**Section 5: Earthing Arrangements and Earthing Conductors**

**5.1 General**

**5.1.1 Application**  
This section specifies the minimum requirements for the selection and installation of earthing arrangements that must be achieved to satisfy Part 1 of this standard.

**5.1.2 Selection and Installation**  
Earthing arrangements shall be selected and installed to perform the following functions, or have the following features:

* (a) Enable automatic disconnection of supply in the event of a short-circuit to earth fault or excessive earth leakage current in the protected part of the installation through protective earthing arrangements.
* (b) Enable equipment requiring an earth reference to function correctly through functional earth (FE) arrangements.
* (c) Mitigate voltage differences appearing between exposed conductive parts of equipment and extraneous conductive parts through equipotential bonding arrangements.
* (d) Provide an effective and reliable low impedance fault path capable of carrying earth fault and earth leakage currents without danger or failure from thermal, electromechanical, mechanical, environmental, and other external influences.
* (e) Provide measures for the connection of exposed conductive parts and extraneous conductive parts.

**5.1.3 MEN Earthing System**  
The protective earthing arrangements required by this standard apply to electrical installations connected to the multiple earthed neutral (MEN) distribution system, the standard distribution system used in Australia and New Zealand. Under the MEN system, the neutral conductor (PEN) of the distribution system is earthed at the source of supply at regular intervals throughout the system and at each electrical installation connected to the system. Within the electrical installation, the earthing system is separated from the neutral conductor and is arranged for the connection of the exposed conductive parts of equipment.

**Notes:**

1. The MEN system as installed in Australia and New Zealand differs from the IEC system. Both systems are identical in principle but vary in detail. For further details refer to AS/NZS 61439 and AS/NZS 3007.
2. The MEN system and its various parts are illustrated in Figures 5.1 and 5.2. Figure 5.1 shows a general arrangement and Figure 5.2 an alternative arrangement in an owner or user-operated supply substation installation. The IEC 60364 series describes the MEN system as a TN-C-S system with the letters signifying:
   * T: The distribution system is directly connected to earth at the neutral point of the supply transformer.
   * N: The exposed conductive parts are connected to the earthed point of the distribution system at the MEN connection.
   * C: The neutral and protective conductor functions are combined in a single conductor (the neutral conductor of the distribution system).
   * S: The protective conductor function is separated from the neutral—separate conductors within the installation.

**5.1.4 Other Earthing Systems**  
Alternatives to the MEN system may be permitted, provided that the requirements of Part 1 of this Standard are satisfied, taking into account any effects on the distribution system supplying the installation.

**Examples:**

1. Electrical installations and supply systems, in accordance with the descriptions and compliance conditions permitted by IEC 60364 series.
2. Electrical installations in surface mines complying with AS/NZS 3007 which permits the use of TN, TT, and IT systems.
3. Existing installations may still remain connected under former direct earthing or voltage-operated earth leakage circuit breaker (ELCB) systems permitted by superseded editions of this Standard.
4. Earthing/bonding arrangements for installations that are not supplied from a distribution system.
5. Electrical installations complying with IEC 60364 series which permits the use of TN, TT, and IT systems as alternatives to the MEN system.

**5.2 Earthing Functions**

**5.2.1 Protective Earthing**  
When a fault occurs between a live part and an exposed conductive part or parts of the protective earthing system, a prospective touch voltage may arise between simultaneously accessible conductive parts. Fault protection by means of automatic disconnection of supply is intended to limit this voltage.

**Automatic disconnection is achieved by:**

* (a) the provision of a protective earthing system in which exposed conductive parts are connected via conductors or similar medium to the earthed neutral of the distribution system; and
* (b) in the event of a fault current or excessive earth leakage current flowing in the protective earthing system, overcurrent or earth leakage current protective devices operate to disconnect the affected part of the installation within the specified maximum duration of the prospective touch voltage.

