

# Electrical safety code of practice 2010

# Works

The Queensland *Electrical safety code of practice 2010 – Works* was made on 18 December 2009 and commenced on 1 January 2010.

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## LEGISLATIVE FRAMEWORK

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The *Electrical Safety Act 2002* (the ES Act) is directed at eliminating the human cost to individuals, families and the community of death, injury and destruction that can be caused by electricity. The ES Act establishes a legislative framework for preventing persons from being killed or injured by electricity, and preventing property from being destroyed or damaged by electricity. The ES Act places the primary electrical safety duty on a person conducting a business or undertaking, who must ensure the business or undertaking is conducted in a way that is electrically safe. Duties are also placed on officers of a person conducting a business or undertaking, workers and other persons at a workplace, as well as electricity entities, designers, manufacturers, importers, suppliers, installers, repairers and persons in control of electrical equipment.

The *Work Health and Safety Act 2011* (WHS Act) requires persons who have a duty to ensure health and safety to 'manage risks' by eliminating health and safety risks so far as is reasonably practicable, and if it is not reasonably practicable to do so, to minimise those risks so far as is reasonably practicable. The WHS Act provides a framework to protect the health, safety and welfare of all workers at work. It also protects the health and safety of all other people who might be affected by the work. The WHS Act places the primary health and safety duty on a person conducting a business or undertaking, who must ensure, so far as is reasonably practicable, the health and safety of workers at the workplace. Duties are also placed on officers of a person conducting a business or undertaking, workers and other persons at a workplace.

In terms of electrical safety, where the ES Act and the WHS Act both apply, the ES Act takes precedence.

## FOREWORD

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This Code of Practice on how to manage risks associated with electricity entity works is made under section 44 of the ES Act.

A code of practice is a practical guide to achieving the standards of electrical safety required under the ES Act and the Electrical Safety Regulation 2013 (the ES Regulation).

A code of practice applies to anyone who has an electrical safety duty in the circumstances described in the code. In most cases, following a code of practice would achieve compliance with the electrical safety duties in the ES Act, in relation to the subject matter of the code. Like regulations, codes of practice deal with particular issues and do not cover all hazards or risks that may arise. Health and safety and electrical safety duties require duty holders to consider all risks associated with work, not only those for which regulations and codes of practice exist.

Codes of practice are admissible in court proceedings under the ES Act and ES Regulation. Courts may regard a code of practice as evidence of what is known about a hazard, risk or control and may rely on the code in determining what is reasonably practicable in the circumstances to which the code relates.

Compliance with the ES Act and ES Regulation may be achieved by following another method, such as a technical or an industry standard, if it provides an equivalent or higher standard of electrical safety than the code.

An inspector may refer to a code of practice when issuing an improvement or electrical safety protection notice.

## SCOPE AND APPLICATION

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This Code gives practical advice on ways for an electricity entity to manage electrical safety risks associated with earthing systems, underground cable systems, and supporting structures for overhead lines forming parts of the works of an electricity entity.

### Meaning of works of an electricity entity

Under section 25 of the ES Act, **works**, of an electricity entity means the electrical equipment, and electric line associated equipment, controlled or operated by the entity to generate, transform, transmit or supply electricity. An example of the works of an electricity entity is an overhead distribution system of a distribution entity, including transformers and switches. Examples of what is not works of an electricity entity are appliances or fixed wiring in an electricity entity's workshop or offices.

### Meaning of electricity entity

An electricity entity is defined in Schedule 2 of the ES Act as:

- a generation entity, transmission entity or distribution entity; or
- a special approval holder that is authorised under the *Electricity Act 1994* to do something that a generation entity, transmission entity or distribution entity may do under that Act; or
- a railway manager, or light rail manager for a light rail, that is exempted by the *Electricity Act 1994*, section 20Q or 20QA, from the requirements of section 88A of that Act; or
- the Authority under the *Queensland Rail Transit Authority Act 2013*; or
- Airtrain Citylink Limited ACN 066 543 315.

### How to use this Code of Practice

This Code should be read in conjunction with the ES Act, the ES Regulation, the WHS Act, the Work Health and Safety Regulation 2011 (the WHS Regulation) and other relevant codes of practice.

In providing guidance, the word 'should' is used in this Code to indicate a recommended course of action, while 'may' is used to indicate an optional course of action. The terms 'health and safety' and 'work health and safety' are used in this Code to indicate a wider application than just 'electrical safety'. However, 'electrical safety' should be taken as being included when the terms 'health and safety' and 'work health and safety' are used.

This Code also includes various references to provisions of the ES Act, the ES Regulation, the WHS Act and the WHS Regulation which set out the legal requirements. These references are not exhaustive. The words 'must', 'requires' or 'mandatory' indicate that a legal requirement exists and must be complied with.

This Code also includes various references to standards (using the designated 'AS') and joint standards (using the designated 'AS/NZS'). In this Code, unless otherwise stated, a reference to a standard (or joint standard) is a reference to that standard (or joint standard) as in force from time to time under that designation. For example, 'AS/NZS 3100' is a reference to the joint standard that is currently in force under that designation.

Key terms used in this Code are defined at Appendix A.

# 1 INTRODUCTION

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## 1.1 What are electrical risks?

Electrical risks are risks of death, electric shock or other injury caused directly or indirectly by electricity. The most common electrical risks and causes of injury associated with electricity entity works are:

- electric shock causing injury or death. The electric shock may be received by direct or indirect contact, tracking through or across a medium, or by arcing. For example, electric shock may result from indirect contact where a conductive part that is not normally energised becomes energised due to a fault.
- arcing, explosion or fire causing burns. The injuries are often suffered because arcing or explosion or both occur when high fault currents are present
- electric shock from 'step-and-touch' potentials
- toxic gases causing illness or death. Burning and arcing associated with electrical equipment may release various gases and contaminants
- fire resulting from an electrical fault.

## 1.2 Who must manage electrical risks?

A **person conducting a business or undertaking** has the primary duty under the ES Act to ensure the person's business or undertaking is conducted in a way that is electrically safe. This duty includes:

- ensuring that all electrical equipment used in the conduct of the person's business or undertaking is electrically safe; and
- if the person's business or undertaking includes the performance of electrical work, ensuring the electrical safety of all persons and property likely to be affected by the electrical work; and
- if the person's business or undertaking includes the performance of work, whether or not electrical work, involving contact with, or being near to, exposed parts, ensuring persons performing the work are electrically safe.

The ES Regulation includes more specific requirements for managing electrical risks associated with electricity entity works.

