

Guide for testing low voltage electrical installations

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1. Scope

This guideline applies when electrical industry workers are required to perform testing of low voltage electrical installations. The *Electrical Safety Act 2002* (the Act) requires that after electrical equipment or installation is installed, a person tests and examines it to ensure it is electrically safe. The processes outlined in this guide are to assist employers and workers to implement appropriate measures to ensure that the electrical equipment or installation is electrically safe.

This guideline does not include testing of high voltage electrical equipment.

Recommendations in this guideline relate to the testing of an electrical installation or part thereof to ensure it is electrically safe prior to placing it into service.

Workplace hazards and associated controls required are not covered within this guide but are to be identified and control measures implemented by risk assessment and subsequent application of the hierarchy of control.

Where there is a conflict between legislation, standards and this guideline, legislation including the Act, Regulations and Codes of practice take precedence followed by the applicable standards.

2. Introduction

Installers of electrical equipment or electrical installations have a duty under electrical safety legislation to ensure that:

- the way the electrical equipment or electrical installation is installed or repaired is electrically safe

and

- the process followed for installing or repairing the electrical equipment or electrical installation ensures that, when installed or repaired, it will be electrically safe

and

- after the electrical equipment or electrical installation is installed or repaired, the electrical worker tests and examines it to ensure it is electrically safe.

This guide outlines a method of inspecting and testing low voltage electrical installation, incorporating a multiple earthed neutral (MEN) system of earthing.

Where more than one test method is available, the appropriate method should be selected after considering all circumstances particular to the installation, including the safety of the person conducting the testing and the effectiveness of the testing in the particular circumstance.

The methods outlined comply with the principles of testing as prescribed under AS/NZS 3000:2018 Electrical Installations – 'Wiring Rules'. Additional information and guidance are provided in AS/NZS 3017:2022 Electrical installations – Verification by inspection and testing.

At all times a safe system for performing electrical work must be in place before any testing is undertaken.

Specific installations may have installation specific additional and/or alternate requirements for testing. These include but are not limited to:

- AS/NZS 3001.1 & 3001.2 – Electrical Installations – Connectable electrical installations and supply arrangements
- AS/NZS 3003 – Electrical Installations – Patient Areas
- AS/NZS 3012 – Electrical Installations – Construction and Demolition sites
- AS/NZS 4777.1 – Grid connection of energy systems via inverters
- AS/NZS 60079.14 – Explosive atmospheres.

Note: Where a definition has not been provided, refer to Electrical Safety Regulation 2013 section 9 dictionary, and/or AS/NZS 3000 Electrical Installations 'Wiring Rules' section 1.4 definitions, and/or AS/NZS 4836 Safe working on low-voltage electrical installations section 1.4 terms and definitions, and/or the normative standard applicable to the installation.

3. Safe systems of work

3.1. Overview

A person conducting a business or undertaking (PCBU) has a duty to ensure the electrical safety of all persons and property likely to be affected by the electrical work. This includes testing of electrical installations and electrical equipment. A PCBU must ensure that work on or near energised electrical equipment is not performed unless permitted in particular circumstances outlined in Part 3, Division 1 of the *Electrical Safety Regulation 2013* (the Regs).

All electrical workers should be familiar with this code: The Electrical safety code of practice – Managing electrical risks in the workplace provides practical guidance for safe working practices, assisting in the compliance with electrical safety legislation requirements. AS/NZS 4836 Safe working on low-voltage electrical installations may assist in developing safe systems of work.

The methods for testing an electrical installation outlined in this guide follow the principles to perform de-energised testing on electrical equipment, wherever practical. Where electrical testing work is performed on energised electrical equipment, a safe system for performing the testing must be in place. This includes performing the work in accordance with a safe work method statement prepared for the work.

When installing and testing circuits added to existing switchboards, risks associated with work on or near energised electrical equipment must always be considered and appropriate control measures must be in place prior to commencing the work. So far as reasonably practicable, de-energisation of all sources of supply must be implemented. Testing such as polarity testing

including neutral integrity testing, upon connection to a distribution network, require work on energised electrical equipment to ensure the safe connection of the electrical installation to supply.

Note: In high fault current applications, the use of current limited test points or other methods to control the risk posed by arcing faults should be considered.

For guidance on safe systems of work refer to the Guide safe working on or near energised electrical equipment.

4. Important information

4.1. The multiple earth neutral (MEN) system

The testing methods described in this guide are designed to ensure the safety of electrical installations, which use the MEN system of earthing. The MEN system provides for an interconnection between the supply neutral and the mass of earth at multiple points on the supply system and at each consumers installation.

In each consumer installation there shall be such a connection (the MEN point). This connection is made at the main switchboard. Where an installation incorporates submains to separate outbuildings there may arise the need for a separate MEN connection at the outbuilding switchboard. If the earthing at the outbuilding is not affected by means of direct connection to the installations earthing system, then a separate earth electrode and MEN connection is required at the outbuilding.

The different methods of earthing are provided for in clause 5.5.3 of AS/NZS 3000.2018 Electrical installations 'Wiring Rules'.

If the MEN connection is omitted from an installation, a failure of the insulation in any part of the installation, typically in an appliance such as a stove or hot water system, will cause the entire earthing system to be raised to a dangerous voltage potential. The MEN link ensures in a fault situation sufficient fault current will flow to earth and operate the protective devices provided appropriate protective devices are installed. Do not rely on the resistance of the earth between an installations earth electrode and the general mass of earth to be low enough to allow the protective devices to operate in a fault situation. This resistance is almost NEVER low enough to ensure safety.

The effectiveness of the MEN system relies on the fact that the earthing system is required to be effectively connected to the neutral in EVERY CASE. Refer to Appendix C for a diagram of MEN system showing earth fault current path.

The consumer main neutral conductor and the neutral conductor of a submain supplying an outbuilding incorporating a separate MEN connection combines functions as a neutral

conductor as well as an earthing conductor. These conductors are known as protective earth neutral (PEN) conductors.

The removal of the MEN connection at a switchboard when supply is energised should be avoided except, when necessary, such as for testing polarity of consumer mains. When testing final subcircuits, removal of the final subcircuit neutral connection at the neutral link or by turning off an Residual Current Breaker with Overcurrent (RCBO) or [Residual Current Device](#) (RCD) which switches all poles, will remove the neutral earth bond from the circuit under test.

Refer to the Guide for service and submain polarity testing for additional information.

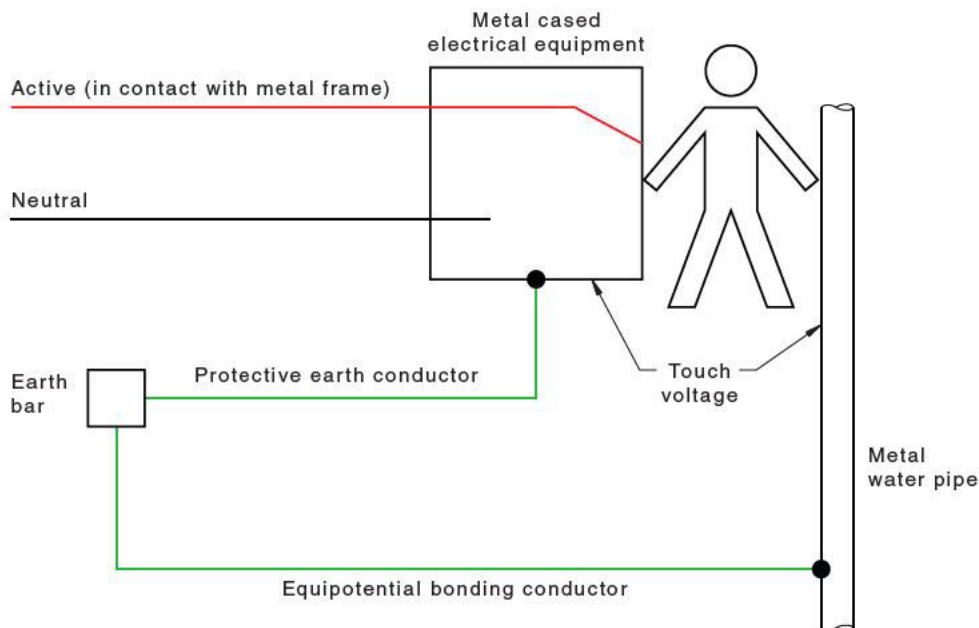
Where whole of installation tests are conducted with supply not connected/isolated, the MEN connection is removed for testing purposes and re-installed prior to energising the installation. Refer AS/NZS 3017 Electrical installations -Verification by inspection and testing, section 4. It is recommended that a failsafe process is implemented to ensure that the MEN connection is installed prior to energising any supply.

Note: Whilst an energised Earth Fault Loop Impedance (EFLI) test is not mandatory, it is recommended that where supply is available, EFLI testing is carried out at a point within every installation after work is performed. An EFLI test measures the impedance of the circuit from the supply transformer. When the test is conducted on a suitable final subcircuit (for example at a socket outlet), the circuit includes critical conductors and connections, such as the MEN and PEN conductors. Recording a suitably low-test result will provide confidence that in the event of an earth fault, the required current will flow to operate the circuit protective devices and prevent a dangerous time/touch voltage relationship occurring on exposed conductive parts.

Refer to Appendix E for a diagram of the approved methods of installing the MEN System.

4.2. Fault protection

The term Touch Voltage is used to define a voltage between simultaneously accessible parts. When a fault occurs, exposed conductive parts may become energised under fault conditions. The energised exposed conductive parts pose a risk of electric shock.



Source: AS/NZS 3017:2022 Figure 4.31 © Standards Australia. Used with permission.

Figure 1 – Example of touch voltage

If the time/touch voltage relationship of an electric shock is exceeded, the likelihood of pathophysiological effects may occur, such as cardiac arrest, breathing arrest, burns or other cellular damage. The probability of ventricular fibrillation increases with current and time.

AS/NZS 3000 Electrical installations 'Wiring Rules', clause 1.5.5.2 specifies several methods which may be used for protection including:

- Protection using Class II (double insulated) equipment to prevent a fault current from passing through a body in accordance with clause 1.5.5.4.
- Protection using Separation (e.g. an isolation transformer) to prevent a fault current from passing through a body in accordance with clause 1.5.5.5.
- Protection by limiting the fault current that can pass through a body to less than the shock current. (e.g. equipotential bonding can be utilised to limit the voltage between simultaneously accessible parts).
- Protection by automatically disconnecting the supply when a fault likely to cause a current to flow through a body occurs, in accordance with Clause 1.5.5.3. This is a commonly used method.

Touch voltage¹

AS/NZS 3000:2018 Appendix B provides the following formula for the calculation of touch voltage.

$$U_T = c U_o m / (1 + m)$$

U_T = prospective touch voltage for the circuit.

c = represents the proportion of supply voltage at the circuit protective device. This will vary. A mean value is 0.8, which should be used in normal circumstances. A c factor of 1.0 should be used if the circuit is supplied directly from the source. e.g. an onsite transformer.

U_o = the supply voltage.

m = the ratio of the cross-sectional area of the active conductor and the protective earthing conductor in the circuit. (e.g. active conductor divided by the protective earthing conductor).

Examples of touch voltage calculation:

1. A 230V electric frypan develops an earth fault. The supply circuit for the socket outlet is a 2.5mm² 2C+E, thus the active and earth conductors are the same size. The prospective touch voltage U_T is calculated:

$$U_T = c U_o m / (1 + m) = 0.8 \times 230 \times 1 / (1 + 1) = 0.8 \times 230 \times \frac{1}{2} = 92V$$

2. A welder connected to a 32A socket outlet develops an earth fault. The supply socket has 6mm² active conductors with a 2.5mm² earth conductor. As the site is close to the supply transformer, full supply voltage is available at the circuit protective device, thus the c factor will be taken as 1.

See table below for touch voltages for common cable combinations.

Use c factor 0.8 for installations supplied from a street service.

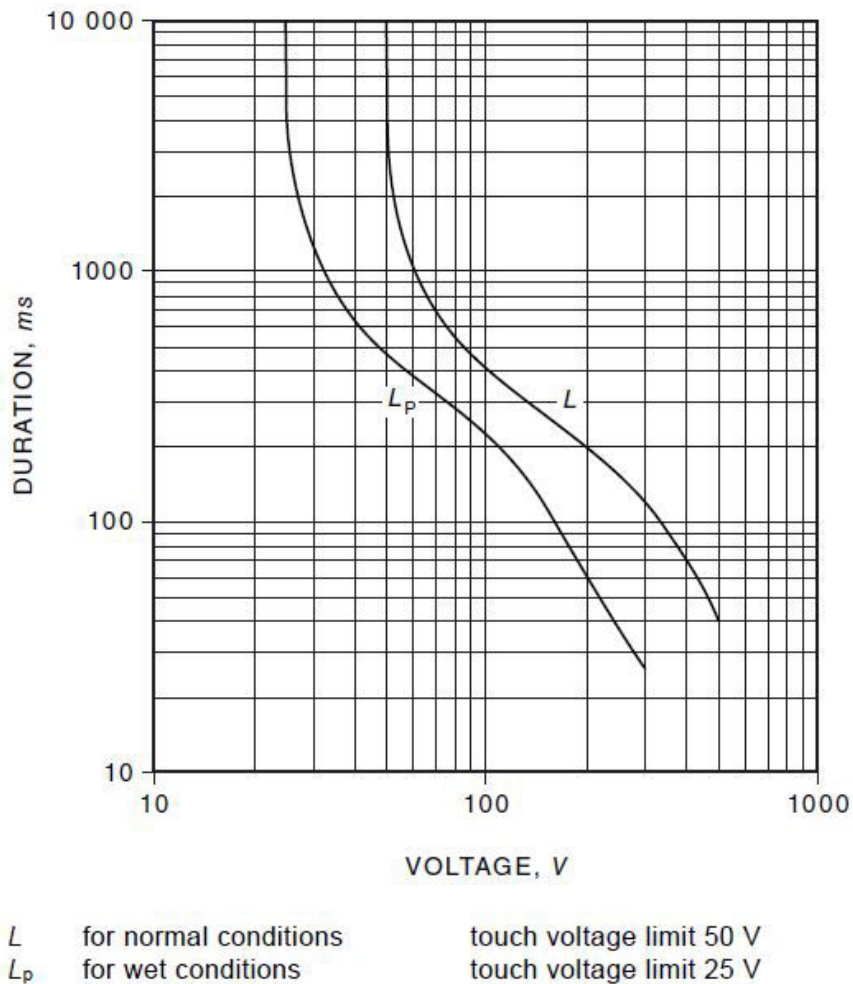
Use c factor 1.0 for installations where the supply transformer is close to the main switchboard.