**5.2.2 Functional Earthing (FE)**  
Equipment may be required to be connected to the earthing system for purposes of correct operation rather than the safety conditions associated with protective earthing. In such cases, functional earthing conductors are not required to be selected and installed to withstand fault currents or to be identified in the same manner as a protective earthing conductor.

**Examples:**

1. Functional earth (FE) connections fitted to certain types of RCDs to provide an earth for an alternative supply connection for the internal electronic circuit operation in the event of the incoming neutral connection becoming disconnected.
2. Conductors connecting cathodic protection systems or radio interference suppression devices to a separate earthing arrangement.
3. Where a 'clean earth' is specified for data or signaling purposes in a particular item of electrical equipment, the manufacturer of the electrical equipment should be consulted to confirm the necessary arrangements.

Where required, for operational purposes, functional earth connections for data and signaling purposes should be insulated from all protective earthing connections and conductors and should only be connected together at one point, normally at the connection to the main earthing terminal/connection or bar. Care needs to be exercised to avoid unintentional contact between the two earthing systems.

A conductor insulation color for functional earth conductors has not been specified in this Standard. However, to ensure that functional earthing connections are made to the correct earthing system, a green or green/yellow conductor identification shall not be used.

In Australia, for telecommunication system earthing, see AS/CA S 009 for the requirements for the color and installation of a Telecommunications Reference Conductor.

**Note:** Additional information on functional earthing is available in IEC 60364-4-44.

**5.2.3 Earthing for Combined Protective and Functional Purposes**  
Where earthing for combined protective and functional purposes is required, the requirements for protective purposes shall prevail.

**5.3 Earthing System Parts**

**5.3.1 General**  
The protective earthing arrangement for an electrical installation providing protection by means of automatic disconnection of supply and connected to the MEN system of distribution shall include the following parts:

* (a) Protective earthing conductors connecting exposed conductive parts as required.
* (b) Main earthing conductor.
* (c) Main earthing terminal, connection, or bar.
* (d) MEN connection between the main earthing terminal, connection, or bar and the supply neutral bar.
* (e) Earth electrode.
* (f) Equipotential bonding of extraneous conductive and other parts as required.

**Note:** Examples of the parts of the MEN system of earthing are shown in Figures 5.1 and 5.2.

The parts of the earthing system shall comply with Clauses 5.3.2 to 5.3.7.

**5.3.2 Earthing Conductor Material and Type**

**5.3.2.1 Conductor Material**

**5.3.2.1.1 Copper Conductors**  
Copper earthing conductors shall be of high conductivity copper and shall be in the form of:

* (a) Stranded conductors;
* (b) Circular braided conductors; or
* (c) Solid conductors having a cross-sectional area not less than 10 mm² and a thickness not less than 1.5 mm.