**Electricity entities** have a duty to ensure its works are electrically safe and are operated in a way that is electrically safe. This includes the requirement that electricity entities inspect, test and maintain its works.

**Officers**, such as company directors, have a duty to exercise due diligence to ensure the business or undertaking complies with the ES Act and ES Regulation. This includes taking reasonable steps to ensure the business or undertaking has and uses appropriate resources and processes to eliminate or minimise risks associated with working near overhead and underground electric lines.

**Workers** have a duty to take reasonable care for their own electrical safety and to not adversely affect other people's electrical safety. Workers must co-operate with reasonable policies or procedures relating to electrical safety at the workplace and comply, so far as they are reasonably able, with reasonable instructions.

**Other persons at the workplace**, like visitors, must take reasonable care for their own electrical safety and must take reasonable care not to adversely affect other people's electrical safety. They must comply, so far as they are reasonably able, with reasonable instructions given by the person conducting the business or undertaking to allow that person to comply with the ES Act.

**Duty holders** will have additional legal duties under the WHS Act and the WHS Regulation.

### 1.3 What is required to manage the electrical risks?

**ES Regulation s11** A person conducting a business or undertaking must manage risks to health and safety associated with electrical risks at the workplace in accordance with the WHS Regulation, chapter 3, part 3.1.

**WHS Regulation s34-38** In order to manage risk, a duty holder must:

- identify reasonably foreseeable hazards that could give rise to the risk
- eliminate the risk, so far as is reasonably practicable
- if it is not reasonably practicable to eliminate the risk, minimise the risk so far as is reasonably practicable by implementing control measures
- maintain the implemented control measure so that it remains effective
- review, and if necessary revise, all risk control measures so as to maintain, so far as is reasonably practicable, a work environment that is without risks to health and safety.

The hierarchy of risk control is described at Chapter 2 of this Code.

Part 9 of the ES Regulation includes a range of specific technical requirements to ensure the electrical safety of the works of an electricity entity.

**ES Regulation s195** A person, including an electricity entity, who designs, builds, maintains or operates works of an electricity entity must ensure that the requirements of Part 9 of the ES Regulation for the works of an electricity entity are complied with.

Under section 198 of the ES Regulation, the following requirements apply for the works of an electricity entity:

- (a) the works must be able to perform under the service conditions and the physical environment in which the works operate;
- (b) the works must have enough thermal capacity to pass the electrical load for which they are designed, without reduction of electrical or mechanical properties to a level below that at which safe operational performance can be provided;
- (c) to the greatest practicable extent, the works must have enough capacity to pass short circuit currents to allow protective devices to operate correctly;
- (d) the works must have enough mechanical strength to withstand anticipated mechanical stresses caused by environmental, construction or electrical service conditions;
- (e) the works must be;
  - i) designed and constructed to restrict unauthorised access by a person to live exposed parts; and
  - ii) operated in a way that restricts unauthorised access by a person to live exposed parts;
- (f) design, construction, operation and maintenance records necessary for the electrical safety of the works must be kept in an accessible form;
- (g) parts of the works whose identity or purpose is not obvious must be clearly identified by labels, and the labels must be updated as soon as possible after any change is made to the works; and
- (h) electrical equipment intended to form part of the works of an electricity entity must undergo commissioning tests and inspection to verify that the electrical equipment is suitable for service and can be operated safely when initially installed or altered.

This Code provides guidance to ensure the electricity entity's works are designed and maintained in accordance with applicable standards. This Code does not provide guidance for managing the risk associated with the carrying out of work on or associated with the works of the electricity entity.

Guidance on the general risk management process is available in the *How to manage work health and safety risks code of practice 2011*.

Guidance on the risk management processes for electrical work is available in the *Managing electrical risks in the workplace code of practice 2013*.

## 1.4 Information, training, instruction and supervision

**WHS Act s19** A person conducting a business or undertaking must ensure, so far as is reasonably practicable, the provision of any information, training, instruction or supervision that is necessary to protect all persons from risks to their health and safety arising from work carried out.

**WHS Regulation s39** You must ensure that information, training and instruction provided to a worker is suitable and adequate having regard to:

- the nature of the work carried out by the worker
- the nature of the risks associated with the work at the time the information, training or instruction is provided
- the control measures implemented.

You must ensure, so far as is reasonably practicable, that the information, training and instruction is provided in a way that is readily understandable by any person to whom it is provided.

Formal or on-the-job training may be appropriate depending on the circumstances. Examples of training are:

- induction training—to ensure new starters or workers new to a job are trained on safe systems of work and other relevant health and safety matters
- supervisor and management training—to ensure that safety issues are appropriately managed at the workplace
- work-specific training—to ensure that workers carrying out particular work are trained on any electrical and other risks specific to the work, as appropriate
- ongoing or refresher training—to ensure that any training on work health and safety matters is repeated as appropriate on a periodic basis
- emergency procedure training—to ensure workers know what to do in the event of an emergency, for example procedures to follow if a person receives an electric shock
- first aid training—to ensure appropriate procedures are followed for administering first aid, for example proper treatment for electric shock
- electrical rescue and resuscitation training for safety observers.

Special needs of workers should be taken into account in deciding the structure, content and delivery of training, including literacy levels, work experience and specific skills required to carry out the work.

## 2 THE RISK MANAGEMENT PROCESS

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### 2.1 *Identify the hazards*

Identifying hazards involves finding all of the tasks, situations and sequences of events that could potentially cause harm.

Hazards arising from electrical equipment or installations may arise from:

- the design, construction, installation, maintenance and testing of electrical equipment or electrical installations
- design change or modification
- inadequate or inactive electrical protection
- where and how electrical equipment is used. Electrical equipment may be subject to operating conditions that are likely to result in damage to the equipment or a reduction in its expected life span.
- electrical equipment being used in an area in which the atmosphere presents a risk to health and safety from fire or explosion, for example confined spaces
- the age of electrical equipment and electrical installations

Exposure to high electromagnetic fields may also present a potential hazard for workers with some medical conditions, for example pace makers. You must inform workers and other persons at the workplace of any potential electromagnetic hazards at the workplace that may affect a medical condition. You must also manage risks to health and safety arising out of electromagnetic hazards, including eliminating the risk so far as is reasonably practicable. If that is not reasonably practicable you must minimise the risk so far as is reasonably practicable.

Potential electrical hazards may be identified in a number of different ways including:

- talking to workers and observing where and how electrical equipment is used
- regularly inspecting and testing electrical equipment and electrical installations as appropriate
- talking to manufacturers, suppliers, industry associations, and health and safety specialists
- reviewing incident reports.

