coking coal. Liddell is connected to a rail loop which takes coal to the Port of Newcastle, about 107km away.

The Liddell Coal Preparation Plant produced 3.1Mt of saleable product in 2007 and employed about 31 people, including the technician.

At the time of the incident the coal handling and preparation plant was about 28 years old (circa-1979) with a nominal feed rated at 700 tonnes per hour (tph).

The coal receipt area adjacent to the plant consists of a run of mine stockpile pad, a dump hopper and a set of roll crushers and a rotary breaker. The plant involved three separate product processes including a dense medium bath, dense medium cyclones and spirals. The plant can produce two products; a semi-soft coking coal and thermal coal.

The washed coal product stockpile has the capacity of 500,000t. The coal is fed from this stockpile via a reclaim tunnel conveyor belt to the Unit Train Loading (UTL) facility at the current rate of 2,000tph.

A number of other mines in the area share this rail loop with Liddell.

Electrical supply

Electrical power Electrical power is supplied to the mine and Liddell Coal Preparation Plant via the State public grid at 66kV. Supply power is converted to 11kV by a 10MVA transformer and substation at the Hunter Valley Train Loader, which is situated on an adjacent coal mining lease. Liddell Coal owns the substation while another mining company carries out the maintenance on it, as the substation also supplies power to the neighbouring site.



Photo shows UTL Building, with UTL switch room below

Photo by Investigator Freeman

UTL Switch room

Electrical equipment

Although the Liddell Coal Preparation Plant was about 28 years old, major upgrade work, including the replacement of switchboards and control panels, was carried out around 1998, and a final upgrade of the motor control centre (MCC) was completed in 2002.

The 11kV feed originates from the 66kV/11kV switchyard and is reticulated via overhead lines and underground cabling to the UTL switch room, which houses 11kV and 3.3kV electrical switching equipment.

The incident

Incident outline

On 15 November 2007 at about 1040 hours, an employee of Liddell Coal Preparation Pty Limited received an electric shock and burns from 3.3kV electrical equipment at the UTL switch room of Liddell Coal Preparation Plant whilst looking for a possible loose connection on the 3.3kV wiring. At the time the technician was overseeing a contractor repairing a slip-ring conveyor motor.

The technician received a severe electric shock between both hands and consequently across the chest. The technician also received burns to both hands and was taken to hospital as per the coal operation's electric shock protocol and received treatment.

Carried out isolation

Several hours prior to the incident the technician had been given the task of isolating a surface conveyor belt and drive motor to allow an electrical contractor internal access to the 3.3kV slip ring conveyor motor for fault diagnostics. The isolation was carried out at a 3.3kV main control cabinet (UTL 3.3/3, shown in Photo below).

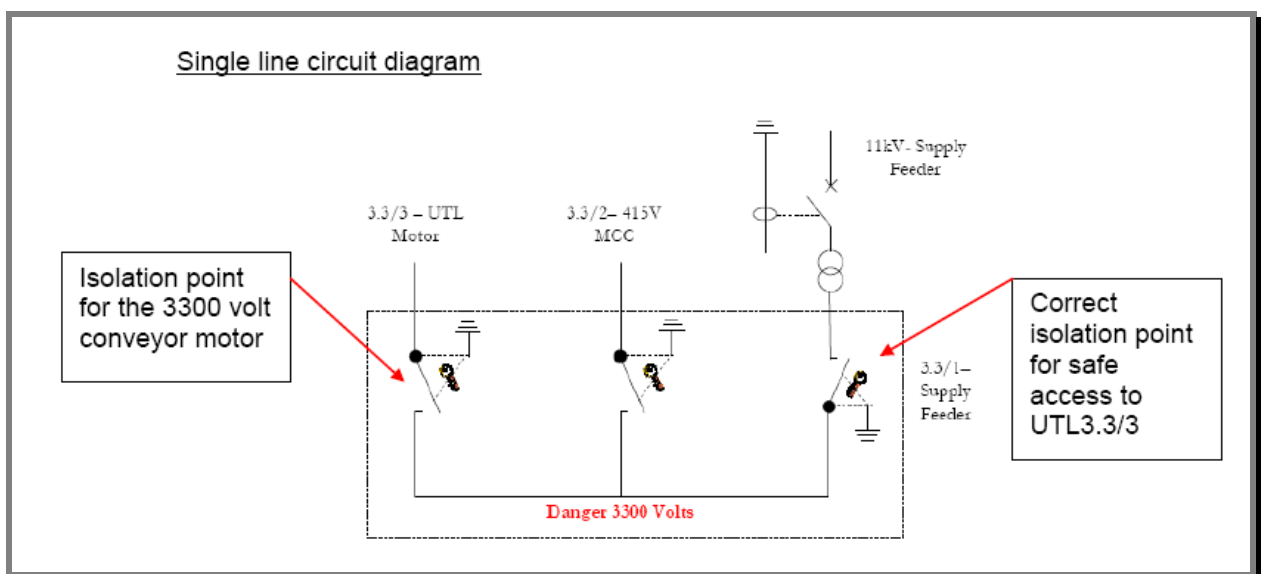
The motor starter panel was supplied from a high-voltage switch fuse (UTL3.3/3). This switch fuse had previously been isolated by the technician. As part of the isolation, an interlocked earth had been applied to the load side of the switch fuse.