**Exceptions:**

1. A smaller solid conductor may be used where permitted by a particular cable standard.
2. This Clause need not apply where copper cable components, such as sheaths or screens, are deemed to be an earthing conductor in accordance with Clause 5.3.2.2.
3. **5.3.2.1.2 Aluminium Conductors**  
   Aluminium conductors may be used as earthing conductors, provided that they comply with the following conditions:  
   (a) Conductors of 10 mm² or less shall be solid conductors.  
   (b) Minimum 16 mm² conductors shall be used for main earthing conductors.  
   (c) Connection methods shall comply with Section 3 of this Standard.  
   (d) Installation methods shall prevent corrosion of the conductor and connections.  
   (e) Conductors shall not be installed underground or in damp situations.  
   **Exception:** Aluminium earthing conductors may be installed underground or in damp situations where designed and suitable for such use.
4. **5.3.2.1.3 Other Materials**  
   Materials other than copper or aluminium may be used as an earthing conductor. In such cases, the conductor resistance shall not be greater than that for a copper earthing conductor determined in accordance with Clause 5.3.3, and the degree of corrosion resistance shall not be inferior to other materials suitable for the purpose.
5. **5.3.2.2 Conductor Type**  
   Protective earthing conductors may include the following:  
   (a) Earthing conductors that comply with Clause 5.3.2.1, separately installed.  
   (b) Earthing conductors that comply with Clause 5.3.2.1, in a common enclosure with live conductors.  
   (c) Earthing conductors in multi-core cables.  
   (d) Busbars.  
   In addition, and subject to the special conditions of Clause 5.3.2.3, the following media may be regarded as a protective earthing conductor:  
   (i) Conductive conduit, tube, pipe, trunking, and similar wiring enclosures.  
   (ii) Conductive sheaths, armours, and screens of cables.  
   (iii) Conductive framework used for mounting electrical equipment.  
   (iv) Catenary wires for the support of cables.  
   **Note:** Sprinkler pipes or pipes conveying gas, water, flammable liquid, or other conductive non-electrical service enclosures shall not be used as an earthing medium. This requirement does not preclude the bonding of such conductive non-electrical service enclosures to conductive electrical service enclosures in accordance with Clause 5.6.  
   Main earthing conductors shall be of a type that complies with Clause 5.3.2.1.
6. **5.3.2.3 Special Conditions**  
   The following conditions apply where the components in Clause 5.3.2.2 (i), (ii), (iii), or (iv) are used for protective earthing:  
   (a) **Conductive conduit, tube, pipe, trunking, and similar wiring enclosures** may be regarded as a protective earthing conductor, provided that:  
   (i) the electrical equipment to be earthed is supplied by live conductors contained within the wiring enclosure; and  
   (ii) for screwed conductive wiring enclosures, the wiring enclosure is directly connected by conductive threads or locknuts to the electrical equipment to be earthed.  
   (b) **Conductive sheaths, armours, and screens of cables** may be regarded as a protective earthing conductor, provided that the electrical equipment to be earthed is supplied only by live conductors incorporated in the cable.  
   **Exception:** This condition does not preclude the use of a MIMS cable sheath as a main earthing conductor, provided that any circuit-protective earthing conductors connected to the sheath are associated only with the circuits supplied through the MIMS cable.  
   (c) **Conductive framework** may be regarded as a protective earthing conductor, provided that:  
   (i) **General:** The exposed conductive parts of electrical equipment are mounted on, and in effective electrical contact with, the framework; and the conductive framework is earthed by the connection of a protective earthing conductor directly to the framework.  
   (ii) **Contact with hinged components:** Hinged components of conductive framework, such as cubicle doors, may be regarded as a protective earthing conductor, provided that the fixed component of the framework is connected to a protective earthing conductor; and the fixed and hinged components of the framework are connected by means of a flexible protective earthing conductor.  
   (iii) **Contact with moving components:** The interface between moving components may be regarded as a protective earthing conductor, provided that the fixed component of the equipment is directly connected to a protective earthing conductor; and the fixed and movable components of the equipment are in effective contact by means of metal-to-metal bearing surfaces, such as the contact between a rail and wheel or between an axle and bearing. Additional means of electrical continuity, such as sliding shoes or spring-loaded brushes, may be required where an accumulation of rust or non-conductive dust is likely to occur.  
   (d) **Catenary wires** may be regarded as a protective earthing conductor, provided that:  
   (i) it has not less than seven strands;  
   (ii) it is supported by means of suitable anchorages;  
   (iii) it has a nominal cross-sectional area of not less than 8.5 mm² if constructed of hard-drawn copper or galvanized low carbon (mild) steel;  
   (iv) it has a resistance in accordance with the requirements of Clause 5.3.3; and  
   (v) it is identified as an earthing conductor, in accordance with Clause 3.8.3.4, and for aerial earthing conductors, at each anchorage point or catenary support.

**5.3.2.4 Insulation**  
Earthing conductors shall be provided with insulation.  
**Exceptions:** The following forms of earthing conductors need not be provided with insulation:

1. Aerial conductors.
2. Flat braided conductors.
3. Busbars.
4. Sheaths of MIMS cable.
5. Conductive framework and wiring enclosures deemed to be an earthing conductor, in accordance with Clause 5.3.2.2.
6. Copper earthing conductors buried directly in the ground in accordance with Clause 5.5.5.5.
7. Catenary wires.