### 2.2 *Assess the risks*

Risk assessment involves considering what could happen if someone is exposed to a hazard (consequence) and the likelihood of it happening.

A risk assessment can help determine:

- the severity of an electrical risk
- whether existing control measures are effective
- what action you should take to control an electrical risk
- how urgently the action needs to be taken.

To assess the risk associated with electrical hazards consider:

- What is the potential impact of the hazard?
  - How severe could the electrical hazard be? For example, direct contact causing electrocution, fire or explosion causing serious burns or death.
  - How many people are exposed to the hazard?
- How likely is the hazard to cause harm?
- Could it happen at any time or would it be a rare event?
- How frequently are workers exposed to the hazard?

Other factors that may affect consequence and likelihood include:

- the conditions under which the electrical equipment is used, for example wet conditions outdoors or confined spaces
- work practices and procedures, for example isolation, to carry out maintenance
- the capability, skill and experience of relevant workers.

## **2.3 Control the risks**

Once hazards have been identified and the risks assessed, appropriate control measures must be put in place.

The ways of controlling risks are ranked from the highest level of protection and reliability to the lowest. This ranking is known as the *hierarchy of risk control*. You must work through this hierarchy to choose the control that most effectively eliminates or minimises the risk in the circumstances, so far as is reasonably practicable. This may involve a single control measure or a combination of two or more different controls.

### ***Elimination***

The most effective control measure is to remove the hazard or hazardous work practice. By designing-in or designing-out certain features, hazards may be eliminated.

### ***Substitution***

Replacing a hazardous process or material with one that is less hazardous will reduce the hazard, and hence the risk. For example, it may be reasonably practicable to use extra-low voltage electrical equipment such as a battery-operated tool rather than a tool that is plugged into mains electricity.

### ***Isolation***

Preventing workers from coming into contact with the source of an electrical hazard will reduce the relevant risks.

### ***Engineering controls***

Use engineering control measures to minimise the risk, for example installing residual current devices to reduce the risk of receiving a fatal electric shock.

### ***Administrative controls***

Administrative controls involve the use of safe work practices to control the risk, for example establishing exclusion zones, use of permits and warning signs.

### ***Personal protective equipment (PPE)***

PPE includes protective eyewear, insulated gloves, hard hats, aprons and breathing protection. Most forms of PPE are not relevant to minimising electrical risks in workplaces, except in relation to energised electrical work.

Administrative controls and PPE do nothing to change the hazard itself. They rely on people behaving as expected and require a high level of supervision. Exclusive reliance on administrative controls and PPE must only occur where other measures are not reasonably practicable or as an interim control while the preferred control measure is being implemented.

You should check that your chosen control measure does not introduce new hazards.

## **2.4 Review the control measures**

The controls that are put in place to protect health and safety must be reviewed regularly to make sure they work effectively.

A person conducting a business or undertaking must review and as necessary revise a control measure in the following circumstances:

- when the control measure does not control the risk it was implemented to control so far as is reasonably practicable
- before a change at the workplace that is likely to give rise to a new or different risk to health or safety that the measure may not effectively control
- if a new relevant hazard or risk is identified
- if the results of consultation indicate that a review is necessary
- if a health and safety representative requests a review.

The following questions will help you evaluate how well you are currently managing electrical risks in your workplace:

Do you talk to your workers about electrical safety? Do any relevant new work methods or equipment have the potential to make work safer in your workplace?

Are procedures for identifying electrical hazards in the workplace effective?

Are electrical safety procedures followed? Do you encourage your workers to report electrical hazards?

Do you regularly inspect and maintain your electrical equipment to identify safety problems?

Do you fix or rectify identified electrical hazards in a timely manner?

## 3 PROTECTIVE EARTHING

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### 3.1 Scope

This chapter sets down the principles for the protective earthing of electrical equipment that forms part of the works of an electricity entity. The principles reflect established design principles used in the electricity supply industry.

Fundamental performance criteria are provided for ensuring permanent protective earthing systems are operated correctly. This is to ensure the correct operation of electrical protection systems so that exposed conductive parts of electrical equipment do not become energised to a potentially dangerous level.

### 3.2 Requirements under the Electrical Safety Regulation 2013

Under section 196 of the ES Regulation:

- (1) The works of an electricity entity must incorporate an earthing and protection system, to a recognised electricity supply industry standard capable of ensuring the following:
  - (a) reliable passage of fault current;
  - (b) reliable passage of single wire earth return load currents to ground or source;
  - (c) reliable operation of circuit protection devices;
  - (d) safe step, touch and transfer potentials for all electrical equipment;
  - (e) appropriate coordination with the earthing and protection systems of other electricity entities;
  - (f) protection against likely mechanical damage, inadvertent interference and chemical deterioration; and
  - (g) mechanical stability and integrity of connections.
- (2) Without limiting subsection (1), the following specific requirements apply for the works of an electricity entity:
  - (a) to stop, as far as practicable, a person suffering electric shock:
    - (i) if the Multiple Earthed Neutral system of earthing is used, the neutral conductor of the system must be effectively earthed; and
    - (ii) each non current carrying exposed conductive part of an electric line or generating plant must be effectively earthed;
  - (b) each non current carrying exposed conductive part of a substation must be effectively earthed;
  - (c) a system of earthing must be tested as soon as practicable after its installation to prove its effectiveness; and
  - (d) a high voltage electric line must be protected by a suitable fuse, circuit-breaker or equivalent device.
- (3) Earthing is not required under subsection (2)(a)(ii) or (b) in circumstances where the electricity entity, in accordance with a recognized practice in the electricity industry, considers that for safety reasons earthing is not appropriate.

#### **Connection of high voltage circuit to earth**

Under section 197 of the ES Regulation:

- (1) Each distinct high voltage system included in the works of an electricity entity must be connected to earth by direct connection or through a resistance or a reactance.
- (2) All reasonable precautions must be taken to ensure that, for the circumstances in which the system is to operate, fuses or circuit-breakers in the system will operate during fault conditions.

#### **Insulation of stay wire**

Under section 199 of the ES Regulation:

- If a stay wire attached to a pole or structure supporting an overhead electric line forming part of the works of an electricity entity does not form part of an earthing system, the wire must be insulated to prevent, as far as practicable, any person suffering an electric shock.