Note: The last row of the table provides an example of a 2.5mm² circuit with a 10mm² earthing conductor. As the touch voltage in this example is 37Vac, automatic disconnection is not a requirement.

¹ Source: AS/NZS 3000:2018 Appendix B © Standards Australia. Used with permission.

Table 1 – Touch voltage

Example of touch voltage for common cable combinations			
Active mm ²	Earth mm ²	Touch Voltage c factor 0.8	Touch Voltage c factor 1.0
1mm ²	1mm ²	92Vac	115Vac
1.5mm ²	1.5mm ²	92Vac	115Vac
2.5 mm ²	2.5 mm ²	92Vac	115Vac
4 mm ²	2.5 mm ²	113Vac	141Vac
6 mm ²	2.5 mm ²	130Vac	162Vac
10 mm ²	4 mm ²	131Vac	164Vac
16 mm ²	6 mm ²	133Vac	167Vac
25 mm ²	6 mm ²	148Vac	185Vac
35 mm ²	10 mm ²	143Vac	178Vac
2.5 mm ²	10 mm ²	37Vac	46Vac



[Source: IEC TR 61200-413:1996 © 1996 (IEC), Geneva, Switzerland, www.iec.ch.]

Source: AS/NZS 3000:2018 Figure B4 © Standards Australia. Used with permission.

Figure 2 – Maximum duration of prospective 50Hz Touch Voltage

The curves in Figure 2 demonstrate that:

- in normal conditions a touch voltage of 50Vac can be sustained by a person indefinitely
- in wet conditions a touch voltage of 25Vac can be sustained by a person indefinitely
- a voltage exceeding these limits cannot be sustained and shall be disconnected.

AS/NZS 3000 Electrical installations 'Wiring Rules', clause 5.7.2² requires that where the touch voltage exceeds 50Vac or 120Vdc for normal conditions, or 25Vac or 60Vdc for wet conditions, the maximum disconnection time shall not exceed:

² Source: AS/NZS 3000:2023 Clause 5.7.2 © Standards Australia. Used with permission.

- 0.4 s for final subcircuits that supply:
 - » socket-outlets having rated currents not exceeding 63A

or

- » hand-held Class I equipment

or

- » portable equipment intended for manual movement during use.
- Disconnection times up to 5s are permitted for other circuits which do not directly supply portable or handheld equipment where touch voltages do not exceed safe limits, for the following reasons:
 - » Faults in such circuits are less likely.
 - » There is less likelihood of persons being in contact with the equipment during a fault.
 - » Equipment supplied by these circuits is not normally gripped.
 - » Touch voltages are not expected to exceed the time/touch voltage relationship in Figure 2.

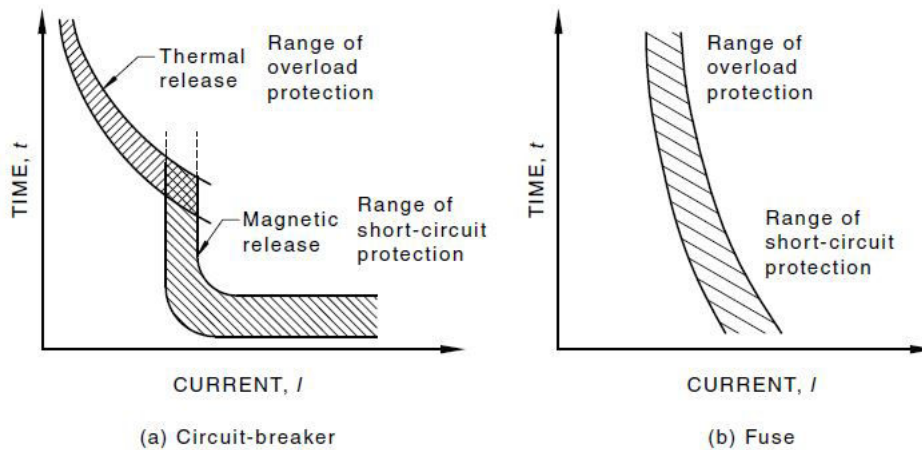
Note: A 5s disconnection time is generally associated with fuses only. Circuit breakers are nonlinear in this range and can vary between manufacturers. Refer to AS/NZS 3000 Tables 8.1 and 8.2.

Where the conditions for automatic disconnection of supply cannot be fulfilled by overcurrent protective devices, protection may be provided by RCD's having a suitable tripping time. Generally, a miniature circuit breaker (MCB) operating in the instantaneous (magnetic trip) curve will disconnect supply in <0.1s. In most cases an MCB instantaneous trip will operate faster than an RCD to disconnect supply.

For circuit breakers the mean tripping current is:

- Type B = 4 x rated current.
- Type C = 7.5 x rated current.
- Type D = 12.5 times rated current.
- Consult the manufacturer for specialist applications. For example: motor protection circuit breakers.

For fuses obtain the approximate mean values from IEC 60269.1 or the fuse manufacturers data.



Source: AS/NZS 3000:2023 Figure B6 © Standards Australia. Used with permission.

Figure 3 – Typical time/current curves for circuit breakers and fuses.

Maximum fault-loop impedance

The maximum value of earth fault loop impedance may be calculated using the following equation:

$$Z_s = U_o / I_a$$

Z_s = earth fault-loop impedance

U_o = nominal phase voltage (230V)

I_a = current causing automatic operation of the protective device.

AS/NZS 3000 Electrical installations 'Wiring Rules', Table 8.1 provides maximum values of earth loop impedance for the total circuit including the supply transformer (Z_s at 230V) values relating to operation of circuit protective devices on the final subcircuit.

AS/NZS 3000 Electrical installations 'Wiring Rules', Appendix B4 and B5 provide additional information, calculations, and tables.

Supplementary equipotential bonding may be used to ensure that the disconnection time is sufficient to satisfy the requirements of AS/NZS 3000 Electrical installations 'Wiring Rules', clause 5.7.2.

Example of maximum earth fault loop impedance:

A welder connected to a 32A socket outlet develops an earth fault. The supply socket has 6mm² active conductors with a 2.5mm² earth conductor.

The touch voltage at the welder is 162.3Vac (see touch voltage example 1). This voltage exceeds 50Vac thus automatic disconnection within 0.4s is required. The circuit is protected by a 32A C curve circuit breaker.

The maximum fault loop impedance permitted is:

$Z_s = U_o / I_a = 230 / (32 \times 7.5) = 0.958\Omega$ (a fault loop impedance test instrument is required to test this as it is the loop from the transformer).

Alternatively, the final subcircuit could be tested to table 8.2 using a suitable low reading ohmmeter. In this case the final subcircuit earth continuity shall be $<0.4\Omega$ and the loop resistance phase to earth from the circuit protective device shall be $<0.6\Omega$. Note: This does not verify connections upstream of the final subcircuit.

5. Test equipment

5.1. Essential requirements

Electrical safety legislation requires that a PCBU must ensure tools, testing equipment and personal protective equipment:

- are suitable for the work

and

- have been properly tested and function correctly

and

- are maintained in good working order.

Listed below is the basic equipment necessary to enable an electrical worker to test low voltage electrical installations.

The minimum test equipment required comprises:

- a low range ohmmeter capable of displaying accurately low readings between 0.01 – 10 Ω Most insulation resistance and installation test instruments have a suitable range. A high current output is one of the qualifying characteristics of a true low resistance ohmmeter. Generic multi-meters do not supply enough current to give a reliable indication of the current-carrying capabilities of joints, welds, bonds and the like under real operating conditions.

An analogue or digital meter designed for low resistance testing, capable of a test current of at least 200mA is recommended.

- a voltage indicator
- a voltmeter
- suitable probes
- a trailing lead of known resistance.

- a suitable instrument for measuring fault-loop impedance
- a suitable instrument or device to check the operation of an RCD
- a means of making a temporary connection to the general mass of earth (independent earth).

Always ensure the test equipment is functioning properly before and after each test.

Test instruments also recommended for an electrical worker to be able to make detailed assessments of electrical installations and circuits include:

- Clamp-on ammeter for measuring circuit load currents.
- Clamp-on milliamp meter for measuring leakage current.
- Phase rotation meter.
- Residual current device test instrument.
- A range of resistors with a tolerance of 1% (to calibrate ohmmeter and insulation resistance meter) such as: 0.1Ω, 0.5Ω, 5.0Ω, 10.0Ω, 1kΩ, 10kΩ and 1MΩ.

5.2. Methods for ensuring correct operation of test equipment

Insulation resistance test instrument

On the MΩ scale:

1. Connect a voltmeter of high impedance, for example: a digital multi-meter to the insulation resistance meter and check that the 500 V test potential is achieved on test (ensure voltmeter can measure 500Vdc).
2. Check the accuracy of insulation resistance meter connected across a 1MΩ resistor with 1% tolerance.
 - » The insulation resistance meter shall display 1MΩ +/- the tolerance as stated by the manufacturer e.g. +/- 5% (995kΩ to 1.05 MΩ).
 - » The insulation resistance meter shall be able to maintain its terminal voltage within +20%, - 10% of the nominal open-circuit terminal voltage (use a 10 MΩ resistor to test the 1000V range).
3. Check the accuracy of insulation test meter when connected across a 10kΩ resistor with 1% tolerance.

On the Ω scale:

1. Short the leads together and check the zero-ohm reading.
2. Check the accuracy of readings when connected across suitable low value resistors such as 0.1Ω , 0.5Ω , 5Ω and 10Ω .

On the $k\Omega$ scale (where applicable):

1. Check the accuracy of the test instrument using the $1k\Omega$ and/or $10k\Omega$ resistors as applicable.

Voltmeter/Voltage indicator

Check against a known source before and after testing to ensure the meter or indicator operates correctly (ensure correct range a.c. or d.c. is always selected).

5.3. Safety in the use of test equipment

When performing any test to detect or confirm live conductors, the following procedures should be adopted as a matter of habit:

- Ensure test instruments are suitable for use on low impedance sources, such as main switchboards. (i.e. Testing at a commercial switchboard will require a category IV meter with category IV test leads).
- Always confirm the correct operation of the test device at the start of testing.
- Check correct operation at completion of testing, to guard against failure during testing.
- Check that the correct function and range has been selected on the test equipment.
- When using test equipment in a manner that requires the completion of a circuit to earth, ensure that the earth is effective. This applies in particular to test lamps and solenoid type devices, which draw over 25mA, a level that presents a safety risk. If, for example, such an instrument was used for testing from a live conductor to an unearthed metal switchboard enclosure, the enclosure would become live. Alternatively, connection to an earthing system which has unusually high main earth resistance to earth, could also result in the whole earthing system, including any appliances connect to it (e.g. stove or HWS), to become live.
- To prevent personal injury and/or damage to equipment, all test instruments should be capable of withstanding the impulse voltages and fault current levels that may be experienced in the particular Installation Category e.g. the rating for test instruments and test probes used on 400/230V mains voltage equipment connected on the supply side of a main switchboard should be Installation Category III or IV.
- When carrying out testing procedures prior to connection to supply, particular care should be taken to ensure there is no risk of injury to yourself or others.

- When carrying out any testing with the MEN link disconnected, when supply is available, a temporary shock hazard may arise. The earthing system, including the water piping and associated equipment can be raised above earth potential to an unsafe touch voltage.
- Take appropriate measures such as using an independent earth as the testing reference point instead of the installation earth or using a high impedance test instrument such as a voltmeter to perform the tests.
- Ensure that alternate energy supplies are isolated at their source, prior to commencing testing. The neutral earth connection for an alternate supply is the installation MEN connection. Neutral and earth circuits may become live under fault conditions or when the MEN connection is removed, whilst the alternate supply is energised.
- Where possible the testing procedure may verify a positive meter result for the first and last test. i.e., 230V or 0 Ω .

6. Inspection and testing

AS/NZS 3000:2018 Electrical installations 'Wiring Rules' Clause 8.1.2.

Requirements

Prior to placing an electrical installation, or any part thereof, in service following construction, alteration, addition or repair thereof, it shall be verified, as far as practicable, that the installation is safe to energise and will operate correctly in accordance with the requirements of AS/NZS 3000 Electrical installations Wiring Rules.

To confirm that the requirements of the standard have been met, after completion and before being placed in service, the installation shall be:

- inspected in accordance with clauses 8.1.3 and 8.2 as far as reasonably practicable

and

- tested in accordance with clause 8.3.

Precautions shall be taken to ensure the safety of persons and to avoid damage to property and the electrical installation equipment during inspection and testing.

Where the electrical installation is an alteration, or repair to an existing electrical installation, it shall be verified that the alteration, or repair complies with the standard and does not impair the safety of the existing electrical installation.³

³ Source: AS/NZS 3000:2023 Clause 8.1.2 © Standards Australia. Used with permission.

6.1. Visual inspection

Electrical workers shall perform a visual inspection prior to performing the mandatory tests to ensure the electrical installation is electrically safe and complies with the wiring rules before it is connected to supply.

Where a visual inspection of part of the electrical installation is not practicable at the completion of the work, inspection could occur during the course of the installation e.g. where cables are enclosed in the building structure.