**5.3.2.5 Identification**  
Insulated earthing conductors shall be identified in accordance with Clause 3.8.

**5.3.3 Earthing Conductor Size (Cross-sectional Area)**  
**5.3.3.1 Protective Earthing Conductors**  
**5.3.3.1.1 General**  
The cross-sectional area of a protective earthing conductor shall ensure:  
(a) Adequate current-carrying capacity for prospective fault currents for a time at least equal to the operating time of the associated overcurrent protective device;  
(b) Appropriate earth fault-loop impedance (see Clause 5.7);  
(c) Adequate mechanical strength and resistance to external influences; and  
(d) For parts of the protective earthing conductor that do not consist of cables, or parts of cables, that there is an allowance for the subsequent deterioration in conductivity that may reasonably be expected.

**5.3.3.1.2 Selection**  
The cross-sectional area of any copper protective earthing conductor required for the protection of any portion of an electrical installation shall be determined either:  
(a) From Table 5.1 in relation to the cross-sectional area of the largest active conductor supplying the portion of the electrical installation to be protected; or  
(b) By calculation, in accordance with Clause 5.3.3.1.3.  
**Exceptions:**

1. The minimum size of a conductor required for the earthing of exposed conductive parts associated with unprotected consumer mains shall be in accordance with Clauses 5.3.3.2 and 5.5.3.5.
2. Aerial earthing conductors shall comply with Clause 5.3.3.3.
3. Earthing conductors in cables, flexible cables, or flexible cords shall comply with Clause 5.3.3.4.

**Notes:**

1. The installation should be prepared so that electrical equipment terminals are capable of accepting the protective earthing conductors.
2. Calculation may be necessary if the choice of cross-sectional area of phase conductors has been determined by consideration of short-circuit current. Where the active conductor comprises a number of conductors connected in parallel, the earthing conductor shall be determined in relation to the summation of the cross-sectional areas of the individual conductors forming the largest active conductor to be protected. Where the summation of cross-sectional areas does not correspond exactly with the nominal size of the active conductor given in Table 5.1, the conductor shall be determined in relation to the nearest larger size of active conductor. The minimum cross-sectional area of any conductive wiring enclosure, cable component, framework, or catenary wire used as an earthing medium in accordance with Clause 5.3.2.2, shall be such that the impedance of the medium is not greater than that determined for a copper earthing conductor in accordance with this Clause (Clause 5.3.3.1.2).

**5.3.3.1.3 Calculation**  
The minimum cross-sectional area determined by calculation shall be not less than the value determined by the following equation (applicable only for disconnection times not less than 0.1 s but not exceeding 5 s):  
𝑆=√(I²t/K²) ... 5.1  
where

* **S** = cross-sectional area of protective earthing conductor, in mm²
* **I** = the value of the fault current in amperes (for a.c. r.m.s. value) that would flow through the overcurrent protective device of the circuit concerned in the event of a short-circuit or negligible impedance
* **t** = the disconnection time of the overcurrent protective device in seconds, corresponding to the value of fault current I
* **K** = factor dependent on the material of the protective earthing conductor, the insulation and other parts, and the initial and final temperatures

**Notes:**

1. Values of **K** for protective earthing conductors in various conditions of service are given in the AS/NZS 3008.1 series, e.g., for copper conductors not laid up with other conductors, with PVC insulation K = 136, or for bare copper conductors K = 170.
2. Examples of the application of this equation are contained in the AS/NZS 3008.1 series.
3. If the application of the equation produces non-standard sizes, conductors of the nearest higher standard cross-sectional area shall be used.
4. Maximum permissible temperatures for joints should be considered (see the AS/NZS 3008.1 series).

**5.3.3.2 Main Earthing Conductor**  
Where the main earthing conductor connects the main earth terminal to an electrode (as depicted in Figure 5.1), the conductor shall be determined from Table 5.1 in relation to the cross-sectional area of the largest active conductor of the consumer mains. The cross-sectional area of such a copper main earthing conductor shall be not less than 4 mm² and need not be greater than 120 mm².