Photo showing 3.3kV switchboard located in UTL building

Photo by Investigator Freeman

Later during the shift the motor repair contractor advised the technician that there could be a loose connection on the mains supply to the motor. The technician went to investigate for a loose connection on the 3.3kV wiring at the MCC switch room. The technician required access to the conveyor motor switch fuse unit (UTL3.3/3) and relied on the isolation that he had previously carried out.

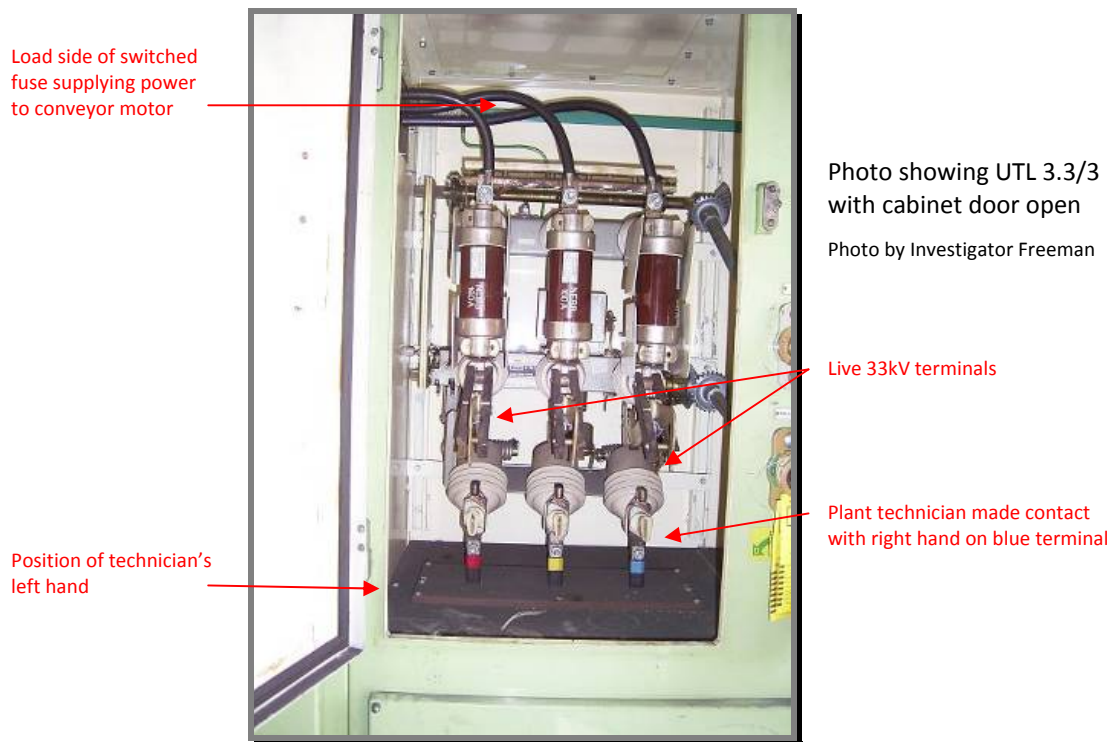


The technician removed a trapped key safety interlock for the isolation of electrical switchgear, known as a Castell key, from adjacent to the earth switch for the fuse switch (UTL 3.3/3); the interlock to the Castell key had been released by the earth switch being applied. The Castell key was used by the technician to gain access to the conveyor switch fuse enclosure (UTL 3.3/3).