Note: The Electrical Safety Regulation 2013 requires that high voltage or hazardous area installations are not connected or reconnected to an electricity source unless the electrical work has been inspected by an accredited auditor, who has confirmed that the electrical installation is electrically safe.

Visual inspection checklist

(Extract Clause 8.2.2 AS/NZS3000:2018 Electrical installations 'Wiring Rules')

General

- Basic protection (protection against direct contact with live parts), for example: insulation and enclosure.
- Fault protection (protection against indirect contact with exposed conductive parts), for example: double insulation or isolating transformers.
- Protection against hazardous parts, for example: enclosure, guarding or screening of flammable materials, hot surfaces and parts that may cause physical injury.
- Protection against spread of fire, e.g. penetration of fire barriers.
- General condition of the electrical equipment, for example: signs of damage that could impair safe operation, disconnection of unused electrical equipment.

Consumer mains

- Current carrying capacity.
- Voltage drop, for example: size of conductors.
- Underground installation conditions, for example: enclosure, depth of burial, mechanical protection.
- Aerial installation conditions.
- Connection of wiring.
- Protection against external influences.

Switchboard

- Location, for example: access and egress.

- Protective devices, for example: selection and setting of adjustable protective devices for compliance with overcurrent protection, arc fault protection and discrimination requirements.
- Isolation devices, for example: main switches.
- Connecting devices, for example: neutral bars, earth bars and active links.
- Connection and fixing of wiring and switchgear.
- Identification and labelling of electrical equipment.
- Protection against external influences.

Wiring systems

- Conductor size, for example: current-carrying capacity and voltage drop.
- Identification of cable cores.
- Adequate support and fixings.
- Connections and enclosures.
- Particular installation conditions, for example: underground, aerial, safety services.
- Segregation from other services and electrical installations.
- Protection against external influences, for example: enclosure.

Electrical equipment

- Isolation and switching devices for protection against injury from mechanical movement devices and motors.
- Isolation and switching devices for protection against thermal effects, for example: motors, room heaters, water heaters.
- Switching devices for particular electrical equipment, for example: socket-outlets, water heaters.
- Particular installation conditions, for example: locations affected by water, explosive atmospheres, extra-low voltage, high voltage.
- Compliance with required standards.
- Connection, support and fixing.
- Protection against external influences including ingress of moisture where required by any clause.
- Suitability for intended voltage, current and frequency.

Earthing

- MEN connection.

- Earth electrode.
- Earthing conductors, for example: size, identification.

Visually confirm the correct wiring of all PEN conductors and that no PEN conductor passes through any switch or device which may affect its continuity.

- Equipotential bonding conductors, for example: size, identification.
- Connections, joints and terminations.
- Protection against external influences.
- Connection to earthing arrangements for other systems.

Testing shall be carried out in such a manner that the safety of the operator, other people in the vicinity, and test equipment are not placed at risk.

- Creation of earthed situation that may require earthing of additional electrical equipment.⁴

6.2. Mandatory test

Mandatory tests: AS/NZS 3000:2018 Electrical installations 'Wiring Rules'

AS/NZS 3017 Electrical installations — Verification by inspection and testing sets out common methods that may be used to verify by testing that a low voltage electrical installation complies with AS/NZS 3000 Electrical installations 'Wiring Rules' and includes minimum safety standards for test instruments:

- Continuity of earthing system (earth resistance of the main earthing conductor, protective earthing conductors and bonding conductors) in accordance with Clause 8.3.5.
- Insulation resistance, in accordance with Clause 8.3.6.
- Polarity and correct circuit connections in accordance with Clause 8.3.7.
- Correct circuit connections, in accordance with Clause 8.3.8.
- Verification of impedance required for automatic disconnection of supply (earth fault-loop impedance), in accordance with Clause 8.3.9.
- Operation of RCDs, in accordance with Clause 8.3.10.

Notes:

1. Verification of impedance required for automatic disconnection of supply may require that supply is available.

⁴ Source: AS/NZS 3000:2018 Clause 8.2.2 © Standards Australia. Used with permission.

2. Operation of RCDs requires that supply is available.
3. High voltage installations may require additional tests (see AS 2067).

If the electrical installation fails a test, that test and any preceding tests that may have been influenced by the fault indicated shall be repeated after the fault has been rectified (clause 8.3.3.).

Continuity of the earthing system

Testing to prove the continuity of the earthing system (earth resistance of the main earthing conductor, protective earthing conductors, combined protective earthing and neutral (PEN) conductors and bonding conductors) shall be carried out to ensure that the earthing system has been installed in a manner that will cause circuit protective devices to operate if there is a fault between live parts, other than the neutral, and the mass of earth.

An effective earthing system will ensure that exposed conductive parts of electrical equipment do not reach dangerous voltages when such faults occur.

Where a PEN submain is installed in accordance with AS/NZS 3000:2018 Electrical installations 'Wiring Rules' clause 5.5.3.1 (c), testing shall confirm that the earth terminal, point or bar of the sub-board is connected via the PEN conductor to the earth terminal, point or bar of the main switchboard.

Where the touch potential exceeds 50 V a.c or 120 V ripple-free d.c., the circuit-protective device shall cause disconnection of supply within the required time. Refer to section 3.2 for further information.

Note:

1. Earth resistance requirements of Clause 8.3.5.2 AS/NZS 3000:2018 –The resistance of the main earth conductor and any equipotential bonding conductor shall be not more than 0.5Ω.
2. The resistance of protective earthing conductors shall be low enough to permit the passage of current necessary to operate the circuit protective device. This condition is satisfied when the fault-loop impedance is low enough to allow sufficient current to flow in the fault loop to cause the protective device to operate within a specified disconnection time.
3. Table 8.2 gives maximum values of resistance and Table B1 gives maximum circuit lengths, in metres, for different sizes of conductors and protective devices using appropriate mean tripping currents.
4. The resistance of protective earthing conductors shall be consistent with the length, cross-sectional area and type of conductor material.

Note: In some circumstances, it may be convenient to complete insulation testing prior to conducting earth continuity testing. All insulation tests shall be repeated if any part of the installation is altered or repaired due to a failure of any earth continuity test.

Insulation resistance

Insulation resistance tests are necessary to ensure the integrity of the insulation between all live conductors (active and neutral) and earth or all live parts and earth.

In addition, an insulation resistance test between all active and neutral (live) conductors is necessary for consumer mains and submains to minimize risk of injury or property damage because of insulation breakdown.

Insulation resistance requirements of Clause 8.3.6.3 AS/NZS 3000:2018 Electrical installations 'Wiring Rules':

1. The insulation resistance between the conductors of consumer mains and submains shall not be less than 1 MΩ
2. The insulation resistance between live and earthed parts of an electrical installation or parts thereof shall not be less than 1 MΩ. The value of 1 MΩ may be obtained with appliances disconnected.
3. This value may be reduced to 0.01 MΩ (10 KΩ) for sheathed heating elements of appliances or a value permitted in the relevant safety standard applicable to electrical equipment.
4. For shorter cable runs, the insulation resistance should be significantly greater than 1 MΩ. For a 50 m run at 20 °C the following would be expected:
 - Polymeric insulated cables >50 MΩ
 - PVC insulated cables >20 MΩ
 - XLPE insulated cables >1500 MΩ⁵

Precautions before testing:

- Where additional MEN connections exist, they shall be disconnected before testing.
- Where electronic devices are installed as part of the fixed installation (for example: smoke detectors), care should be taken to avoid damaging such devices by overvoltage. Damage may be avoided by carrying out insulation resistance test with the active and neutral conductors for the circuit under test connected together, then testing between these conductors and earth.
- When the earth sheath return (ESR) system is used, the neutral conductor shall not be connected to any active conductor for the purpose of the insulation resistance test.

⁵ Source: AS/NZS 3000:2023 Clause 8.3.6.3 © Standards Australia. Used with permission.

- If earthing arrangements for functional purposes are provided, any connections to the protective earthing arrangements should be disconnected for this test.
- All switch positions/combinations need to be tested in two-way and intermediate switching applications and on the load side of devices such as contactors.
- Where equipment, such as electromagnetic compatibility (EMC) filters, equipment containing surge protective devices connected to earth, or electronic equipment, is likely to be damaged by the test:
 - such equipment may be disconnected or switched off before carrying out the insulation resistance test on the circuit, for example: when the equipment manufacturer requires that the equipment is not subjected to an insulation test

or

- the test voltage for the circuit may be reduced to 250 V d.c.
- When testing long runs of cable, an insulation test instrument charges up the insulation of the device or cable that is under test. The output from the test instrument alone may be insufficient to cause serious injury or death, but the stored charge can easily deliver a serious electric shock. Be aware that the cable capacitance may store a charge after conducting insulation testing. Care must be taken to avoid the risk of electric shock. The cable should be discharged after your test, by short-circuiting and grounding the insulation to eliminate the risk of electric shock from the stored energy.

Note: Earthed electrical equipment incorporating electronic control circuits e.g. air conditioners, generally contain EMC filters and metal oxide varistors (MOV's) (a form of surge diverter) between live conductors, and/or live conductors and earth. During an insulation test the capacitors will charge and this will not affect the test. MOV's are nonlinear, bidirectional devices, having a resistance of several hundred MΩ. When subjected to a peak voltage exceeding the rated voltage of the device (normally around 400Vdc for an MOV used on 230Vac) the device breaks over and conducts. Thus, a test conducted at 500Vdc will indicate an insulation failure, however if the voltage is reduced to 250Vdc the MOV will not influence the test.

Polarity and correct circuit connections

Polarity testing is necessary to ensure no shock hazards exist from incorrect connection of active, neutral, and earthing conductors.

This testing is intended to prevent:

- The transposition of active and neutral conductors of the consumer mains, or submains supplying an outbuilding having an MEN connection, resulting in the electrical installation earthing system becoming energised.
- Combinations of incorrect active, neutral and earthing conductor connections resulting in exposed conductive parts becoming energised.

- Incorrect connection of switches in neutral conductors, except where permitted, resulting in parts of appliances, such as heating elements and lamp holders, remaining energised when switches are in the OFF position.
- Multiphase equipment, such as multiphase motors, and semiconductor-controlled equipment operating in an unpredictable manner.
- Protective earthing conductors carrying current under normal conditions of operation.

Note: For the purposes of this Clause, a PEN conductor is not regarded as a protective earthing conductor (PEC).

- Short-circuits existing between conductors.

Note: A short-circuit current flowing between live conductors or through part of the earthing system can cause considerable fire damage or personal injury, particularly in high current locations.

Polarity and correct circuit connections requirements of AS/NZS 3017:2022 (Clause 4.6.3):

- Every single-pole switch or protective device shall operate in the active conductors of the circuit in which it is connected.

Note: Other special types of installations may have additional active and neutral switching requirements for example: AS/NZS 3001.2 Connectable electrical installations.

- A switch or protective device of a multi-phase circuit, other than some types of motor overload protective devices, shall operate in all active conductors of the circuit in which it is connected.
- RCDs required to switch all live conductors, shall switch the active and neutral conductors of the circuit.
- Where multi-phase socket-outlets of the same type of form part of an electrical installation the phase sequence of the socket-outlets shall be the same (see Clause 4.7.4).
- Socket-outlets, which accommodate flat-pin plugs, shall be connected so that, when viewed from the front of the socket-outlet, earth, active and neutral are connected in a clockwise direction.
- All neutral conductors shall be connected to the neutral bar of the switchboard.
- The consumer's mains neutral shall be connected to the neutral bar of the main switchboard.

The active, neutral and protective earthing conductors of each circuit shall be correctly connected so that:

- there is no short-circuit between the conductors

- there is no transposition of conductors that could result in the earthing system and any exposed conductive parts of the electrical installation becoming energised
- there is no interconnection between live (active or neutral) conductors of different circuits.⁶

Note: Any MEN or earth sheath return connection is not considered as a short-circuit.

Check of phase sequence

Phase sequence testing is necessary to ensure that multi-phase equipment such as multi-phase motors and semiconductor-controlled equipment operates in a predictable manner.

If supply is available use a phase sequence meter in accordance with the manufacturer's instructions.

If supply is not available test as shown in step 10.2.

Earth fault-loop impedance

The earth fault-loop impedance of a circuit is measured to ensure that, if a fault of negligible impedance occurs between an active conductor and a protective earthing conductor or an exposed conductive part, sufficient current will flow in the earth fault-loop to cause a protective device to operate within a specified disconnection time.

Verification of Impedance

AS/NZS 3000:2018 Electrical installations 'Wiring Rules' (Clause 8.3.9.1).

Where an installation includes circuits satisfying the points below, EFLI testing, in accordance with Clause 8.3.9.2, shall be carried out for those circuits:

- Fault protection is by automatic disconnection of supply.
- Supplying one or more socket-outlets.
- Where socket-outlets are not protected by a residual current device with a residual current rating of 30 mA or less.

Notes:

1. The tests described in Clause 8.3.9.2 are carried out in order to verify that the protective device will operate to disconnect an earth fault current within the time and touch voltage requirements of Clauses 5. 7 and 1.5.5.3.
2. Further information on the earth fault-loop impedance is contained in Appendix 8, Paragraph 84 and Clause 5.7.

⁶ Source: AS/NZS 3017:2018 Clause 4.6.3 © Standards Australia. Used with permission.

3. EFLI testing is not required for RCD-protected socket-outlets, as the maximum operating time of RCDs providing additional protection is less than the 0.4 s specified by Clause 5.7.2, Item (a) and Clause 1.5.5 .3, Item (d).
4. EFLI testing is not required for socket-outlets on separated supplies (i.e. isolation transformer) because for these circuits fault protection is not by automatic disconnection.
5. EFLI testing is not specifically required for circuits supplying equipment other than socket-outlets because of the risk of electric shock when performing the test on live electrical equipment. For a circuit supplying other than socket-outlets, the longer permitted operating time combined with verification of earth continuity in accordance with Clause 8.3.5.2, is considered to adequately verify compliance with Clause 5.7.
6. While EFLI testing is not required for other circuits, the maximum trip time requirement still has to be complied with. In most cases, if voltage drop requirements are complied with, the EFLI will be acceptable.