**Exceptions:**

1. Where double insulation is maintained between the point of supply and the load terminals of the protective devices for the submains and final subcircuits outgoing from the main switchboard. The minimum size of the main earthing conductor may be determined in relation to the cross-sectional area of the largest active conductor of the largest outgoing submain or final subcircuit.
2. Where the cross-sectional area of the consumer mains is larger than that required to carry the maximum demand of the installation because of voltage-drop limitations. The minimum size of the main earthing conductor may be determined in relation to the cross-sectional area of the minimum cable size required to carry the maximum demand.

NOTE: In this application, the main earthing conductor forms part of the earth fault current path and its size needs to be determined based on the prospective fault current level and duration.

**5.3.3.3 Aerial Earthing Conductors**  
The minimum size of a protective earthing conductor installed as an aerial conductor shall be selected in accordance with Clause 5.3.3.1. Additionally, the cross-sectional area of the earthing conductor shall be not less than the size specified in Clause 3.12.2 and Table 3.9 according to the type of conductor and length of span.

**5.3.3.4 Earthing Conductors in Cables, Flexible Cables or Flexible Cords**  
The minimum size of a protective earthing conductor in the form of a cable, flexible cable, or flexible cord shall be selected in accordance with Clause 5.3.3.1.2, and the cross-sectional area of the earthing conductor shall comply with the following requirements appropriate to the type of cable or cord:

**(a) Single-core cable, flexible cable, or flexible cord:** The minimum size of a copper earthing conductor in the form of a single-core insulated cable, flexible cable, or flexible cord shall be 2.5 mm².

**Exception:** Where connections in a multi-core cable require a short length of single-core insulated earthing conductor to be unenclosed, the earthing conductor size may be not less than 1 mm².

* 1. **Multi-core cable or flexible cable:** The minimum size of an earthing conductor incorporated with associated live conductors in a sheathed multi-core cable or flexible cable shall be 1 mm².
  2. **Multi-core flexible cord:** The minimum size of an earthing conductor incorporated with the associated live conductors in the sheath of a multi-core flexible cord shall be not less than the cross-sectional area of the largest active conductor incorporated in the flexible cord, provided that the cross-sectional area of the largest active conductor incorporated in the flexible cord is more than 0.5 mm² and less than 2.5 mm², and the flexible cord is used to supply a hand-held or portable appliance.
  3. **Screen and drain wires:** The minimum cross-sectional area of any screen or drain wire incorporated in a sheathed cable, flexible cable, or flexible cord shall be selected in accordance with Clause 5.3.3.1.2 and, in addition, shall be not less than that required by this Clause (Clause 5.3.3.4) for a protective earthing conductor.

**Exception:** This requirement need not apply where the screen or drain wire is separated from live conductors by double insulation or the equivalent thereof.

**Note:** AS/NZS 3191 precludes the use of aluminium conductors in flexible cords.

**5.3.4 Main Earthing Terminal/Connection or Bar**

In every electrical installation, a main earthing terminal/connection or bar must be provided at the main switchboard. The following conductors should be connected, either directly or indirectly, to form an equipotential bonding network with such conductors connected to the main earthing terminal/connection or bar:

* **(a)** Protective earthing conductors.
* **(b)** Main earthing conductor.
* **(c)** MEN connection.
* **(d)** Equipotential bonding conductors.
* **(e)** Functional earthing conductors, if required.

**Note:** A main earthing terminal/connection can be a soldered connection.

**5.3.5 MEN Connection**

**5.3.5.1 General**

In every electrical installation, there must be an MEN connection (also known as the MEN link) at the main switchboard.

**Note:** The function of the MEN connection is to connect the earthing system within the electrical installation to the supply neutral conductor by means of a connection from the main earthing terminal/connection or bar to the earthing terminal on the main neutral bar (refer to Figure 5.1).