### ***Protection of earth conductors***

Under section 200 of the ES Regulation:

- To prevent, as far as practicable, any person suffering an electric shock, earthing conductors installed on the outside of a pole or structure supporting an overhead electric line forming part of the works of an electricity entity must be, from ground level to a height of at least 2.4m:
  - (a) insulated or suitably covered by a nonconductive material; and
  - (b) protected from mechanical damage.

## **3.3 Earthing system requirements**

### **3.3.1 The Multiple Earthed Neutral (MEN) system**

Where an MEN earthing system is used, the following conditions should be met:

- The neutral conductor should be earthed at or near each LV distribution centre; and
- where necessary, the neutral should be earthed at other points along the distribution system; and
- the earthing should be arranged so as to ensure that resistance of neutral to earth at any location does not exceed 10 ohms.

In the MEN system the high voltage and low voltage earthing systems should be kept separate if resistance to ground of 1 ohm cannot be achieved (Separate Earthing System).

The high voltage earthing system provides an earth return path for the high voltage system. The earthing system protects plant and equipment capable of being energised by the high voltage system e.g. surge arrester or transformer tank. This earth should always be insulated from the low voltage earth.

Where the LV distribution centre is in a remote location, permanently electrically isolated from other distribution centres and is rated at not more than 63 kVA, the limit of 10 ohms may be increased provided that:

- where there are bare high voltage conductors above the low voltage conductors of an overhead electric line, the low voltage conductors must be insulated with 0.6/1 kV grade insulation; and
- the high voltage protection will clear any high voltage to low voltage fault in less than 0.2 seconds.

### **3.3.2 Earthing of LV distribution centres**

If an MEN system is used, the low voltage earthing system should be separate and distinct from the high voltage earthing system for the distribution centre. The earthing systems should be designed and installed to prevent any significant portion of the high voltage system voltage gradient being superimposed on the low voltage earthing system and as a result, transferred to the customer's electrical installation through the MEN system.

When the two earthing systems are located where a person may make contact between the earthed exposed conductive parts or conductors connected to the earthing systems, adequate separation or insulation should be provided between the exposed conductive parts or conductors or both.

The following should be connected to the high voltage earthing system:

- Transformer tank or tanks.
- HV surge protection devices.
- HV cable sheaths/screens/guards.
- Exposed conductive parts of all other high voltage (HV) equipment. The design and impedance to remote earth of the high voltage earthing system should be arranged so that:
  - the HV protection system will operate in the event of a high voltage to exposed conductive parts fault; and

- the prospective touch voltage on uninsulated conductive parts up to 2.4 metres above ground level and prospective step voltages meet requirements set down in the prospective touch and step voltages section.

The low voltage earthing system should be bonded to:

- the neutral terminal of the distribution transformer; and
- any earth leads of low voltage surge protection devices at the distribution centre.

The impedance to remote earth of the low voltage earthing system should not exceed the value for the high voltage earthing system except in the case of some SWER applications which may require a HV earth resistance value below 10 ohms.

### **3.3.3 Exposed conductive parts within 2.4m above ground associated with high voltage in an MEN system**

Exposed conductive parts that may become energised from the electricity supply system if there is an insulation failure or contact with a conductor, should be:

- insulated; or
- earthed to a separate and distinct earthing system from the high voltage earthing system; the impedance to remote earth should allow the HV protection system to operate in the event of a high voltage to exposed conductive part fault; and
- be designed so that the prospective touch and step voltages meet the requirements set down in the prospective touch and step voltages section.

### **3.3.4 The Common Multiple Earthed Neutral (CMEN) system**

If an electricity entity uses a CMEN system, the low voltage neutral conductor, and the low voltage earthing system, should be connected to the high voltage earthing system. This requirement includes the earthing system of transformer stations, zone substations and at poles carrying exposed conductive parts associated with high voltages.

The CMEN system should only to be used for distribution voltages up to and including 33 kV and where the design limits prospective touch voltages – including within any part of the associated LV installations – to within curve A1 of Figure 2.

The resistance to ground of the LV neutral at any location should be no greater than 1.0 ohm.

### **3.3.5 Earthing at a distribution centre (CMEN)**

If a CMEN system of earthing is used at a distribution centre the following should be connected to it:

- the transformer tank and any high voltage surge protection devices;
- the low voltage neutrals and earth leads of low voltage surge protection devices;
- any exposed conductive parts that may reasonably be expected to become energised from the electricity supply system if there is an insulation failure or contact with a conductor; and
- a separate earthing system with a resistance to earth that will ensure the HV protection system operates in the event of a high voltage to exposed conductive parts fault and where the low voltage neutral may be disconnected.

### **3.3.6 Exposed conductive parts within 2.4m above ground associated with high voltage in a CMEN system**

Exposed conductive parts that may reasonably be expected to become energised from the electricity supply system if there is an insulation failure or contact with a conductor, should be:

- insulated; or
- bonded to the CMEN system low voltage neutral.

### 3.3.7 The Single Wire Earth Return (SWER) system

If an electricity entity uses the single wire earth return earthing system, a separate high voltage earthing system and low voltage earthing system should be used. Thus, for each installation, there will be only a low voltage earth electrode system at the transformer and an earth electrode at the customer's premises earthing the low voltage neutral.

The high voltage and low voltage earthing systems should be separated to avoid any significant portion of the SWER earthing system voltage gradient being superimposed on the low voltage earthing system and as a result, transferred to the customer's electrical installation through the MEN system.

Where the two earthing systems are located so that personal contact may be made between the earthed exposed conductive parts or conductors connected to the earthing systems, adequate separation or insulation should be provided between the exposed conductive parts or conductors or both. This does not apply to spark gap devices fitted to protect the transformer against lightning damage.

The earthing of SWER distribution centres should be designed for continuous passage of electric current, in addition to protective earthing.

For a SWER distribution centre, two separate and distinct earthing systems should be provided:

- a SWER earthing system; and
- a low voltage earthing system.

The following exposed conductive parts should be connected to the SWER Earthing System:

- transformer tank or tanks;
- HV earth bushing;
- HV surge protection devices; and
- exposed metalwork of all other HV equipment.

The SWER earthing system should be designed so that:

- at least two earthing conductors are installed with maximum separation. The conductors should:
  - be connected to an inter connected earthing system that consists of at least three earthing electrodes not less than three metres apart; and
  - arranged so that in the event of one or two earthing conductors between two electrodes being severed, at least one earth path will remain.
- any joint in the SWER earthing conductors between the transformer terminals and the earth electrodes should not be disconnectable;
- at a SWER LV distribution centre, earthing conductors within 2.4m of the ground should be insulated with 0.6/1.1 kV grade insulation and must be mechanically protected; and
- the maximum voltage on the earth lead with respect to remote earth under operating conditions resulting in maximum continuous earth current, should not exceed 20 Volts.