Whilst an energised EFLI test is not mandatory in several instances as listed above, it is recommended that where supply is available, an EFLI test is carried out at a suitable point within every installation after work is performed. An EFLI test measures the impedance of the circuit from the supply transformer. When an EFLI test is conducted on a suitable final subcircuit (e.g. at a socket outlet), the circuit includes critical conductors and connections, such as the MEN and PEN conductors. Recording a suitably low-test result will provide confidence that in the event of an earth fault, the required current will flow to operate the circuit protective devices and prevent the earthing system becoming energised for >0.4s.”⁷

Operation of residual current devices

To verify that RCDs have been correctly installed, tests shall be performed on all RCDs.

The function of the RCD shall be verified either by the operation of the integral test device, or by the use of special test equipment.

In all cases, isolation of all switched poles shall be verified after the RCD has operated to disconnect the designated circuit.

Isolation of all poles shall be verified by voltage tests or, after removing supply, by continuity checks through each pole.

Notes:

1. Tripping the RCD by means of the integral test device establishes
 - a) the RCD is functioning correctly

⁷ Source: AS/NZS 3000:2018 Clause 8.3.9.1 © Standards Australia. Used with permission.

and

b) the integrity of the electrical and mechanical elements of the tripping device.

2. Operation of the integral test device does not provide a means of checking
 - a) the continuity of the main earthing conductor or the associated circuit protective earthing conductors.
 - b) any earth electrode or other means of earthing
 or
 - c) any other part of the associated electrical installation earthing.
3. Guidance on the suitability of types of RCD is contained in Clause 2.6.2.2.
4. There is no requirement to test the operating time of RCDs. Operating time is a function of the type of RCD.
5. A suitable test could be performed using a test plug with a resistor between the active and earth pins.

Testing of RCDs in workplace electrical installations in accordance with division 6 of *Electrical Safety Regulation 2013* requires tests for the operating time of RCDs. Refer to AS/NZS 3012 Electrical installations – Construction and demolition sites and AS/NZS 3760 In-service inspection and testing of electrical equipment and RCDs.

Medical installations have specific requirements regarding the testing of RCDs. Refer to AS/NZS 3003 Electrical Installations-Patient areas.

Recording test results

The results of inspection and testing should be recorded. These records will assist supervisors to verify that all applicable inspection and testing have been completed, and the results support that the electrical installation is electrically safe.

Records should include:

- visual inspection
- a record of the testing conducted
- the results of the conducted tests
- the identity and/or licence number of the person responsible for completing the testing
- the date that the testing was conducted.

Careful consideration should be given to the methods used to record test results. Some methods may include any of the following:

- Results from test equipment with a data logging function.
- Results recorded on test sheets.

- Results recorded in software or an app.
- Photographs.
- Recordings.
- Checklists.

If any part of the electrical installation fails a test, that test and any preceding tests that may have been influenced by the fault indicated shall be repeated after the fault has been rectified.

Consideration should be given to ensuring the recording methods used, minimise distraction from the inspection and testing process. An example could be to have a second person recording the results when test sheets are used. A combination of recording methods may be most effective.

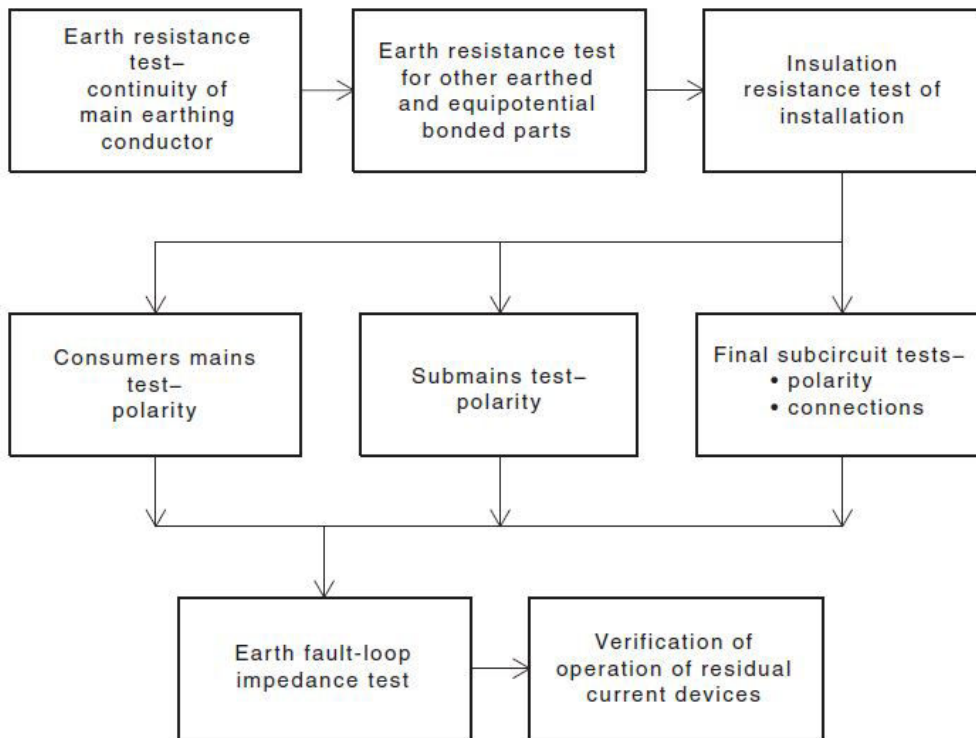
The results of inspection and testing should be kept for five years.

7. Testing procedure

Assume all exposed parts are energised until isolated and proved de-energised.

Additional guidance to assist with performing the following tests in an electrically safe manner is provided in AS/NZS 4836 Safe working on low-voltage electrical installations and the following guides:

- Fault currents.
- Isolation and lockout procedures.
- Safe working on or near energised electrical equipment.



Source: AS/NZS 3000:2018 Figure 8.1 © Standards Australia. Used with permission.

Figure 4 – Test sequence

7.1. Main earthing conductor resistance test

Sequence: (After visual inspection of installation):

1. Ensure all supplies are deenergised for example: by turning off all main switches.
Important: Ensure that alternate energy supplies are isolated at their source, prior to commencing testing.
2. Check operation of voltage indicator.
3. Test between load side of each main switches and neutral, result should indicate NO VOLTAGE is present.
4. Check operation of voltage indicator.
5. Disconnect main earthing conductor or MEN link from the neutral bar.
6. Check operation of ohmmeter and set zero Ω with leads connected together.
7. Test between disconnected main earthing conductor or MEN link and main earthing conductor at earth electrode. Results should indicate that resistance does not exceed 0.5 Ω .
8. Disconnect test leads.
9. Reconnect the main earthing conductor or MEN link at the neutral bar.

7.2. Equipotential bonding conductor resistance test

Test sequence:

1. Ensure supply is isolated.
2. Check operation of ohmmeter (set meter to zero Ω with leads connected together).
3. Test between each end of the equipotential bonding conductor under test. Results should indicate that resistance does not exceed 0.5 Ω (if trailing lead is used for this test, take the resistance of the lead into consideration).
4. Repeat steps 1-3 for each equipotential bonding conductor for example: bonding at conductive water pipes, swimming pool, conductive reinforcing, PV arrays and service support bracket bonding (where applicable).

Note: In some situations, such as the connection of equipotential bonding conductors to water piping or swimming pools, the parts to be bonded may not be accessible due to further building activities or enclosure.

- If this is expected to occur, testing at the bonded part should be carried out at the time of initial connection or other convenient time when the bonded part is still accessible.
- Where this is not practicable, the equipotential bonding may be proven by testing at a more convenient point on the parts which are to be earthed or bonded by the conductor.

In some situations, parallel paths may exist for example: a hot water system final subcircuit earthing conductor plus the equipotential bonding connection to conductive piping. In this case the parallel path shall be removed for testing and reconnected after testing.

7.3. Protective earthing conductor resistance test

Protective earthing conductor resistance test (whole installation)

Where a PEN submain is installed to supply a separate MEN installation in an individual outbuilding, testing shall confirm that the earth terminal, point or bar of the sub-board is connected via the PEN conductor to the earth terminal, point or bar of the main switchboard.

The earthing system in a separate MEN installation shall be connected to the submain neutral conductor supplying the outbuilding. In this case, the submain neutral conductor supplying the outbuilding is a combined protective earthing and neutral (PEN) conductor.

Where there is a possibility of a parallel connection between a protective earthing conductor and other conductive parts, for example: a water heater, the protective earthing conductor should be disconnected from the electrical device and tested independently.

Test sequence:

1. Ensure supply is isolated.
2. Disconnect the MEN link.

3. Check operation of ohmmeter and set zero Ω with leads connected together.
4. Test between main earthing conductor or earth bar and each part of the installation required to be earthed. Results should indicate that the resistance in each test is sufficiently low enough to allow the protective device to operate and complies with the requirements of AS/NZS 3000:2018 Clause 8.3.5.2. Refer to Table 8.2 Maximum value of resistances (if a trailing lead is used for this test, take the resistance of the lead into consideration).
5. Disconnect test leads.
6. After completing testing reconnect the MEN link and any other conductors disconnected to enable testing.

Protective earthing conductor resistance test (final subcircuit added to an existing installation)

1. Check operation of ohmmeter and set zero Ω with leads connected together.
2. Prior to connecting the final subcircuit earthing conductor to the earth bar - test between the earth conductor to be connected to the earthing bar and each part of the final subcircuit required to be earthed. Results should indicate that the resistance in each test is sufficiently low enough to allow the protective device to operate and complies with the requirements of AS/NZS 3000:2018 Clause 8.3.5.2. Refer to Table 8.2 Maximum value of resistances (if a trailing lead is used for this test, take the resistance of the lead into consideration).
3. Connect the final subcircuit earthing conductor to the earthing bar. test between the earthing bar and at least one part of the final subcircuit required to be earthed (this will verify the connection to the earth bar). Result shall be the same as in step 2.

PEN conductor resistance of long submain

Where the electrical installation includes a long submain to an outbuilding with a separate MEN connection, it may not be practicable to run a trailing lead to test the resistance of the PEN conductor. In such cases the following may be used to measure the resistance of the PEN conductor.

Test sequence:

1. Ensure supply is isolated.
2. Identify the submain neutral conductor and disconnect it from the neutral bar at the main switchboard.
3. Disconnect the submain neutral conductor from the neutral bar at the outbuilding switchboard.

Insulation test

4. Conduct an insulation test between the disconnected neutral conductor and associated active conductors. RESULT >1MΩ.
5. Temporarily bridge one submain active conductor to the disconnected submain neutral conductor at the main switchboard.

Continuity test

6. Check operation of low reading ohmmeter and set zero Ω with leads connected together.
7. Measure the resistance between the bridged active conductor and the submain neutral conductor at the outbuilding. RESULT XΩ.
8. Remove the temporary bridge and re-test the insulation between the submain active and neutral conductors. RESULT >1MΩ.
9. Reconnect the submain neutral conductor at the main switchboard and the outbuilding switchboard.
10. Where the submain active and neutral conductors are the same size the PEN conductor resistance can be calculated as X/2.

Example: X is measured at 0.52Ω, therefore $0.52/2 = 0.26$. The resistance of the submain neutral PEN conductor is 0.26Ω.

11. The resistance shall be consistent with the length, cross-sectional area, and type of conductor material. Refer to AS/NZS 3008 Table 34 for the a.c. resistance of single core cables (see Appendix D)

Note: If the neutral conductor is not the same size as the active conductor, the resistance can be calculated using the a.c. resistance of the cable. See guidance in step 3.3.

Earthing conductor resistance of a long submain with included earth conductor**Sequence:**

1. Ensure supply is isolated.
2. Identify the submain neutral conductor and disconnect it from the neutral bar at the main switchboard.
3. Disconnect the submain neutral conductor from the neutral bar at the distribution switchboard.

Insulation test

4. Conduct an insulation test between the disconnected neutral conductor and the included earth conductor. RESULT >1MΩ.
5. Temporarily bridge the submain earth conductor to the disconnected submain neutral conductor at the main switchboard.

Continuity test

6. Check operation of low reading ohmmeter and set zero Ω with leads connected together.
7. Measure the resistance between the bridged earth conductor and the submain neutral conductor at the distribution switchboard. RESULT $X\Omega$.
8. Remove the temporary bridge and re-test the insulation between the submain earth and neutral conductors. RESULT $>1M\Omega$.
9. Reconnect the submain neutral conductor at the main switchboard and the outbuilding switchboard.

Using method 1, 2 or 3 calculate the earth resistance.

Calculation method 1

10. Refer to Appendix D: Table 34 a.c. Resistance of cables. Obtain the a.c. resistance values per km for the applicable conductor size and type. Example: 16mm Cu neutral (RN) 1.26 Ω /km, with 6mm Cu earth (RE) 3.38 Ω /km.
11. Sum the values to obtain total resistance 1.26 + 3.38 = (RT) 4.64. Determine the ratio of earth resistance RE to total resistance (RT). $RE/RT = 3.38/4.64 = 0.728$ or 72.8%.
12. The earth conductor resistance can be calculated as measured resistance X multiplied by the ratio RE/RT. Example: X is measured at 0.52 Ω , therefore $0.52\Omega \times 0.728 = 0.38\Omega$. The resistance of the submain earth conductor is 0.38 Ω .

Calculation method 2

Note: Steps 10 to 12 may be replaced with the following simplified method.

$$Re = \frac{Rm \times An}{Ae + An}$$

Re = Resistance of the earthing conductor in Ω .