**Exceptions:**

1. The NE connection may be made at an earth bar within an owner or user-operated supply substation (refer to Figure 5.2).
2. The NE connection may be made at an electricity distributor neutral bar within the electrical installation, e.g., at the supply substation or meter panel, if required by the distributor.
3. The NE connection may be made through an earthing conductor or terminal, provided by the electricity distributor.

**Note:** An earthing conductor or terminal provided by the electricity distributor may include a special earthing conductor, the conductive sheath of a supply cable, or a neutral bar at a substation.

* The MEN or NE connection should be located in an accessible position for disconnection and testing purposes.

**5.3.5.2 Size**

The MEN connection should be a conductor complying with Clause 5.3.2 and have a cross-sectional area capable of carrying the maximum current that it may be required to carry under short-circuit conditions.

**The minimum size shall be:**

* **(a)** Not less than the current-carrying capacity of the main neutral conductor; or
* **(b)** For switchboards described in Clause 2.5.5 as rated at 800 A or more per phase, as determined for a protective earthing conductor from Table 5.1 or by calculation.

**Exceptions:** The minimum size of the MEN connection need not exceed that of the main earthing conductor in the following circumstances:

1. Where short-circuit protection is provided on the supply side of the consumer mains.
2. Where the earthing of an enclosure containing consumer mains not provided with short-circuit protection on the supply side is made by connection directly to the neutral bar in accordance with Clause 5.5.3.5.
3. Where double insulation of the consumer mains conductors is maintained up to the supply terminals of the service protective devices, and short-circuit protection is provided by such devices.

**Note:** An electricity distributor's upstream service protective device may provide short-circuit protection of consumer mains.

**5.3.5.3 Identification**

Where the MEN connection is insulated, the insulation should be colored green or in a combination of green and yellow, in accordance with Clause 3.8.

**5.3.6 Earth Electrodes**

**5.3.6.1 General**

The connection of the electrical installation earthing system to the general mass of earth shall be achieved by means of an earth electrode.

**Note:** No specific value of resistance to earth is required by this Standard for the earth electrode at an electrical installation connected to a MEN system. However, the impedance of the combined earthing system of the electrical installation connected to an MEN system is required to meet the earth fault-loop impedance requirements specified in Clause 5.7. AS/NZS 3017 provides guidance on methods of measurement of resistance to earth and earth fault-loop impedance.

**5.3.6.2 Types**

Materials and dimensions of earth electrodes shall be selected to withstand corrosion and to have adequate mechanical strength.

**Note:** Consideration should be given to the nature of the soil and environmental conditions.

Earth electrodes shall be of a type and shall be installed in accordance with Table 5.2.

**Exception:** Conductive reinforcement of:

* **(a)** concrete foundations embedded directly in the soil; or
* **(b)** concrete foundations of a building or floor slab in contact with the ground and not impeded by a continuous insulating barrier, may be used in lieu of an electrode specified in Table 5.2.

**5.3.6.3 Installation**

Vertical-type earth electrodes shall be driven to a minimum depth of:

* **(a)** in Australia, 1.2 m; and
* **(b)** in New Zealand, 1.8 m.

Strip-type earth electrodes buried in a horizontal trench shall be laid at a depth having not less than 0.5 m cover and with a minimum horizontal length of:

* **(i)** in Australia, 3 m; and
* **(ii)** in New Zealand, 7.5 m.

**5.3.6.4 Location**

Earth electrodes shall be installed in a location that satisfies the following conditions:

* **(a)** The electrode maintains effective contact with moist soil that is not subject to excessive drying out.

**Note:** This condition is deemed to be satisfied by locating the electrode:

* + **(a)** external to the building in ground that is exposed to the weather; or
  + **(b)** in other locations where the ground remains moist because of soil conditions or covers that reduce loss of moisture.
* **(b)** The electrode is separated from conductive enclosures of other buried services, such as water, gas, telecommunications, and flammable liquid, in order to reduce possible electrolytic action affecting the electrode or the other service.

**Note:** Separation distances are specified in Table 3.7.

* **(c)** The main earthing conductor connection to an electrode is accessible, in accordance with Clause 5.5.1.2.