The low voltage earthing system should be bonded to:

- the low voltage neutral terminal of the transformer; and
- any earth leads of low voltage surge protection devices at the distribution centre.

The design and impedance to remote earth of the low voltage earthing system should be arranged so that the MEN system complies as documented in the MEN section.

### 3.3.8 Exposed conductive parts within 2.4m above ground associated with high voltage in a SWER system

Exposed conductive parts that may reasonably be expected to become energised from the electricity supply system if there is an insulation failure or contact with a conductor, should be insulated.

### **3.3.9 Earthing of high voltage distribution centres**

Earthing of exposed conductive parts of HV distribution centres including external metal fences should comply with the *ENA EG1-2006: Substation Earthing Guide* and the *Institute of Electrical and Electronics Engineers Guide for Safety in AC Substation Grounding – IME Std. No. 80. Earthing of Works other than distribution centres*.

### **3.3.10 Exposed conductive parts within 2.4m above ground associated with high voltage transmission systems**

Exposed conductive parts that may reasonably be expected to become energised from the electricity transmission system in the event of failure of insulation or contact with a conductor, should be designed so that the prospective touch and step voltages do not exceed the allowable prospective touch and step voltages.

### **3.3.11 Exposed conductive parts within 2.4m above ground associated with low voltage only**

Exposed conductive parts that may reasonably be expected to become energised from the electricity supply system in the event of failure of insulation or contact with a conductor, should be either insulated or bonded to the low voltage neutral of the system.

### **3.3.12 Induced voltage on the sheath of underground electric lines**

Cable sheaths or screens should be earthed to ensure that the prospective touch voltages that may appear on any accessible exposed conductive parts of the underground electric line for both load and fault current conditions, meet the requirements set down in the prospective touch and step voltages section.

### **3.3.13 Exposed conductive parts higher than 2.4m above ground**

Non-current carrying exposed conductive parts located 2.4m or higher above ground and not exposed to personal contact need not be earthed. If these parts are associated with high voltage or low voltage works or both and are required by the electricity entity to be earthed, these parts should be earthed in accordance with sections on high voltage in an MEN system, CMEN system or low voltage only systems.

## **3.4 Earthing Conductors**

### **3.4.1 Minimum size of earthing conductors**

Earthing conductors should have sufficient cross-sectional area and mechanical strength to be capable of carrying, without sustaining damage or deterioration, any currents that may reasonably be expected.

### **3.4.2 Materials for earthing conductors**

The material for earthing conductors should be suitable for site conditions.

### **3.4.3 Mechanical protection of earthing conductors**

In locations controlled by an electricity entity and where a suitable enclosure prevents unauthorised access, the following apply:

- the entity should effectively protect an earthing conductor against mechanical damage to a height of 2.4m above ground level; and
- where the earthing conductor is installed below ground level, it should be buried to a minimum depth of 0.5m. Where necessary, this can be done by installing the earthing conductor in a channel chased in the rock and covered with concrete at least 50mm thick.

### 3.4.4 Materials for earthing electrodes

Earthing electrodes should be made from metals that will not be materially affected by any corrosive or other adverse influences.

### 3.4.5 Test links

If test links are inserted in earthing conductors connected to earthing electrodes, the test links should be arranged so that the opening of any one link does not interfere with earth connections, other than the one under test. Links should not be installed in a SWER earthing system.

### 3.4.6 Earth fault currents

Earthing electrodes should be capable of carrying, without sustaining damage, any earth fault currents that may reasonably be expected.

## 3.5 Prospective touch and step voltages

### 3.5.1 Prospective touch voltages – special locations

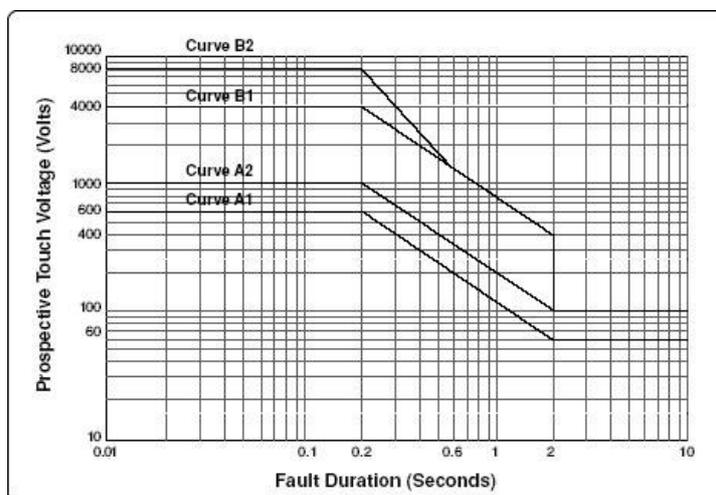
Lines operating at voltages less than or equal to 66kV should comply with the requirements of curve A1 of Figure 2. Lines operating at voltages greater than 66 kV should comply with the requirements of curve A2 of Figure 2.

### 3.5.2 Prospective touch voltages – frequented locations

Lines operating at voltages less than or equal to 66kV should comply with the requirements of curve B1 of Figure 2.

Lines operating at voltages greater than 66 kV should comply with the requirements of curve B2 of Figure 2.

Figure 2: Touch Voltage versus Duration



Fault

### **3.5.3 Remote locations**

Aside from ensuring positive primary protection operation, it is not necessary to make specific provisions for limiting prospective touch and step voltages on exposed conductive parts. However, in the case of pole-mounted equipment that may be operated from the ground in remote locations, you should consider limiting step and touch voltages to the levels recommended for frequented locations.

To protect workers working near exposed conductive parts in remote locations, special operating procedures such as temporary earth rods or portable equipotential mats and gloves may be used.

### **3.5.4 Prospective step voltages**

Prospective step voltages should not exceed twice the value of the prospective touch voltage determined for the corresponding location as outlined in the sections, Prospective touch voltages – special locations and Prospective touch voltages – frequented locations.

### **3.5.5 Testing and maintenance of earthing systems**

All earthing systems should be tested periodically to ensure the earthing system integrity. Adequate records of all earthing system tests should be maintained.