Rm = Measured resistance of bridge N & E conductors.

An = Cross sectional area of neutral conductor in mm^2 .

Ae = Cross sectional area of earth conductor mm^2 .

$$\text{Example: } Re = \frac{0.52 \times 16}{6 + 16} = \frac{8.32}{22} = 0.38\Omega$$

Calculation method 3

Multiply Rm by the RE/RT ration from Table 2 below.

$$\text{Example: } Re = RT \times \text{ratio } r = 0.52 \times 0.727 = 0.38\Omega$$

Table 2 – RE/RT ratio for common cables

RE/RT ratio for common cables		
Neutral mm ²	Earth mm ²	RE/RT Ratio (<i>r</i>)
1mm ²	1mm ²	0.5
1.5mm ²	1.5mm ²	0.5
2.5 mm ²	2.5 mm ²	0.5
4 mm ²	2.5 mm ²	0.615
6 mm ²	2.5 mm ²	0.705
10 mm ²	4 mm ²	0.714
16 mm ²	6 mm ²	0.727
25 mm ²	6 mm ²	0.806
35 mm ²	10 mm ²	0.777

Mandatory requirement

The resistance shall be consistent with the length, cross-sectional area and type of conductor material and meet the requirements of AS/NZS 3000 Table 8.2 where automatic disconnection is used for fault protection. Refer to AS/NZS 3008 Table 34 for the a.c. resistance of single core cables(see Appendix D).

7.4. Insulation resistance

1A Insulation resistance test of complete installation

Test sequence:

1. Check operation of voltage indicator.
2. All circuits, including consumer mains, sub-mains and final sub-circuits shall be proven de-energised and isolated from supply before they are tested.
3. Consumer mains shall not be connected to the distribution neutral conductor, and the installation MEN link shall be removed.
4. Conductors where metering or service equipment is to be installed will require bridging or each conductor will require a separate test.
5. Outbuildings or other distribution boards that have additional MEN or N-E connections, such connections shall be disconnected before conducting the test.
6. Isolate and test all alternate sources of supply.

7. Check operation of voltage indicator.
8. Disconnect all portable appliances and ensure all circuit switches are ON.
9. Check operation of insulation resistance test instrument and set to $M\Omega$.
10. Test between each live conductor and each other live conductor of consumers mains and submains.
11. Test between all live (active and neutral) conductors and earth for consumers mains, submains and final subcircuits. Note: Two way or intermediate switching shall be tested in all positions. Electronic (smart switches), contactors or relays may require bridging for the test.
12. Test between all live (active and neutral) conductive parts and earthed parts (earthing system) of equipment connected to the installation.
13. Result should comply with Clause 8.3.6. e.g. not less than $1 M\Omega$ with appliances disconnected. For sheathed heating elements of appliances, not less than $0.01 M\Omega$.
14. Reconnect MEN link and remove any bridging installed for testing.

Notes:

Avoid overvoltage damage of electronic devices by connecting the active and neutral conductors together.

Surge protection devices or other equipment likely to influence the test or be damaged, should be disconnected before carrying out the resistance tests. Where it is not reasonably practical to disconnect such equipment (e.g. in the case of fixed socket-outlets incorporating an SPD) the test voltage of the particular circuit shall be reduced to 250 V d.c. The insulation resistance shall have a value of at least $1 M\Omega$.

If a low insulation test is measured, isolate the active and neutral conductors for each circuit and test insulation of each circuit individually. Refer to section 6.4.1B for testing insulation of a final subcircuit. All sections of the installation affected by a fault or repair, shall be retested after the installation is altered or repaired.

1B Insulation resistance test of a final subcircuit or submain

Test sequence:

1. Check operation of voltage indicator.
2. Disconnect or otherwise isolate all active and neutral conductors for the circuit to be tested. The final sub-circuit shall be proven de-energised and isolated from all sources of supply.
3. Outbuildings or other distribution boards that have additional MEN or N-E connections, such connections shall be disconnected before conducting the test.
4. Check operation of voltage indicator.

5. Disconnect all portable appliances and ensure all circuit switches are ON.
6. Check operation of insulation resistance test instrument and set to $M\Omega$.
7. Test between each live conductor and each other live conductor of submains. Do not test between live conductors of final subcircuits unless all electronic equipment has been disconnected from the circuit.
8. Test between all live (active and neutral) conductors and earth for the submain or final subcircuit under test. Note: Two way or intermediate switching shall be tested in all positions. Electronic (smart switches), contactors or relays may require bridging for the test.
9. Test between all live (active and neutral) conductive parts and earthed parts (earthing system) of equipment connected to the installation.
10. Result should comply with Clause 8.3.6, for example: not less than $1 M\Omega$ with appliances disconnected. For sheathed heating elements of appliances, not less than $0.01 M\Omega$.

Note: Low impedance test equipment, for example: test lamps, may not operate correctly when used in conjunction with an independent earth electrode not connected to the electrical installation earthing system, so use of a voltmeter is recommended.

7.5. Polarity test of consumers mains using voltage indicator (supply connected)

Note: Additional information is available in the Guide for service and submain polarity testing

Test sequence:

Some of the following tests involve energised electrical equipment. Ensure a safe system of work is in place before commencing any testing where supply is connected.

Ensure persons are protected from contact with live parts during testing. Ensure that the available fault current has been assessed and appropriate measures taken with regard to the available incident energy.

Prove polarity

1. Ensure appropriate verification and inspection tests have been carried out including the consumers mains and main switchboard.
2. Check operation of voltage indicator.
3. Turn main switch/s OFF, including alternate supplies.
4. Turn OFF all circuit protective devices at switchboard.
5. Disconnect any bonding conductor provided to bond the service neutral to a service support.

6. Disconnect the main earth or MEN as applicable and the main neutral from the neutral link.
7. An independent earth shall be positioned in the ground remote (greater than two metres) from any conductive metallic surfaces that are in contact with the general mass of earth, including the earth stake.
8. Ensure consumers mains are connected to entity service conductors and energise the consumer mains.
9. Test between the main neutral and line terminal of the main switch (es). Results should indicate PHASE (230V) VOLTAGE.
10. Test between main neutral and independent earth. Results should indicate NO VOLTAGE.
11. Test between main earth conductor and independent earth. Results should indicate NO VOLTAGE.
12. Test between the line terminal of the main switch and independent earth. Result should indicate PHASE (230V) VOLTAGE.
13. If a multiphase installation, test between line terminals at main switch. Results should indicate LINE (400V) VOLTAGE.

Prove neutral integrity (EFLI Method)

14. Connect a fault loop impedance test instrument neutral and earth leads to the main neutral (PEN) conductor.
15. Connect the fault loop impedance test instrument active lead to a line terminal of the main switch.
16. Carry out Fault Loop Impedance test. The result should be less than 1Ω . The length and size of the supply conductors and consumer mains and submain should be considered. A result $>0.5\Omega$ may require further investigation.

Where the EFLI test instrument has a 'no trip' low current test and a 'trip' high current test selection, this test shall be performed using the 'trip' high current setting.

Note: Alternative tests include Voltage Method and Current Method as per AS:4741-2010, Appendix B3 or AS/NZS 3017 section 4.12.

Reconnection

17. If correct indications were obtained for all tests, reconnect main neutral (PEN conductor) then the MEN connection. Ensure connections are correctly made.
18. If a bonding conductor was removed at the point of attachment, use a proximity test instrument to:

- Test an active conductor. RESULT Indication.
- Test the neutral bond tail. RESULT No indication.
- Test the service bracket. No indication.
- Connect the bond and confirm the bonded metalwork is not live. RESULT No indication.
- Test an active conductor. RESULT Indication

19. Turn main switch (es) ON.

20. Check for correct phase rotation.

21. Close all other circuit protection devices and alternative supplies as found prior to carrying out testing.

22. To verify main neutral connection and MEN integrity, a fault loop impedance test at a convenient socket outlet is recommended.

23. Apply a proximity test instrument to any part of the earthing system to confirm it is not energised.

Polarity test of consumers mains using ohmmeter (supply not connected)

Note: Additional information is available in the Guide for service and submain polarity testing.

Test sequence:

Prove polarity

1. Ensure appropriate verification and inspection tests have been carried out including the consumers mains and main switchboard.
2. Ensure all conductors from the supply are NOT connected to the installation.
3. Turn main switch (es) OFF, including alternate supplies.
4. Bridge conductors where metering and service equipment is not installed.
5. Set meter to read Ω – set 0 Ω with leads connected together.
6. Measure the resistance of the active conductor of the consumer mains between the point of connection and the line side of the main switch. Repeat for each active supply conductor. RESULT 0 Ω .
7. Measure the resistance of the neutral conductor of the consumer mains between the point of connection and the neutral bar. RESULT 0 Ω .
8. After completing the tests remove metering and service equipment bridging conductors.

7.6. Polarity test of submains with men connection at outbuilding (supply connected)

Note: Additional information is available in the Guide for service and submain polarity testing.

Test sequence:

Prove polarity

1. Ensure appropriate verification and inspection tests have been carried out.
2. Identify the submain protection device and place it in the OFF position.
3. Check operation of voltage indicator.
4. Confirm correct identification of supply isolation device. Measure the voltage between the line side of the main switch and neutral bar at the outbuilding switchboard.
5. Turn main switch (es) at outbuilding OFF, including alternate supplies.
6. Turn OFF all circuit protective devices at outbuilding.
7. Disconnect the main earth or MEN as applicable and the main neutral (PEN conductor) from the neutral link in the outbuilding.
8. An independent earth shall be positioned in the ground remote (greater than 2 metres) from any conductive metallic surfaces that are in contact with the general mass of earth, including the earth stake.
9. Energise the submain to the outbuilding.
10. Test between the main neutral (PEN conductor) and line terminal of the main switch (es). Results should indicate PHASE (230V) VOLTAGE.
11. Test between main neutral (PEN conductor) and independent earth. Results should indicate NO VOLTAGE.
12. Test between main earth conductor and independent earth. Results should indicate NO VOLTAGE.
13. Test between the line terminal of the main switch and independent earth. Result should indicate PHASE (230V) VOLTAGE.
14. If a multiphase installation, test between line terminals at main switch. Results should indicate LINE (400V) VOLTAGE.

Prove Neutral Integrity (EFLI Method)

15. Connect a fault loop impedance test instrument neutral and earth leads to the main neutral (PEN) conductor.
16. Connect the fault loop impedance test instrument active lead to a line terminal of the main switch.

17. Carry out fault loop impedance test. The result should be less than 1Ω . The length and size of the supply conductors and consumer mains should be considered.

Important: Where the EFLI test instrument has a 'no trip' low current test and a 'trip' high current test selection, this test shall be performed using the 'trip' high current setting.

Note: Alternative tests include Voltage Method and Current Method as per AS:4741-2010, Appendix B3 or AS/NZS 3017 section 4.12.

Reconnection

18. Place the submain protection device in the OFF position.
19. If correct indications were obtained for all tests, reconnect main neutral then the MEN connection. Ensure connections are correctly made.
20. Place the submain protection device in the ON position.
21. Turn main switch (es) ON.
22. Check for correct phase rotation.
23. Close all other circuit protection devices and alternative supplies as found prior to carrying out testing.
24. To verify main neutral connection and MEN integrity, a fault loop impedance test at a convenient socket outlet is recommended.
25. Apply a proximity test instrument to any part of the earthing system to confirm it is not energised.

Polarity test of submains with MEN connection at outbuilding (supply not connected)

Note: Additional information is available in the Guide for service and submain polarity testing.

Test sequence:

Prove polarity

1. Ensure appropriate verification and inspection tests have been carried out.
2. At main switchboard (MSB) confirm isolation of all main switches.
3. At MSB confirm isolation of the submain Circuit protective device (CPD).
4. At distribution switchboard (DSB) turn isolation/main switch (es) at OFF, including alternate supplies.
5. At DSB Turn OFF all circuit protective devices.
6. At DSB Disconnect the submain neutral from the neutral link.
7. At DSB Disconnect main earth conductor.
8. At MSB, Install a temporary bridge between the load side of the submain CPD and the neutral bar.

9. Set meter to read Ω – set 0 Ω with leads connected together.
10. At DSB Measure resistance between the line side active conductor and the disconnected main neutral conductor. RESULT $\approx 0 \Omega$. If polyphase repeat test for each phase conductor.
11. At MSB Remove the temporary bridge.
12. At DSB Measure resistance between the line side active conductor and the disconnected main neutral conductor. RESULT $\approx \infty \Omega$. If polyphase repeat test for each phase conductor.
13. Set insulation test instrument to the 500V range.
14. At DSB Measure resistance between the line side active conductor and the disconnected main earth conductor. RESULT $\approx \infty \Omega$. If polyphase repeat test for each phase conductor.
15. At DSB measure resistance between disconnected main neutral conductor and disconnected main earth conductor. RESULT $\approx$ A LOW INSULATION VALUE. (The actual measured value will depend upon soil resistance at the location)
16. After completing the tests reconnect the submain neutral and earthing conductors at the distribution board.

7.7. Polarity test of submain incorporating protective earthing conductor (supply connected)

Note: Additional information is available in the Guide for service and submain polarity testing.

Test sequence:

1. Ensure appropriate verification and inspection tests have been carried out.
2. At main switchboard (MSB) Identify the submain protection device, place it in the OFF position and ensure appropriate isolation and lockout.
3. Check operation of voltage indicator.
4. At distribution switchboard (DSB) Confirm correct identification of supply isolation device. Measure the voltage between the line side of the main switch and neutral bar. RESULT 0V
5. At DSB Turn isolation/main switch (es) at OFF, including alternate supplies.
6. At DSB Turn OFF all circuit protective devices.
7. At DSB Disconnect the submain neutral from the neutral link.
8. At MSB Place the submain protection device in the ON position.
9. At MSB Test between load side of submain protective device and neutral bar. RESULT PHASE (230V) VOLTAGE.