No test for dead

The technician opened the switch fuse unit door and assumed that the bottom of the switch was isolated (dead). It appears that the technician made the assumption that the power (live side of the switch) was connected to the top side of the combination-fused switch. The technician could see the switch was open. The technician did not “test for dead” before attempting to touch electrical conductors.

The technician had placed his left hand on the bottom of the panel frame. He then went to check for a loose connection on the blue phase with his right hand. When he made contact with the blue phase nut he received a severe electric shock between both hands and consequently across the chest. He also received burns to both hands.



Earth leakage tripped power

Earth leakage protection located on the neutral of the supply transformer operated and disconnected the 3.3kV supply by tripping off the transformer primary (11kV) circuit breaker via a shunt trip.

The injured person

Age at time of incident:	54 years
Sex:	Male
Occupation at time of incident:	Plant technician Role was to assist in production and processing of coal and to perform electrical and maintenance work when required.
Employer:	Liddell Coal Preparation Pty Limited
Mining experience	Employed at preparation plant for 27 years

Electric shock	<p>The technician was subjected to an electric shock current at approximately 1.15 amperes with a peak value of current flowing through him of 1.6534 amperes.</p> <p>As a result of the electric shock, he felt "a bit shaky" and sat down. The technician received a severe electric shock between both hands and consequently across the chest, and burns to both hands.</p>
Hospital treatment	<p>He was transported to Muswellbrook Hospital for assessment, as per the coal operation's electric shock protocol. He was discharged a few hours later. He returned to work for his next scheduled shift.</p>

The investigation

Investigation methodology

The Department's Authority	<p>The Department has authority to investigate the incident as it occurred at coal preparation plant within the colliery holding of a coal mine.</p> <p>The Department's investigator who led the investigation into the incident, Mark Freeman, holds an appointment as an investigator under section 145 of the <i>Coal Mine Health and Safety Act 2002</i> (CMHSA). Investigator Freeman also holds an identification card issued under section 48 of the <i>Occupational Health and Safety Act 2000</i> (OHSa).</p> <p>Under section 47B of the OHSa Investigator Freeman is taken to have been appointed an Inspector for the purposes of the OHSa and its accompanying Regulation. As a result Investigator Freeman is authorised to exercise functions under the OHSa with respect to a coal workplace, and other premises, for the purpose of investigating any matter under the OHSa in relation to a coal workplace.</p>
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The lines of inquiry	The investigation took place over several months during 2007 and 2008, and relied on examination of the scene and the electrical equipment, discussions with witnesses, and examination of documents and records.
Testing of earth leakage	Testing was conducted of the earth leakage relay. No evidence of equipment failure or malfunction was found.
Review of electrical plans	A third party engineering risk consultant undertook a review of the Electrical Engineering Management Plan and UTL electrical installations to assess compliance with requirements of occupational health and safety legislation, and electrical guidelines.