## **3.6 References**

*Institute of Electrical and Electronics Engineers Guide for Safety in AC Substation Grounding – IEEE Std. No. 80.*

*Institute of Electrical and Electronics Engineers Recommended Guide for Measuring Ground Resistance and Potential Gradients in the Earth - IEEE Std. No. 81.*

*ENA EG1 – 2006 Substation Earthing Guide*

## **4 DESIGN AND INSTALLATION OF UNDERGROUND ELECTRIC CABLE SYSTEMS**

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### **4.1 Scope and application**

This chapter sets down the principles for the mechanical and electrical design of underground electric lines, other than those operating at voltages normally not exceeding 50 volts alternating current or 120 volts ripple-free direct current.

The requirements have been based on recognised industry standards. They represent the minimum standards necessary to meet an electricity entity's obligations.

Unless otherwise expressly stated, this chapter does not apply to:

- any underground earthing conductor not specifically associated with an underground electric line or with an underground control cable;
- underground electric lines or underground control cables fully or partly constructed in places owned only by an electricity entity and where a substation enclosure prevents unauthorised access;
- submarine cables; or
- fibre optic cables.

### **4.2 Compliance with Standards**

Underground electric cable systems should be designed in accordance with an appropriate Australian Standard or ENA Guideline. Where there is no appropriate Australian Standard, an appropriate IEC Standard should be used.

### **4.3 Selection of cables**

#### **4.3.1 General**

Cables used in underground cable systems should comply with an appropriate Australian Standard.

In addition, consideration should be given to the following:

- safety;
- environmental conditions;
- life cycle assessment;
- insect or vermin attack;
- vibration;
- ultraviolet degradation;
- economic, security and reliability factors;
- forces incurred during installation;
- forces incurred during the service life of the cable; and
- corrosion protection of armouring and sheathing.

### **4.3.2 Conductors**

When selecting the cross-sectional area of the conductors of an underground electric cable, keep in mind the:

- prospective load;
- voltage drop;
- fault currents;
- fault clearing times;
- proximity of other heat sources, e.g. cables; and
- thermal properties of the surrounding environment.

### **4.3.3 High voltage cables**

High voltage underground cables should have integral metallic conducting screens or sheathing or both.

### **4.3.4 Low voltage cables**

All conductors including the neutral should be insulated to the full voltage rating of the cable. Bare neutral conductors should not be used.

### **4.3.5 Neutral connections**

The connections between neutral conductors should be designed and installed to ensure the connections maintain the required conductivity during the service life of conductors.

### **4.3.6 Route selection**

Basic factors to be considered during the selection of an optimum cable route are set out in *ENA C(b)2*.

In addition, consideration should be given to:

- EMF mitigation; and
- Environmental impact issues.

## **4.4 Installation**

### **4.4.1 General**

Underground electric cables and underground control cables should be installed having regard to system reliability, ease of future maintenance and safety. Consideration should also be given to minimising damage to underground assets.

Basic factors to be considered during the installation of underground cables are set out in *ENA C(b)2*.

### **4.4.2 Cable depths**

The depth of cover for underground electric cables and underground control cables should not be less than:

For open trench construction:

- 750mm below the surface of a roadway for any cable installed under a roadway; and
- 600mm below the finished ground surface for cables installed in other locations.

Where physical obstructions such as other services make it impossible to achieve these depths, additional mechanical protection should be provided by means of a minimum cover of 100mm of 20 MPa concrete or equivalent. Any additional mechanical protection should be marked with the words *electric cable* or similar along its length.

For trenchless construction:

- 900mm below the finished ground surface.

This clause does not apply to that part of an underground cable or an underground control cable entering or leaving the ground vertically or fixed above the ground to a secure structure, so long as adequate mechanical protection is provided.

### **4.4.3 Laying of cables**

The technique used for installing underground cables should ensure that damage to the cables is negligible. Consideration should be given to:

- maximum hauling tensions;
- minimum bending and setting radii;
- cable side wall pressures; and
- cable abrasion avoidance.

### **4.4.4 Separation of cables**

When determining minimum separation from telecommunication plant in a shared trench, refer to *HB 100-2000 (CJC 4): Coordination of power and telecommunications - Manual for the establishment of safe work practices and the minimization of operational interference between power systems and paired cable telecommunications systems*.

Consult the authority concerned about separation from other services sharing the trench, keeping in mind:

- worker and public safety;
- potential cable damage due to failure of other services; and
- future access for repairs/maintenance.

## **4.5 Protection of cables**

### **4.5.1 Identification of underground cables**

The presence of buried underground electric cables and underground control cables should be identified. Accepted methods of identification include:

Where the depth of cover is between 600mm and 900mm:

- laying a strip of bright orange polyvinyl chloride or polyethylene or similar marker tape above the cable. The tape is to have the words *electric cable* or similar, boldly printed on the upper side continuously along its length; and
- where appropriate, using on-ground or above ground marker systems.

The position of marker tape, should provide effective warning to anyone engaged in manual or machine excavation.

Where the depth of cover is 900mm or greater, it is not a requirement to place cable protection covers or marker tape above the cable or conduits. However, the location of cables should be marked with permanent on-ground or above ground cable marker systems.

### **4.5.2 Protection general**

An electricity entity should have procedures in place to protect people and prevent damage to underground cables during excavation near underground cables.

These procedures should include but are not limited to:

- maintenance of 'as installed' records of underground cables by an electricity entity;
- provision at the worksite of 'as installed' underground cable records to anyone concerned with planning, organising and supervising excavation work;
- the use of records and other locating methods to positively identify the position of underground cables; and
- exercising care during subsequent excavation.

### 4.5.3 Protection – mechanical

In addition to the principles outlined in parts 4.5.1 and 4.5.2 of this Code, mechanical protection should be provided to minimise the risk of injury to anyone digging by hand near underground cables by providing the minimum requirement for mechanical protection of underground cables in accordance with the table below.

Cable Location	Minimum Requirement
Where the underground electric cables and underground control cables are installed with a depth of cover between 600mm and 900mm.	Install the cable in a suitable conduit for application under roads, and LD Class electrical conduit for application in the electricity footpath allocation. For application outside the electricity footpath allocation LD Class electrical conduit with a polymeric cable protection cover complying with AS4702 not less than 75mm above the cable or, polyethylene orange coloured pressure pipe of minimum rating PN10 for PE80 Class pipe complying with AS/NZS4130.  OR  A polymeric cable protection cover complying with AS4702, not less than 75mm above the cable.  OR  Approved bricks manufactured especially for the protection of electric cables. Assess the risk for each location type to determine the method of mechanical protection.
Where the depth of cover for any underground electric cables and underground control cables is 900mm or greater.	No additional mechanical protection is required.