10. At DSB Test between line side of isolation switch and the submain neutral conductor.
RESULT PHASE (230V) VOLTAGE.
11. At DSB Test between the earth bar (submain earth) and the submain neutral conductor.
RESULT NO VOLTAGE.
12. At DSB Test between line side of isolation switch and the earth bar (submain earth).
Results should indicate PHASE (230V) VOLTAGE.
13. At MSB Place submain protection device in the OFF position.
14. At DSB Reconnect the submain neutral to the neutral link.
15. At MSB and DSB Energise/re-energise the distribution switchboard.
16. To verify earthing system integrity, a fault loop impedance test may be carried out at a convenient socket outlet supplied from the DSB.

7.8. Polarity test of submain incorporating protective earthing conductor (supply not connected)

Note: Additional information is available in the guide for service and submain polarity testing.

Test sequence:

1. Ensure appropriate verification and inspection tests have been carried out.
2. At main switchboard (MSB) Identify the submain protection device, place it in the OFF position and ensure appropriate isolation and lockout.
3. At distribution switchboard (DSB) Turn isolation/main switch (es) at OFF, including alternate supplies.
4. At DSB Turn OFF all circuit protective devices.
5. At DSB Disconnect the submain neutral from the neutral link.
6. At DSB Disconnect submain earth conductor from the earth bar.
7. Set meter to read Ω – set $0\ \Omega$ with leads connected together.
8. At DSB Measure resistance between the disconnected submain earthing conductor and the line side of the protective devices or DSB isolator as applicable. RESULT $\approx \infty\ \Omega$. If polyphase repeat test for each phase conductor.
9. At DSB Measure the resistance between the disconnected submain earthing conductor of the distribution board and the disconnected submain neutral conductor. RESULT $\approx 0\ \Omega$.
10. After completing the tests reconnect the submain neutral and earthing conductors at the DSB.
11. Reverse isolation as required.

Note: Where the submain is short, a trailing lead may be used between the MSB and DSB to test polarity. Refer to AS/NZS 3017:2022 Figure 4.8 for more detail.

Polarity and correct circuit connection test of lighting points using voltage indicator and voltmeter (supply connected)

Sequence:

1. Ensure appropriate verification and inspection tests have been carried out (earth continuity, insulation and polarity of consumer mains and any applicable submain).

Note: Earth continuity testing shall be conducted with the final subcircuit neutral conductor disconnected either physically or via an RCBO which switches all poles.

When performing earth continuity also test to the neutral at each point and verify no continuity. This will confirm that there is no interconnection with earth and the correct circuit neutral has been disconnected.

If physically disconnected, the final subcircuit neutral conductor shall be reconnected prior to proceeding.

2. Check operation of high impedance voltage indicator and/or voltmeter.
3. Confirm isolation of all main switches.
4. Remove isolation and place main switch (normal supply only) ON.
5. Place the final subcircuit protection device of circuit under test at the switchboard in the ON position.
6. Test lighting point between active and neutral terminals. Results should indicate:
 - (i) With switch ON – $\approx 230\text{V}$.
 - (ii) With switch OFF – $\approx 0\text{V}$.
7. Test lighting point between earth and neutral. Results should indicate:
 - (i) With switch ON – $\approx 0\text{V}$.
 - (ii) With switch OFF – $\approx 0\text{V}$.
8. Test lighting point between active and earth. Results should indicate:
 - (i) With switch ON – $\approx 230\text{V}$.
 - (ii) With switch OFF – $\approx 0\text{V}$.
9. Test between light switch line active and earth. Results should indicate:
 - (i) With switch ON – $\approx 230\text{V}$.
 - (ii) With switch OFF – $\approx 230\text{V}$.

Note: A correct reading in step 9 verifies the voltmeter operation.

Polarity test of single pole switch using an ohmmeter (supply not available)**Test sequence:**

1. Turn OFF circuit protection device for circuit under test and confirm the circuit is de-energised (lock out as required).
2. Set meter to read Ω – set 0 Ω with leads connected together.
3. Connect one test lead to load side of protective device.
4. Connect other test lead to terminals (one at a time) of switch under test.
5. Test that resistance is:
 - (i) With switch ON $\approx 0 \Omega$ (short circuit) both terminals
 - (ii) With switch OFF $\approx 0 \Omega$ (short circuit) line terminal
and
 - (iii) Infinity (open circuit) load terminal.
6. Disconnect test leads.

Polarity and correct circuit connection test of lighting points using resistors (supply not available)**Test sequence:**

1. Isolate circuit at circuit protective device for circuit under test.
2. Disconnect active and neutral conductor for circuit under test.
3. Remove lamps or disconnect lamp loads from circuit under test (i.e. unplug downlight from socket outlet).
4. Connect 10 Ω resistor between disconnected circuit active conductor and disconnected circuit neutral conductor.
5. Connect 5 Ω resistor between disconnected neutral conductor and the earth bar.
6. Set meter to read Ω – set zero Ω with leads connected together.

Polarity test:

7. Connect one test lead to earth of lighting point under test.
8. Connect other test lead to active of lighting point under test.
9. Check that test results indicate:
 - (i) With control switch ON, $\approx 15\Omega$.
 - (ii) With control switch OFF, $\approx \infty \Omega$.
10. Connect one test lead to earth of lighting point under test.

11. Connect other test lead to neutral of lighting point under test.
12. Check that test results indicate:
 - (i) With control switch ON, $\approx 5\Omega$.
 - (ii) With control switch OFF, $\approx 5\Omega$.
13. Connect one test lead to active of lighting point under test.
14. Connect other test lead to neutral of lighting point under test.
15. Check that test results indicate:
 - (i) With control switch ON, $\approx 10\Omega$.
 - (ii) With control switch OFF, $\approx \infty \Omega$.
16. Repeat the polarity and circuit connection tests for each light point.
17. After completing the tests, disconnect the resistors and reconnect active and neutral conductors to their respective circuit protective device.

Note: All switch positions/combinations need to be tested in two-way and intermediate switching applications and on the load side of devices such as contactors.

Note: Where electronic switching devices are utilised, testing the switch polarity may require temporary bridging of the device.

Polarity and correct circuit connection test of socket-outlets using voltage indicator (supply connected)

Test sequence:

1. Ensure appropriate verification and inspection tests have been carried out (earth continuity, insulation and polarity of consumer mains and any applicable submain).

Note: Earth continuity testing shall be conducted with the final subcircuit neutral conductor disconnected either physically or via an RCBO which switches all poles.

When performing earth continuity also test to the neutral at each point and verify no continuity. This will confirm that there is no interconnection with earth and the correct circuit neutral has been disconnected.

If physically disconnected, the final subcircuit neutral conductor shall be reconnected prior to proceeding.

2. Check operation of high impedance voltage indicator and/or voltmeter.
3. Confirm isolation of all main switches.
4. Remove isolation and place main switch (normal supply only) ON.
5. Place the final subcircuit protection device of circuit under test at the switchboard in the ON position.

6. Test between active and neutral terminals of socket outlet. Results should indicate:
 - (i) With switch ON – $\approx 230\text{V}$.
 - (ii) With switch OFF – $\approx 0\text{V}$.
7. Test each socket outlet between earth and neutral terminals of socket outlet. Results should indicate:
 - (i) With switch ON – $\approx 0\text{V}$.
 - (ii) With switch OFF – $\approx 0\text{V}$.
8. Test between active and earth. Results should indicate:
 - (i) With switch ON – $\approx 230\text{V}$.
 - (ii) With switch OFF – $\approx 0\text{V}$.
9. Check operation of high impedance voltage indicator and/or voltmeter.

Polarity and correct circuit connection test of socket-outlets using resistors (supply not available)

Test sequence:

1. Isolate circuit at circuit protective device for circuit under test.
2. Disconnect active and neutral conductor for circuit under test.
3. Ensure that no loads are connected to the circuit under test.
4. Connect 10Ω resistor between disconnected circuit active conductor and disconnected circuit neutral conductor.
5. Connect 5Ω resistor between disconnected neutral conductor and the earth bar.
6. Set meter to read Ω – set zero Ω with leads connected together.

Polarity test:

7. Connect one test lead to earth of the socket outlet under test.
8. Connect other test lead to active of socket outlet under test.
9. Check that test results indicate:
 - (i) With control switch ON, $\approx 15\Omega$.
 - (ii) With control switch OFF, $\approx \infty \Omega$.
10. Connect one test lead to earth of socket outlet under test.
11. Connect other test lead to neutral of socket outlet under test.
12. Check that test results indicate:
 - (i) With control switch ON, $\approx 5\Omega$.
 - (ii) With control switch OFF, $\approx 5\Omega$.

13. Connect one test lead to the active of socket outlet under test.
14. Connect other test lead to neutral of socket outlet under test.
15. Check that test results indicate:
 - (i) With control switch ON, $\approx 10\Omega$.
 - (ii) With control switch OFF, $\approx \infty \Omega$.
16. Repeat the polarity and circuit connection tests for each socket outlet.
17. After completing the tests, disconnect the resistors and reconnect active and neutral conductors to their respective circuit protective device.

Check of phase sequence and polarity of polyphase socket outlet or polyphase electrical equipment (supply not available – trailing lead method)

Test sequence:

1. Confirm isolation of circuit under test.
2. Check operation of voltage indicator.
3. Test between each active and earth. Result should indicate NO VOLTAGE is present.
4. Perform IR test between earth and the circuit conductors and then between conductors to ensure the conductors are electrically isolated from each other.
5. Bridge across the line and load terminal for switching devices such as contactors and electronic control equipment that may contain contactors/relays.
6. Disconnect the load terminals at permanently connected consumer equipment.
7. Place socket outlet or equipment isolation switch in the ON position.
8. Check operation of ohmmeter and set zero Ω with leads connected together (when a trailing lead is used the resistance of the trailing lead shall be considered).
9. Connect test lead to load side of protective device A (red) PHASE.
10. Connect other test lead to L1 contact on 3 phase socket outlet or electrical equipment.
RESULT SHOULD BE $\approx 0 \Omega$.
11. Connect test lead to load side of protective device B (white) PHASE.
12. Connect other test lead to L2 contact on 3 phase socket outlet or electrical equipment.
RESULT SHOULD BE $\approx 0 \Omega$.
13. Connect test lead to load side of protective device C (blue) PHASE.
14. Connect other test lead to L3 contact on 3 phase socket outlet or electrical equipment.
RESULT SHOULD BE $\approx 0 \Omega$.
15. Disconnect the circuit neutral conductor at the neutral link or circuit protective device (if applicable).

16. Connect test lead to disconnected circuit neutral conductor.
17. Connect other test lead to neutral contact on 3 phase socket outlet or electrical equipment. RESULT SHOULD BE $\approx 0 \Omega$.
18. Disconnect test leads.
19. Reverse isolation if applicable.

Note: This test can be completed at the same time as earth continuity testing, for convenience.

Polarity and correct circuit connection test of equipment using voltage indicator (supply connected)

Test sequence:

1. Ensure appropriate verification and inspection tests have been carried out (earth continuity, insulation and polarity of consumer mains and any applicable submain).

Note: Earth continuity testing shall be conducted with the final subcircuit neutral conductor disconnected either physically or via an RCBO which switches all poles.

When performing earth continuity also test to the neutral at each point and verify no continuity. This will confirm that there is no interconnection with earth and the correct circuit neutral has been disconnected.

If physically disconnected, the final subcircuit neutral conductor shall be reconnected prior to proceeding.

2. Check operation of high impedance voltage indicator and/or voltmeter.
3. Confirm isolation of all main switches.
4. Remove isolation and place main switch (normal supply only) ON.
5. Place the final subcircuit protection device of circuit under test at the switchboard in the ON position.
6. Test electrical equipment between active and neutral terminals. Results should indicate:
 - (i) With switch ON – $\approx 230V$.
 - (ii) With switch OFF – $\approx 0V$.
7. Test electrical equipment between earth and neutral terminals. Results should indicate:
 - (i) With switch ON – $\approx 0V$.
 - (ii) With switch OFF – $\approx 0V$.
8. Test electrical equipment between active and earth. Results should indicate:
 - (i) With switch ON – $\approx 230V$.
 - (ii) With switch OFF – $\approx 0V$.
9. Test between isolation switch line active and equipment earth. Results should indicate:

- (i) With switch ON – $\approx 230\text{V}$.
- (ii) With switch OFF – $\approx 230\text{V}$.

10. Note correct reading in step 10 verifies the voltmeter.

Note: If equipment is remotely controlled and supply is not available, you may need to follow procedure for testing when supply is not connected or by-pass the control relay or contactor.

Polarity and correct circuit connection test of equipment (supply not available)

Test sequence:

1. Isolate circuit at circuit protective device for circuit under test.
2. Set meter to read Ω – set zero Ω with leads connected together.
3. Verify that MEN connection is in at switchboard or upstream if equipment is supplied from a sub-board supplied by included earth.
4. If isolation device is an RCD switching all poles, the neutral contact will require bridging for the tests.
5. Place circuit control switch and any appliance switch in the ON position.
6. Test between active and neutral terminal at terminal block of equipment under test. Results should indicate the resistance value is equal to the load of the equipment e.g. a 4.8KW heating equipment $\approx 12\Omega$ at 240V.
7. Test between active and earth terminal at terminal block. Results should indicate the resistance value is equal to the load of the equipment e.g. a 4.8KW heating equipment $\approx 12\Omega$ at 240V.
8. Test between neutral and earth connection at terminal block of equipment. Results should indicate resistance $\approx 0\Omega$.
9. Disconnect the final subcircuit neutral conductor from the neutral bar or remove the bridge across the RCD neutral contact.
10. Test between active and earth terminal at terminal block. Results should indicate $\approx \infty \Omega$
11. Test between neutral and earth connection at terminal block of equipment. Results should indicate resistance is $\approx \infty \Omega$.
12. Repeat the polarity and correct connection test for each phase of all multi-phase appliances
13. Verify meter - zero Ω with leads connected together.
14. After completing the tests, reconnect all conductors disconnected for testing and remove any bridges across switching devices.