The location of the earth electrode shall be identified at the main switchboard.

**5.3.7 Functional Earthing Conductors**

Functional earthing conductors are provided solely to ensure the correct operation of electrical equipment or to permit reliable and proper functioning of electrical installations. These conductors need not comply with the requirements for main and protective earthing conductors.

**Where earthing for combined protective and functional purposes is required, the requirements for protective purposes shall prevail.**

**Notes:**

1. The functional earth connection should be independent of the protective earth to comply with the manufacturer's requirements. Connection would thus be limited to the main earth connection point.
2. Where a 'clean earth' is specified for a particular item of electrical equipment, the manufacturer should be consulted to confirm the necessary arrangements.

**5.4 Earthing of Equipment**

**5.4.1 General**

**5.4.1.1 Exposed Conductive Parts**

The exposed conductive parts of electrical equipment shall be earthed in the following scenarios:

* **(a)** Installed or could operate in an earthed situation.
* **(b)** Not installed in an earthed situation but any exposed conductive part of the electrical equipment is electrically continuous with an extraneous conductive part that is located in an earthed situation.

Exposed conductive parts of electrical equipment protected by electrical separation in accordance with Clause 7.4.3(c) shall not be earthed. Exposed conductive parts need not be earthed if supplied by a Safety Extra Low Voltage (SELV) or Protective Extra Low Voltage (PELV) system in accordance with Clause 7.5.

**Exception:** Electrical equipment need not be earthed if the wiring conforms to protection by the use of double insulation under the following conditions:

* **(a)** Electrical equipment complying with AS/NZS 3100 for double insulation need not be earthed.
* **(b)** Installation wiring entering equipment: Where cables connecting electrical equipment having double insulation enter the equipment in such a manner that they may come into contact with accessible external conductive parts of the electrical equipment, the cables shall be of a type affording double insulation.

**Note:** Where double insulation is afforded by means of insulated and sheathed cables alone, care should be taken that screws or nails forming part of the structure or equipment are not liable to penetrate the cable, particularly where the cable is subject to movement during maintenance or other operations. See also Clauses 3.9.3 and 3.9.4.

* **(c)** Internal electrical equipment wiring: Conductors within electrical equipment having double insulation shall be protected, secured, or insulated so that, if any one conductor becomes detached from its termination, neither the conductor nor its functional insulation can come into contact with accessible conductive parts. The attachment of one conductor to another by tying, lacing, clipping, or the like, in such a manner as to prevent either conductor from coming into contact with accessible conductive parts if it becomes detached from its termination, shall be deemed to comply with this requirement.

**5.4.1.2 Conductive Building Materials**

Conductive building materials shall be earthed in accordance with Clause 5.4.6.

**5.4.1.3 Connection of Electrical Equipment to Earth**

Equipment required to be earthed shall be arranged for connection to:

* **(a)** Protective earthing conductors in the form of cables, cords, busbars, or similar forms of current-carrying material.
* **(b)** Another earthing medium, such as conductive parts of cables, wiring enclosures, switchboard framework, or the like, in accordance with Clause 5.3.2.

Equipotential bonding shall be arranged in accordance with Clause 5.6.

**5.4.2 Socket-outlets**

The earthing contact of every socket-outlet shall be earthed.

**Exceptions:**

1. An earthing contact of a socket-outlet supplied as a separated circuit shall be bonded to the protective bonding system, in accordance with Clause 7.4.
2. In accordance with Clause 7.5.fO, a socket-outlet supplied as an extra-low voltage circuit shall not be provided with an earthing contact.

**5.4.3 Lighting Points**

A protective earthing conductor, connected to a terminal or suitably insulated and enclosed, shall be provided at every lighting point, including transformers supplying Extra Low Voltage (ELV) lighting systems.