Findings

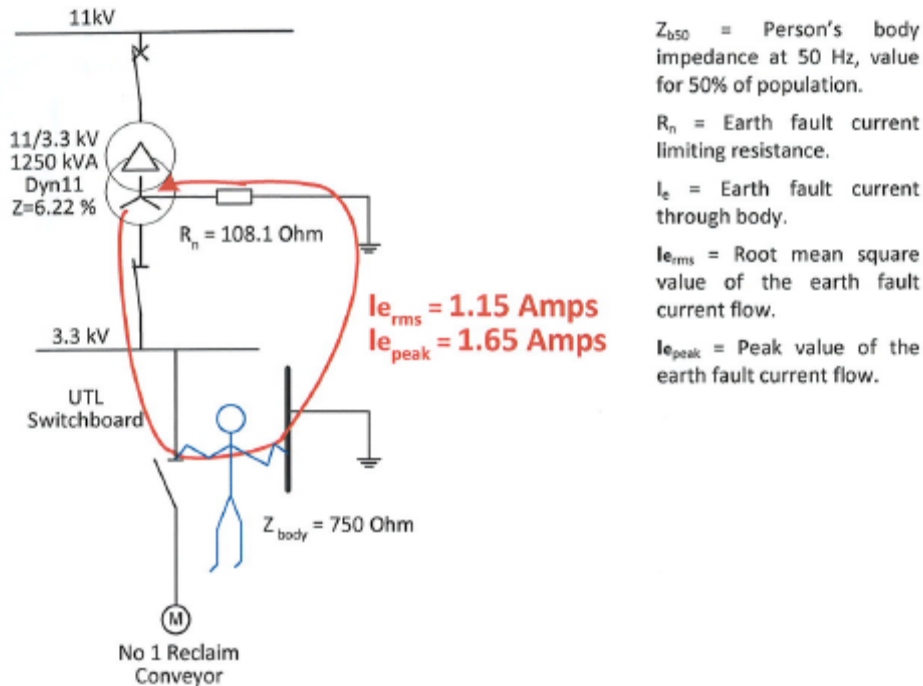
Incident causes

Main causes	<p>The primary cause of the incident is the failure to identify the potential risk of access to live electrical installations and to protect persons from contacting live electrical terminals and parts when, and after, accessing the 3.3/3 electrical cabinet. The electrical cabinets in the switch room were readily accessible to authorised and unauthorised persons.</p> <p>The investigation identified a number of fundamental causes of the incident:</p> <ul style="list-style-type: none"> ▪ The isolation system in place, being the Castell key system, did not isolate the incoming power to the 3.3kV electrical cabinet. ▪ There was no barrier or internal interposing screen in place to prevent access to live parts. ▪ High voltage rules were not being used in relation to the 3.3kV installations at the plant. ▪ The high voltage access permit system was not being used for 3.3kV work. ▪ Built in safeguards normally found in high voltage procedures were not in place to prevent harm arising from inadvertent human error. ▪ Employees performing electrical work at the preparation plant had not been provided with formal training in high voltage. ▪ High voltage testing equipment was not available in the UTL switch room.
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Specification of risk exposure

The following is an extract of the third party engineering risk consultant review Burgess J., *Report of Investigation into Specific Elements of an Electric Shock Incident* (2009)

- Risk realised** The technician made contact with energised and uninsulated 3.3kV electrical conductors in the isolator compartment UTL 3.3/3 of the 3.3kV switchboard located in the UTL switch room.
- He made contact with the energised and uninsulated 3.3kV conductors of the supply side of the isolator, identified as UTL 3.3/3, with his right hand while his left hand rested upon the earthed, metallic structure of the switchboard permitting electric current flow through his right arm, across his chest and finally through his left arm to earth.
- Effect of current** AS/NZS 60479.1:2002, *Effects of current on human beings and livestock, Part 1: General requirements*, provides data that enables an estimation of the current flowing through a person's body and the likely physiological effects of the current flow.
- The value of and effect of an electric current passing through a person's body along a hand-to-hand path will vary as a function of many factors, including:
- voltage;
 - contact area at each hand (AS/NZS 60479.1:2002 in cl.2.5.1 notes that this is not a significant factor at alternating voltages above 150V);
 - duration of current flow;
 - electrical impedance of the skin, limbs and torso;
 - any earth fault current restriction installed in the circuit; and
 - the individual physiology of the person.
- Table 1 of AS/NZS 60479.1:2002 provides the following asymptotic values for total body impedance at 50/60Hz and large hand contact:
- 5% of population 650Ω
 - 50% of population 750Ω
 - 95% of population 850Ω
- Electric circuit diagram** The electrical circuit formed during contact with the 3.3kV supply can be represented by the following diagram. The diagram notes the fault currents calculated as described below.