7.9. Interconnection test between conductors of different circuits (supply not connected)

Test sequence:

1. Turn main switch (es) OFF, including alternate supplies and confirm isolation.
2. Open circuit protective device for the circuit under test.
3. Close all other circuit protection devices.
4. Disconnect load neutral conductor of circuit under test.
5. For the circuit under test, and for all other circuits, place all control switches in the ON position and bridge all other switching devices (for example: relays, contactors)
6. Set meter to Ω range and verify operation.
7. Test between the neutral conductor of the circuit under test and each live (active/s and neutral conductors) of every other circuit. RESULT $\approx \infty \Omega$.
8. Test between each active conductor of the circuit under test and each live (active and neutral conductors) of every other circuit. RESULT $\approx \infty \Omega$.
9. Check operation of Ω meter.
10. After completing the tests, reconnect the disconnected neutral conductors and remove any bridges installed in step 5.
11. Repeat steps 1-10 for other circuits to be tested.

Note: Where any circuit includes two-way switching; tests from or to that conductor shall be repeated with one of the switches reversed.

Caution: This procedure does not confirm there are no interconnections with circuits originating at other switchboards. Interconnections are most likely to occur where more than one circuit is connected within a common enclosure.

7.10. Check of phase sequence and polarity of polyphase socket outlet or polyphase electrical equipment (supply not available – resistor method)

Test sequence:

1. Confirm isolation of circuit under test.
2. Check operation of voltage indicator.
3. Test between each active and earth. Result should indicate NO VOLTAGE is present.
4. Perform IR test between earth and the circuit conductors and then between conductors to ensure the conductors are electrically isolated from each other.

5. Bridge across the line and load terminal for switching devices such as contactors and electronic control equipment that may contain contactors/relays.
6. Disconnect the load terminals at the permanently connected consumer equipment.
7. Disconnect the circuit neutral conductor at the neutral link or circuit protective device (if applicable)
8. Place socket outlet or equipment isolation switch in the ON position.
9. Connect the following resistors at the switchboard:
 - (i) A (red) PHASE to earth 10 Ω
 - (ii) B (white) PHASE to earth 20 Ω
 - (iii) C (blue) PHASE to earth 50 Ω
 - (iv) Disconnected circuit neutral to earth 5 Ω
10. Check operation of ohmmeter and set zero Ω with leads connected together.
11. Complete the following resistance measurements at the socket outlet or equipment:
 - (i) A (red) PHASE to earth RESULT SHOULD BE $\approx 10 \Omega$
 - (ii) B (white) PHASE to earth RESULT SHOULD BE $\approx 20 \Omega$
 - (iii) C (blue) PHASE to earth RESULT SHOULD BE $\approx 50 \Omega$
 - (iv) Neutral (where applicable) to earth RESULT SHOULD BE $\approx 5 \Omega$
12. After completing tests, disconnect resistors.
13. Re-connect sub circuit neutral conductor.
14. Reverse isolation as required.

Check of phase sequence and polarity of polyphase socket outlet or polyphase electrical equipment (supply not available – trailing lead method)

Test sequence:

1. Confirm isolation of circuit under test.
2. Check operation of voltage indicator.
3. Test between each active and earth. Result should indicate NO VOLTAGE is present.
4. Perform IR test between earth and the circuit conductors and then between conductors to ensure the conductors are electrically isolated from each other.
5. Bridge across the line and load terminal for switching devices such as contactors and electronic control equipment that may contain contactors/relays.
6. Disconnect the load terminals at permanently connected consumer equipment.
7. Place socket outlet or equipment isolation switch in the ON position.

8. Check operation of ohmmeter and set zero Ω with leads connected together. (When a trailing lead is used the resistance of the trailing lead shall be considered)
9. Connect test lead to load side of protective device A (red) PHASE.
10. Connect other test lead to L1 contact on 3 phase socket outlet or electrical equipment.
RESULT SHOULD BE $\approx 0 \Omega$.
11. Connect test lead to load side of protective device B (white) PHASE.
12. Connect other test lead to L2 contact on 3 phase socket outlet or electrical equipment.
RESULT SHOULD BE $\approx 0 \Omega$.
13. Connect test lead to load side of protective device C (blue) PHASE.
14. Connect other test lead to L3 contact on 3 phase socket outlet or electrical equipment.
RESULT SHOULD BE $\approx 0 \Omega$.
15. Disconnect the circuit neutral conductor at the neutral link or circuit protective device (if applicable).
16. Connect test lead to disconnected circuit neutral conductor.
17. Connect other test lead to neutral contact on 3 phase socket outlet or electrical equipment. RESULT SHOULD BE $\approx 0 \Omega$.
18. Disconnect test leads.
19. Reverse isolation if applicable.

Note: This test may be completed at the same time as earth continuity testing, for convenience.

Check of phase sequence of polyphase socket outlets (supply connected).

Test sequence:

1. Using a phase rotation meter, connect/clamp the test probes in accordance with the test instrument manufacturer's instructions and record the test result.
2. If the circuit under test has phase sensitive equipment connected (for example: roller door, motor etc.) and provided the rotation result is correct, energise the equipment and check the operation is in the correct direction of travel.
3. RESULT: Phase sequence testing of socket outlets shall show a consistent phase polarity across all multi-phase socket-outlets of the same type of the installation on the circuit and be compatible with the operational requirements of connected consumer equipment.

7.11. Fault-loop impedance test (supply connected)

Where an installation includes circuits satisfying (a), (b) and (c) below, EFLI testing, in accordance with AS/NZS clause 8.3.9.2, shall be carried out for those circuits:

- Fault protection is by automatic disconnection of supply.
- Supplying one or more socket-outlets.
- Where socket-outlets are not protected by a residual current device with a residual current rating of 30 mA or less.

Earth continuity, insulation, interconnection and polarity tests should be carried out prior to measuring the fault-loop impedance.

Where supply is available, the earth fault-loop impedance for each branch of each final subcircuit shall be determined using an Earth Fault-Loop Impedance (EFLI) test instrument at the socket-outlet furthest from the supply on each branch of the final subcircuit.

The MEN connection shall be left intact.

The maximum value of fault-loop impedance shall not exceed the values shown in AS/NZS 3000:2018 Table 8.1 (see Appendix A).

Note: Deenergised tests as per step 6.11.2 in combination with an energised test at a suitable socket outlet, using a plug in EFLI test instrument may provide practical risk management, whilst ensuring the integrity of the installation including components upstream of the circuit protective device for the circuit.

Test sequence:

1. Ensure that the circuits to be tested are energised.
2. At the furthest point on each branch of the circuit, insert the EFLI test instrument plug and switch the outlet ON. Note – Some socket outlets may require adaptors for the safe connection of the EFLI test instrument.
3. Initiate an EFLI test and record results.
4. Check that the results do not exceed values shown in AS/NZS 3000:2018 Table 8.1 (see Appendix A).

Measurement of an individual circuit earth fault-loop impedance (supply not connected)

Where supply is not connected the resistance of the conductors of an individual circuit, which forms part of the fault-loop, may be measured by a low reading ohmmeter.

Test sequence:

1. Verify isolation of circuit under test.
2. Check operation of voltage indicator.
3. Test between active and neutral at switchboard. Result should indicate NO VOLTAGE is present.
4. Make a temporary connection between the load side of circuit protective device and the earth bar at the switchboard.

5. Check operation of ohmmeter and set zero Ω with leads connected together.
6. At furthest point on circuit, switch the socket outlet ON. Test between active and earth contacts. Result should indicate that the resistance does not exceed the R_{phe} value in AS/NZS 3000:2018 Table 8.2 (maximum values of resistances).
7. Remove temporary connection between the load side of circuit protective device and the earth bar at the switchboard.
8. Reverse isolation as required.

7.12. Verification of operation of residual current breaker (RCD) (supply connected)

To verify that RCDs have been correctly installed, tests shall be performed on all RCDs.

The function of the RCD shall be verified either by the operation of the integral test device, or by the use of special test equipment.

In all cases, isolation of all switched poles shall be verified after the RCD has operated to disconnect the designated circuit.

Isolation of all poles shall be verified by voltage tests or, after removing supply, by continuity checks through each pole.

Notes:

1. Tripping the RCD by means of the integral test device establishes:
 - a) the RCD is functioning correctly
 - and
 - b) the integrity of the electrical and mechanical elements of the tripping device.
2. Operation of the integral test device does not provide a means of checking:
 - a) the continuity of the main earthing conductor or the associated circuit protective earthing conductors
 - b) any earth electrode or other means of earthing
 - or
 - c) any other part of the associated electrical installation earthing.
3. Guidance on the suitability of types of RCD is contained in Clause 2.6.2.2.
4. There is no requirement to test the operating time of RCDs. Operating time is a function of the type of RCD.
5. A suitable test could be performed using a test plug with a resistor between the active and earth pins.

Confirmation that the correct type and rating of RCD has been selected is a matter of visual inspection.

Any standing leakage current on the protected circuit(s) may add or subtract vectorially from the test current, causing either nuisance tripping or delayed operation. To reduce such effects, the protected circuits should be carrying no load when tested.

Test sequence:

1. Ensure applicable verification testing has been completed (earth continuity, insulation resistance, interconnection, and polarity).
2. Ensure that the circuits to be tested are energised.

Note: Where grid supply is not available this may require a temporary power source or return to site, to complete RCD/RCBO testing when power is available.

3. Turn ON isolation switch at a socket outlet or at electrical equipment on the circuit to be tested.
4. Measure voltage between active and earth. RESULT $\approx 230V$.

The wave form of a fault current to earth can affect the operation of both an RCD and test equipment, in particular, circuits utilizing a variety of semiconductor devices. The suitability of an RCD shall be confirmed.

Example: Where electrical equipment includes an inverter generally a type AC RCD is not suitable. Refer AS/NZS 3000:2018 clauses 2.6.2.2, 4.12.5.2.2 and the manufacturers recommendations. Both supply characteristics and load characteristics shall be considered.

The installation of a Type AC RCD is no longer permitted. Refer AS/NZS 3000:2018 clause 2.6.2.2.2.

5. Where all live conductors are required to be switched by the RCD/RCBO, Turn OFF isolation switch at a socket outlet or at electrical equipment on the circuit to be tested.
6. Where all live conductors are required to be switched by the RCD/RCBO, test between the neutral and earth terminal with Ω meter. RESULT $\approx 0 \Omega$.
7. Push test button on RCD.
8. Check that RCD trips when test button operated.
9. Measure voltage between active and earth. RESULT $\approx 0V$.

Note: Polyphase outlets or equipment require verification all phases are de-energised.

10. Where all live conductors are required to be switched by the RCD/RCBO, test between the neutral and earth terminal with Ω meter. RESULT $\approx \infty \Omega$.
11. Reset RCD/RCBO.

12. Measure voltage between active and earth. RESULT $\approx$ 230V.

13. Connect an RCD test instrument as per the manufacturer's instructions. Set to the rated residual current and initiate the test which shall result in the RCD under test being tripped without undue delay.

14. Measure voltage between active and earth. RESULT $\approx$ 0V.

Note: Some RCD test instruments will display that the circuit is energised or de-energised accordingly. Where this is the case, there is no need to repeat the test with a separate voltmeter.

Note: Some RCD test instruments enable selection of the RCD waveform type. Where available the correct type should be selected, for example Type A.

8. Appendix

8.1. Appendix A: Table 8.1 testing procedure checklist

Testing checklist			
Mandatory Tests	Type of test	Required results	Completed
Step 6.1	Main earthing conductor resistance	$\leq 0.5\Omega$	
Step 6.2	Equipotential bonding conductor resistance	$\leq 0.5\Omega$	
Step 6.3	Protective earthing conductor resistance	See Table 8.2	
Step 6.4	Insulation resistance of complete installation	$\geq 1 \text{ M}\Omega$ (with appliances disconnected)	
	Insulation resistance of consumers mains or submains	$\geq 1 \text{ M}\Omega$ (with appliances disconnected)	
	Insulation resistance of subcircuits	$\geq 1 \text{ M}\Omega$ (with appliances disconnected)	
Step 6.5	Polarity of consumers mains		
Step 6.6	Polarity of submains with an MEN connection at outbuilding		
Step 6.7	Polarity of submains incorporating a protective earthing conductor		
Step 6.8	Polarity and correct circuit connection of lighting points, socket-outlets and electrical equipment		
Step 6.9	Interconnection test between conductors of different circuits	$\text{M}\Omega$	
Step 6.10	Check phase sequence		
Step 6.11	Fault-loop impedance (where required)	See Table 8.1	
Step 6.12	Verification of operation of RCD's (Supply Required)	2.Disconnect the designated circuits	

8.2. Appendix B: Table 8.2 Maximum values of resistance

TABLE 8.2
MAXIMUM VALUES OF RESISTANCE OF FINAL SUBCIRCUITS
AT 80% RATED CURRENT RELATING TO Z_s
IMPEDANCE VALUES IN TABLE 8.1