*Note: Polymeric cable protection cover and approved bricks provide superior protection. These should be considered for locations where cables would not normally be found e.g. parklands or unsealed walkway easements. Also consider using armoured or metallic sheathed cable buried according to cable depths in this chapter.*

For cable circuits requiring high security or where the risk of excavation is high, increased protection should be provided by:

- using a combination of the above provisions for mechanical protection; or
- the use of a heavier duty conduit; or
- encasing the cables in concrete.

Where there is a risk of cable or duct damage by excavating plant or vibration, increased protection should be provided by:

- laying the cable at a greater depth; or
- selecting a less exposed cable route.

#### **4.5.4 Protection – above ground**

Looping, linking and servicing connections made above ground should be housed in pillars or pits that must:

- be externally marked to include the words electric, electrical, or electricity;
- be secured using a special tool or key;
- when enclosing switchgear, be constructed to prevent water from accumulating, unless the switchgear is specifically designed for operation when submerged;
- be designed so that an object (defined as a standard test finger by AS/NZS 3100) cannot be inserted into the interior and come into contact with or within arcing distance of live parts; and
- be installed in places where vehicles are not likely to damage them.

Where an underground electric cable or underground control cable is located between the laying depth prescribed in this chapter and a distance of 2.4m above ground, the cable must be suitably protected so that the cable will withstand, without undue damage, any impact that might normally be expected at that location.

#### **4.5.5 Protective earthing of cables**

When earthing single core cables, consider the special bonding arrangements used to minimise sheath losses and induced sheath voltages.

#### **4.5.6 Records**

Records should be current for all cable installations using maps, plans or computer databases. When preparing a record system, consider the following details:

- alignments
- cable depths
- number of cables
- cable details
- specialised backfill
- reduced levels
- direct buried or ducted
- service history
- position of joints, and
- date of installation.

## 4.6 References

### 4.6.1 Cable Selection

AS/NZS 1026: 2004	Electric cables – Impregnated paper insulated – Working voltages up to and including 19/33 (36) kV.
AS 1049 - 2003	Telecommunication cables – Insulation, sheath and jacket.
AS/NZS 1429.1:2006	Electric cables – Polymeric insulated – For working voltages 1.9/3.3 (3.6) kV up to and including 19/33 (36) kV.
AS/NZS 1429.2 :1998	Electric cables – Polymeric insulated – For working voltages above 19/33 (36) kV up to and including 76/132 (145) kV.
AS/NZS 5000.1:2005	Electric cables - Polymeric insulated - For working voltages up to and including 0.6/1 kV.
AS/NZS 4961:2003	Electric cables - Polymeric insulated - For distribution and service applications.
AS/NZS 4026:2001	Electric cables – For underground residential distribution systems.

### 4.6.2 Route Selection & Cable Selection Accessories

ENA C (b)2	Guide to the Installation of Cables Underground.
HB 100-2000 (CJC 4)	Coordination of power and telecommunications - Manual for the establishment of safe work practices and the minimization of operational interference between power systems and paired cable telecommunications systems.
AS/NZS 2053	Conduits and fittings for electrical installations.
AS 4702: 2000	Polymeric cable protection covers.
AS/NZS 3100:2002	Approval and test specification - General requirements for electrical equipment.
AS/NZS 4130:	Polythene (PE) pipes for pressure applications.

## **5 MAINTENANCE OF SUPPORTING STRUCTURES FOR LINES**

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### **5.1 Scope and application**

This chapter sets down the principles and minimum requirements for maintaining the supporting structures for overhead lines.

An electricity entity should have a maintenance system that achieves a minimum three-year moving average reliability against the incidence of failure of 99.99 per cent a year.

Special consideration should be given to poles in areas of higher risk, such as cities and towns.

### **5.2 Serviceability determination**

Provisions of this Code should be accompanied by responsibly developed and documented procedures for inspecting, assessing, marking and maintaining poles and structures that support overhead lines. Such procedures should be supported by appropriate work practices, and competency training and assessment.

The serviceability of a pole shall be determined by its:

- above ground condition;
- ground line and below condition; and
- strength in its 'as is' condition.

An electricity entity should develop a periodic maintenance program to deliver the reliability level set out at the beginning of this chapter. This program should include an inspection system to verify structural integrity, both above and below ground.

Where appropriate for the supporting structure, the inspection should also determine the bending strength of a pole for comparison with its design load and an applied factor of safety.

Pole strength may be determined by:

- measuring physical dimensions and calculation; or
- proof testing; or
- non-destructive evaluation.

Where resultant pole top forces result in a bending moment at ground line of equal to or close to zero e.g. a fully supported pole situation, the following requirements should be satisfied:

- the conductors and attachments should be capable of continuing to support the pole top loading conditions; and
- a minimum pole tip loading should be adopted to ensure the groundline shear strength of the pole is adequate.

Poles should be classified as either serviceable, suspect or unserviceable.

#### **5.2.1 Frequency of inspection**

An electricity entity's inspection program should ensure the entity meets its safety obligations. Each pole should be inspected at intervals deemed appropriate by the entity. The intervals may be based on documented knowledge of the durability rating, preservation type, inspection procedures, age, performance of the poles, fungal decay, termite risk and so on.

In the absence of documented knowledge of pole performance, poles should be inspected at least every five years.

## **5.3 Marking of poles**

### **5.3.1 General**

An electricity entity should mark poles assessed as suspect or unserviceable. All markings should be about 1.5m above ground line and on the side of the pole to which the pole identification record is fixed e.g. pole number. Markings should be in white or yellow paint and bold enough to be easily identifiable, even when visibility is poor. Any suspect or unserviceable poles shall be appropriately marked before the inspector leaves the site.

### **5.3.2 Marking scheme**

- Serviceable poles – No marking required.
- Suspect Poles – A single diagonal stripe '/'.
- Unserviceable poles – A single 'X'.

### **5.3.3 Removal of markings**

Where it is necessary to remove the suspect or unserviceable mark, the painted cross or diagonal slash should, on the authority of a responsible officer, be either over-painted with a dark coloured paint or removed.

### **5.3.4 Resultant action and timeframes**

Once a pole's serviceability has been determined, the following action and timeframes should apply:

- Serviceable pole – no further action.
- Suspect pole – assess pole within three months.
- Unserviceable pole – replace or reinstate pole within six months.

When a pole, at the time of inspection or assessment, is considered to present a high risk of injury or damage to property, immediate remedial action should be taken.