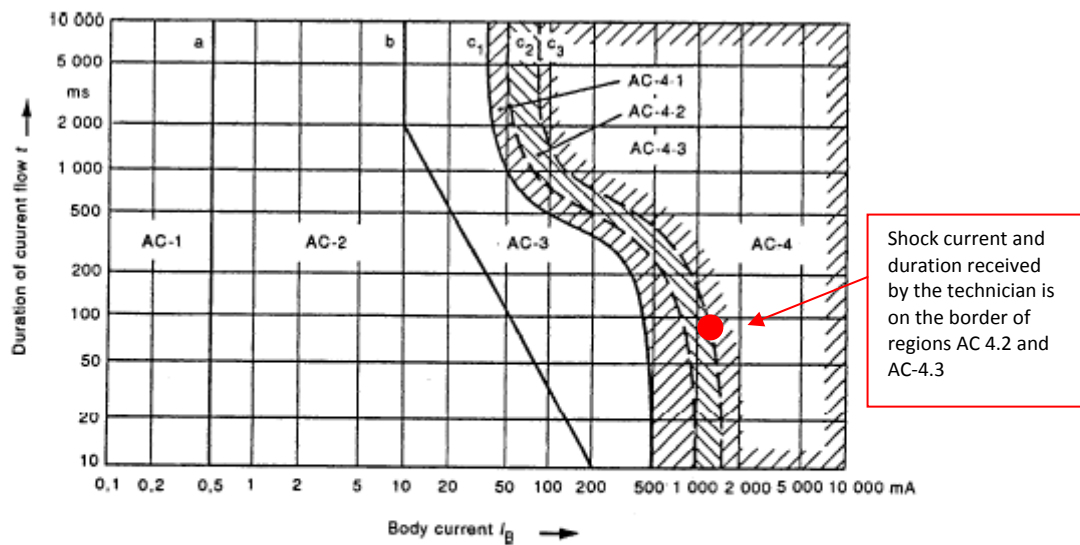
Using the data noted on the diagram above the earth fault current that flowed through the technician's body was calculated using a computer software program named Interactive Mine Power System Analysis that was sourced from the US Department of Interior, Bureau of Mines. This software program implements the Gauss Sidle Technique of load flow analysis.

Based on the data of the diagram above the computer software calculated values of the earth fault current that passed through the technician's body were:

- Root mean square value of the earth fault current flow ($I_{e_{rms}}$) = 1.1462 Amps.
- Peak value of the earth fault current flow ($I_{e_{peak}}$) = 1.6534 Amps.

Performance testing of the earth leakage relay that was fitted to the circuit and which imitated the opening of the 3.3kV supply with which the technician made contact confirmed that the relay operated in 107 milliseconds. Until such time as the earth relay initiated the opening of the high voltage supply, current was flowing through the technician's body.

Figure 14 and Table 4 of the AS/NZS 60479.1:2002 plot body current against current flow duration to indicate varying effects upon the human body. These tables are reproduced below and are marked for the current values and shock current duration, which approximates the electric shock current and shock duration received by the technician.



NOTE – As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path left hand to both feet. For other current paths, see 3.6 and table 5. The threshold values for durations of current flow below 0,2 s apply only to current flowing during the vulnerable period of the cardiac cycle.

Figure 14 – Time/current zones of effects of a.c. currents 15 Hz to 100 Hz
(For explanations, see table 4)

Table 4 - Time/current zones for a.c. 15 Hz to 100 Hz

Zone designation	Zone limits	Physiological effects
AC-1	Up to 0,5 mA line a	Usually no reaction.
AC-2	0,5 mA up to line b *	Usually no harmful physiological effects.
AC-3	Line b up to curve c ₁	Usually no organic damage to be expected. Likelihood of cramplike muscular contractions and difficulty in breathing for durations of current-flow longer than 2 s. Reversible disturbances of formation and conduction of impulses in the heart, including atrial fibrillation and transient cardiac arrest without ventricular fibrillation increasing with current magnitude and time.
AC-4	Above curve c ₁	Increasing with magnitude and time, dangerous pathophysiological effects such as cardiac arrest, breathing arrest and severe burns may occur in addition to the effects of zone AC-3.
AC-4.1	c ₁ -c ₂	Probability of ventricular fibrillation increasing up to about 5 %.
AC-4.2	c ₂ -c ₃	Probability of ventricular fibrillation up to about 50 %.
AC-4.3	Beyond curve c ₃	Probability of ventricular fibrillation above 50 %.