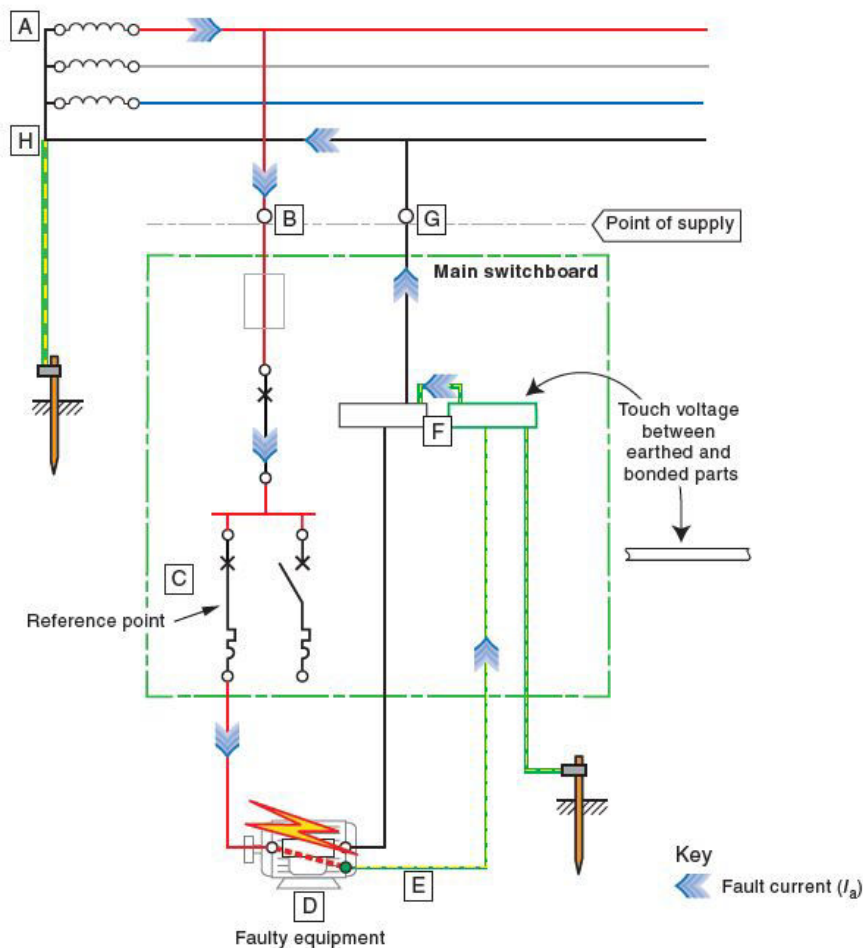
Protective device rating, amps	Conductor size		Circuit breakers						Fuses			
			Disconnection times									
	Active mm ²	Earth mm ²	0.4 s						0.4 s		5.0 s	
			Type B MCB		Type C MCB		Type D MCB		HRC fuses			
			R _{phe}	R _e	R _{phe}	R _e	R _{phe}	R _e	R _{phe}	R _e	R _{phe}	R _e
			Maximum final subcircuit resistance, Ω									
6	1.0	1.0	6.1	3.1	3.3	1.6	2.0	1.0	7.4	3.7	9.8	4.9
10	1.0	1.0	3.7	1.8	2.0	1.0	1.2	0.6	4.1	2.0	5.9	2.9
10	1.5	1.5	3.7	1.8	2.0	1.0	1.2	0.6	4.1	2.0	5.9	2.9
16	1.5	1.5	2.3	1.2	1.2	0.6	0.7	0.4	2.0	1.0	3.2	1.6
16	2.5	2.5	2.3	1.2	1.2	0.6	0.7	0.4	2.0	1.0	3.2	1.6
20	2.5	2.5	1.8	0.9	1.0	0.5	0.6	0.3	1.3	0.7	2.3	1.1
25	4.0	2.5	1.5	0.9	0.8	0.5	0.5	0.3	1.0	0.6	1.7	1.1
32	4.0	2.5	1.2	0.7	0.6	0.4	0.4	0.2	0.8	0.5	1.4	0.9
40	6.0	2.5	0.9	0.6	0.5	0.3	0.3	0.2	0.6	0.4	1.0	0.7
50	10.0	4.0	0.7	0.5	0.4	0.3	0.2	0.2	0.5	0.3	0.8	0.6
63	16.0	6.0	0.6	0.4	0.3	0.2	0.2	0.1	0.4	0.3	0.6	0.4

NOTES:

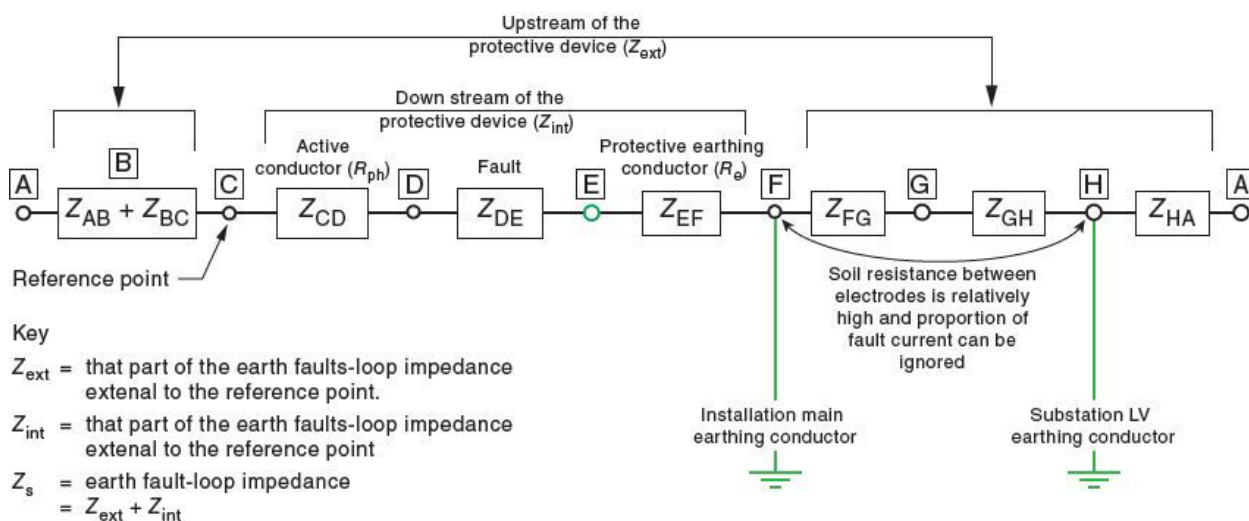
- 1 The values, which have been rounded to one decimal place, are calculated using R_{phe} as $64\% \times Z_s$ in Table 8.1.
- 2 64% takes into account deemed reduction values of $80\% \times Z_s$ (typical value for the final subcircuit) $\times 80\%$ assumes that conductor temperature for Z_s at rated current is 70°C and for tests at no load current is 20°C .
- 3 Table B1 gives earth fault loop route lengths for final subcircuits will satisfy the requirements of Clauses 1.5.5.3, 5.7 and 8.3.9 for automatic disconnection of supply for the conditions of Paragraph B5.2.2. These values comply with Table 8.2 and may be used as an alternative to resistance values.
- 4 In addition, Table B1 also includes final subcircuit route length for voltage drops complying with Clause 3.6.2.
- 5 To comply with both earth fault loop and voltage drop route length the shortest route length is required.

Source: AS/NZS 3000:2018 Table 8.2 © Standards Australia.

8.3. Appendix C: MEN system showing earth fault current path



At the instant of the fault, current will flow through the earth fault-loop and its magnitude is only limited by the total system impedance Z_s that is obtained from all the individual impedances in the earth fault-loop as follows:



Source: AS/NZS 3017:2022 Figure 4.23 © Standards Australia.

8.4. Appendix D: Table 34 a.c. Resistance of cables

TABLE 34
a.c. RESISTANCE (R_c) AT 50 Hz

CABLE TYPE: SINGLE-CORE

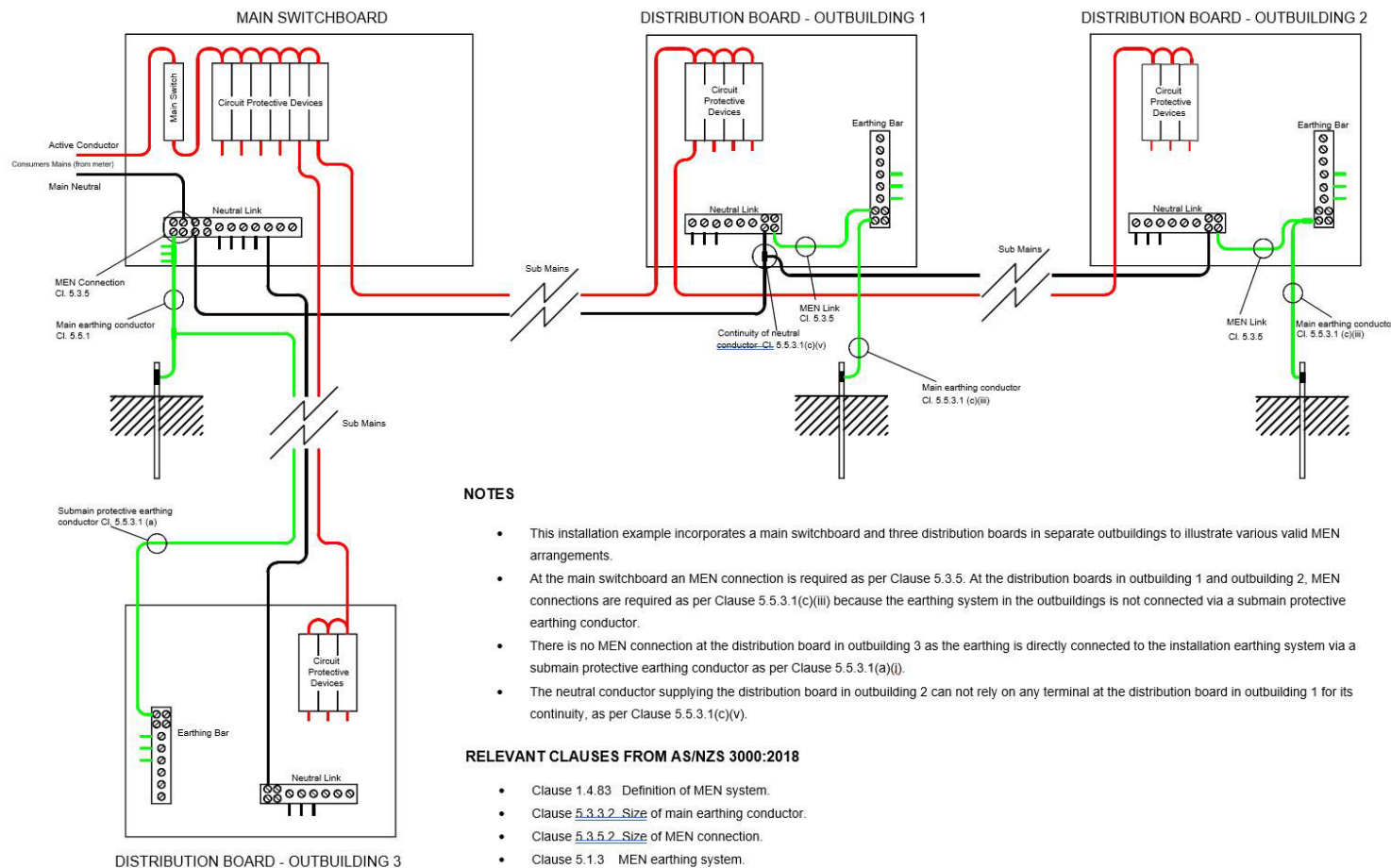
1	2	3	4	5	6	7	8	9	10	11	12
Conductor size	a.c. resistance (R_c) at 50 Hz, Ω/km										
	Copper*						Aluminium				
	Conductor temperature, $^{\circ}\text{C}$						Conductor temperature, $^{\circ}\text{C}$				
	45	60	75	80	90	110	45	60	75	80	90
mm ²											
1	23.3	24.5	25.8	—	27.0	28.7	—	—	—	—	—
1.5	14.9	15.7	16.5	—	17.3	18.4	—	—	—	—	—
2.5	8.14	8.57	9.01	—	9.45	10.0	—	—	—	—	—
4	5.06	5.33	5.61	—	5.88	6.24	—	—	—	—	—
6	3.38	3.56	3.75	3.81	3.93	4.17	—	—	—	—	—
10	2.01	2.12	2.23	2.26	2.33	2.48	—	—	—	—	—
16	1.26	1.33	1.40	1.42	1.47	1.56	2.10	2.22	2.33	2.37	2.45
25	0.799	0.842	0.884	0.899	0.927	0.984	1.32	1.39	1.47	1.49	1.54
35	0.576	0.607	0.638	—	0.668	0.710	0.956	1.01	1.06	1.08	1.11
50	0.426	0.448	0.471	—	0.494	0.524	0.706	0.745	0.783	0.796	0.822
70	0.295	0.311	0.327	—	0.342	0.363	0.488	0.515	0.542	0.551	0.568
95	0.213	0.225	0.236	—	0.247	0.262	0.353	0.372	0.392	0.398	0.411
120	0.170	0.179	0.188	—	0.197	0.208	0.279	0.295	0.310	0.315	0.325
150	0.138	0.145	0.153	—	0.160	0.169	0.228	0.240	0.253	0.257	0.265
185	0.111	0.117	0.123	—	0.129	0.136	0.182	0.192	0.202	—	0.212
240	0.0862	0.0905	0.0948	—	0.0991	0.105	0.140	0.147	0.155	—	0.162
300	0.0703	0.0736	0.0770	—	0.0803	0.0846	0.113	0.119	0.125	—	0.130
400	0.0569	0.0595	0.0620	—	0.0646	0.0677	0.0890	0.0936	0.0981	—	0.103
500	0.0467	0.0487	0.0506	—	0.0525	0.0547	0.0709	0.0744	0.0779	—	0.0813
630	0.0389	0.0404	0.0418	—	0.0432	0.0448	0.0571	0.0597	0.0623	—	0.0649

* For the a.c. resistance of tinned copper conductor, multiply copper value by 1.01.

Source: AS/NZS 3008 Table 34 © Standards Australia.

8.5. Appendix E: Multiple Earthed Neutral (MEN) System Installation Methods

MULTIPLE EARTHED NEUTRAL (MEN) SYSTEM to AS/NZS 3000:2018+A3



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