### **5.3.5 Pole records**

An electricity entity should develop a reference system for supporting structures, to establish inspection and maintenance records.

Pole records should enable an electricity entity to:

- demonstrate that the entity's pole reliability objective is achieved;
- compile statistics to determine the service performance of poles;
- determine future policies from a better knowledge of pole performance, maintenance and preservation methods;
- demonstrate that this chapter's requirements have been complied with; and
- programme the inspection and maintenance of poles.

## **5.4 Reference**

*ENA C(b)1-2006 : Guidelines for design and maintenance of overhead distribution and transmission lines.*

## APPENDIX A MEANING OF TERMS USED IN THIS CODE

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**CMEN** means Common Multiple Earthed Neutral.

**Design load** means the calculated load imposed upon a pole under the loading conditions (calculated maximum service load) adopted by the electricity entity.

**Distribution system** means a system operating at a nominal voltage not exceeding 33 kV.

**Earth connection** means a connection to the general mass of earth by means of an earthing electrode or earthing electrodes electrically connected at a given location.

**Earth resistance**, in relation to an earth connection, means the resistance to the general mass of earth measured in ohms.

**Earthing conductor** means a conductor connecting any portion of the earthing system to works required to be earthed, or to any other portion of the earthing system.

**Earthing electrode** means a metal rod, tube, pipe, plate or other conductor buried in or driven into the ground and used for making a connection to the general mass of earth.

**Earthing values** means values measured with an earth resistance tester.

**Earthing system** means all conductors, piping, electrodes, clamps and other connections whereby conductors or other works are earthed.

**Electricity footpath allocation** means the corridor in the footpath allocated by the local authority for installation of electric cables and plant.

**EMF** means Electro Magnetic Field.

**Exposed conductive parts** includes electrical equipment that can be touched by the standard test finger as specified in AS/NZS 3100 and is not live, but can become live if basic insulation fails. The term includes reinforced concrete work or reinforced concrete parts but excludes minor fastenings, wood pole identification discs and street lights.

**Factor of safety** means the ratio of assessed pole bending strength to its design bending strength.

**Failed pole** means a pole which, due to loss of strength has broken off or become incapable of standing without mechanical means of support other than permanent reinstatement. The following exclusions apply:

- weather more severe than design conditions allowed for at that location e.g. lightning, severe storms and so on;
- impact loads contacting poles or their attachments, e.g. vehicles, falling trees or wind borne objects;
- unforeseeable changes in ground conditions e.g. flooding or earthworks;
- bush fires and grassfires; and
- vandalism.

**Fault duration** means the time during which a fault current may flow before being cleared by the primary protection of a distribution or transmission system.

**Frequented location** means any urban area associated with a city or town other than special locations.

**Fully supported pole** means a pole in which resultant pole-top forces are countered by changed tensions in conductors or stay wires or both (other than service lines). This support ensures little or no bending moment at ground line.

**HV distribution centre** means any substation or generating station other than a low voltage distribution centre including high voltage switching stations;

**IEC Standard** means a standard rule, code or specification of the International Electrotechnical Commission.

**Insulated** means separated from adjoining conducting material by a non-conducting substance which provides resistance to the passage of current, or to disruptive discharges through or over the surface of the substance at the operating voltage, and to obviate danger of shock or injurious leakage of current.

**LV distribution centre** means any substation or generating station from which electricity is or can be supplied directly at low voltage to a distribution system or to a consumer's electrical installation. A Single Wire Earth Return (SWER) isolating transformer substation and compact standalone distribution switchgear shall be classed as LV distribution centres for the purposes of this Code. An LV distribution centre may consist of one or more transformers on a pole, on or under the ground or in a building, or it may consist of one or more low voltage generating sets. A low voltage distribution centre may be located in a generating station or in a zone substation.

**MEN** means Multiple Earthed Neutral.

**Non-destructive evaluation** means an assessment in which the strength of a pole is verified by validated non-destructive techniques.

**Pole** means an overhead line or street light support structure, excluding attachments e.g. x-arms.

**Proof testing** means an assessment in which the strength of a pole is verified by validated application of a mechanical load to simulate the design load multiplied by the factor of safety.

**Prospective step voltage** means the voltage that may appear between any two points on the surface of the ground one metre apart. This voltage is defined as an open circuit voltage measured using a high impedance voltmeter.

**Prospective touch voltage** means the voltage that may appear between any point of contact with exposed conductive parts within 2.4 metres of the ground, and within a radius of 1.0m at ground level. This voltage, too, is defined as an open circuit voltage measured using a high impedance voltmeter.

**Reinstated pole** means a pole in which the original foundation has been supplemented or replaced by a structurally effective support system.

**Remote location** means an area not defined as either special or frequented.

**Roadway** means that part of a road intended for use by vehicles but not including a driveway crossing a footpath.

**Serviceable pole** means a pole in service which, at the time of inspection and assessment, is considered capable of bearing its design load with the relevant Factor of Safety (FOS). The FOS for wood poles is equal to or greater than 2. The FOS for other structures as per *ENA C(b)1*.

**Special locations** mean a location within a school's grounds or within a children's playground, or within a public swimming pool area, or at popular beach or water recreation area, or in a public thoroughfare within 100 metres of any of the above locations.

**Step voltage** means the voltage drop caused by a current flowing through the body between both feet, in contact with the ground one metre apart.

**Suspect pole** means a pole in service which, at the time of inspection, is considered to require further assessment to determine whether or not it is serviceable.

**SWER** means Single Wire Earth Return.

**The ES Act** means the *Electrical Safety Act 2002*.

**The ES Regulation** means the Electrical Safety Regulation 2013.

**Touch voltage** means the voltage drop caused by a current flowing through the body between both hands and both feet. In this instance, the hands are in contact with an earthed conductive part within 2.4 metres of the ground. The feet are within a radius of 1.0m at ground level.

**Transmission system** means a system operating at a nominal voltage above 33kV and includes a sub transmission system.

**Trenchless construction** means the technique of installing cables and ducting by means of directional drilling and systems with minimum excavation.

**Underground cable** means one or more insulated conductors encased in a protective sheath or enclosure and forming part of an underground electric circuit.

**Underground control cable** means an auxiliary cable with one or more insulated conductors encased in a protective sheath or enclosure and forming part of a measuring, control, protection or communication circuit.

**Unserviceable pole** means a pole in service which, at the time of inspection and assessment, is considered incapable of bearing its design load with the relevant Factor of Safety (FOS). The FOS for wood poles is equal to or greater than 2. The FOS for other structures as per *ENA C(b)1*.