* For durations of current-flow below 10 ms, the limit for the body current for line b remains constant at a value of 200 mA.

Serious consequences

Application of the shock current and duration received by the technician, as detailed in Figure 14 and Table 4 of AS/NZS 60479.1:2002, indicates that he was exposed to the following severe risks:

- Cardiac arrest
- Breathing arrest
- Severe burns
- A probability of ventricular fibrillation of, or in excess of, 50%.

Strategies to prevent recurrence

Expected risk controls

Electrical engineering safety relates first and foremost to preventing electric shock and burns.

This is achieved by ensuring:

- Electrical installations are fit for purpose. That is, that they have adequate electrical protection, and meet, as a minimum, the requirements of Australian Standards AS/NZS 3000 *Electrical installations (known as the Australian/New Zealand Wiring Rules)* and AS 3007-series, Electrical installations for surface mines and associated processing plants.
- Competent people; who are trained, assessed and authorised to work on high voltage electrical installations. The high voltage competency process must include appropriate refresher or re-training for validation of authorisation.
- Information and instruction provided includes all sources of high voltage and the appropriate risk controls for work on such installations. This includes isolation procedures, electrical testing procedures and high voltage procedures.
- Regularly conducting inspections and risk assessments of electrical installations to identify potential hazards such as; energised installations, isolation failures, and inadequate barriers for protection of contact with live equipment.
- Appropriate signage providing advice on isolation points and warning of electrical hazards.
- Adequate testing equipment is readily available at each high voltage installation.
- Enforce 'test before you touch' for all electrical work.

Actions post-incident

Response by mine

The following remedial measures were undertaken following the incident:

- additional signs and locks fitted to 3.3 kV switchboard after incident;
- all preparation plant technician/electricians received high voltage training;
- internal screen placed to prevent access to potential live electrical parts in 3.3/3 cabinet;
- investigation into and then fitting of further Castell locking system to 3.3kV switchboard;
- review of electrical authorisations and permit to work system;
- external safety consultant review of electrical procedures; and
- review of electrical engineering management plan to ensure compliance with requirements of *Coal Mine Health and Safety Act 2002* and *Coal Mine Health and Safety Regulation 2006*.

Safety alert released

As a result of the incident a safety alert, SA08-02 *Electric shock direct contact with high-voltage electricity*, was released to industry and published on the Department's mine safety internet on 4 January 2008.

Related publications

Guidelines and standards

Department information	<p>Information and advice published by the Department on electrical engineering safety:</p> <ul style="list-style-type: none">▪ EES-001 Electrical Engineering Management Plan▪ EES-002 Control and Supervision of Electrical Work▪ EES-006 Removal and Restoration of Power▪ MDG 40 Guidelines for Hazardous Energy Control (Isolation or Treatment)▪ MDG2004 Guidelines for the Safe Use of Electricity in NSW Mines – Supplement to Guidelines for Safe Mining; <p>http://www.dpi.nsw.gov.au/minerals/safety/resources/electrical-engineering</p>
Australian standards	<ul style="list-style-type: none">▪ AS/NZS 3000:2007 <i>Electrical installations (known as the Australian/New Zealand Wiring Rules)</i>; and▪ AS 3007-2004 Series: <i>Electrical installations - Surface mines and associated processing plant.</i>

Further reading

Investigation reports	<p>Department's investigation reports of electrical incidents: Electrical isolation, Dartbrook Colliery</p> <p>http://www.dpi.nsw.gov.au/minerals/safety/major-investigations/investigation-reports</p>
Safety alerts	<p>SA 08-02 Electric shock direct contact with high-voltage electricity</p> <p>SA 05-11 Electric shock from 11kV bus tie</p> <p>SA 05-06 Serious electric shock incident</p> <p>http://www.dpi.nsw.gov.au/minerals/safety/safety-alerts</p>