**Exceptions:**

1. A protective earthing conductor shall not be provided for luminaires located in Zone 0 of swimming and spa pools installed in accordance with Clause 6.3.4.5 and Zone 0 of fountains and water features installed in accordance with Clause 6.4.4.5.
2. A protective earthing conductor need not be provided for the following lighting points:
   * Festoon-type lampholders of the all-insulated type.
   * Lighting points where the luminaire is earthed by attachment to screwed conductive conduit or pipe in accordance with Clause 5.3.2.3.
   * Lighting points consisting of a luminaire installed outdoors on a non-conductive pole where the luminaire is not in an earthed situation.
   * ELV lighting points.

**5.4.4 Luminaires**

The exposed conductive parts of luminaires shall be earthed.

**Exceptions:**

1. Luminaires need not be earthed where earthing of equipment is not required in accordance with Clause 5.4.1.
2. Where a protective earthing conductor is not required in accordance with Clause 5.4.3.
3. Where installed outdoors on a non-conductive pole and the luminaire is not in an earthed situation.
4. Where supplied at ELV in accordance with Clause 7.5.

**5.4.5 Conductive Supports for Aerial Conductors**

Conductive poles, posts, struts, brackets, stay wires, and other conductive supports for low voltage aerial conductors shall be earthed.

**Exceptions:**

1. Conductive supports effectively and permanently separated from all conductors by double insulation need not be earthed. An acceptable method would include the use of XLPE type X-90UV cable to AS/NZS 3560 with insulated strain clamps and double insulated connectors to AS/NZS 4396.
2. Conductive supports effectively and permanently separated from aerial conductors by insulators mounted on timber, or other insulating supports, need not be earthed where the space between the conductors and the conductive supports is not less than:
   * For single-core conductors, half the space between the conductors as specified in Clause 3.12.5.4; or
   * For multi-core conductors, 100 mm.
3. Conductive supports beyond arm's reach and effectively and permanently separated from any conductive guttering, roof, or structural metalwork by a clearance or creepage distance of at least 25 mm need not be earthed.
4. Any stay wire that is attached to a conductive support fitted with a robust strain insulator so that any portion of the stay wire that is within arm's reach and that is readily accessible is isolated from the remainder of the stay wire, need not be earthed.

**5.4.6 Structural Metalwork Including Conductive Building Materials**

**5.4.6.1 General**

* Structural metalwork forming the frame of a structure containing an electrical installation or part thereof, including sheds or similar structures that are permanently connected to the electrical installation wiring, shall be earthed. The size of the earthing conductor used for earthing the frames shall be determined from Clause 5.3.3 in relation to the cross-sectional area of the largest active conductor that is contained within the framework of that electrical installation.
* For combined outbuildings, each outbuilding shall contain its own individual A1 earthing connection to the conductive frames within that outbuilding.

All other conductive building materials shall be earthed where: (a) the risk of contact with live parts of electrical equipment or insulated, unsheathed cables exists; or (b) double insulation or cables in contact with conductive building materials is not permanently and effectively maintained.

The breaking of a conductor at a termination shall not result in contact between unearthed conductive building material and: (i) live parts; or (ii) parts separated from live parts by single insulation.

This requirement may be satisfied by: (A) restraining the conductor by tying, lacing, or clipping; or (B) containing the termination within a non-conductive shroud or enclosure.

**5.4.6.2 Connection to Protective Earthing Conductors**

Earthing of parts of structural metalwork, including conductive building materials, may be effected by the connection of a protective earthing conductor of appropriate size at one point of the metalwork, provided that the resistance between the earth bar and any part required to be earthed does not exceed 0.5 Ω.

**5.4.7 Submersible Pumps**

The exposed conductive parts of a submersible pump shall be earthed by means of a protective earthing conductor that is terminated at the pump motor.

The termination shall be made in a manner that provides sealing against ingress or moisture, and protection against possible mechanical damage and corrosion likely to occur at the point of installation.

This requirement may be satisfied by terminating the protective earthing conductor on the motor at: (a) a terminal incorporated in a housing; or (b) an internal or external constructional component, in accordance with Clause 5.5.6.2.

**5.4.8 Variable Frequency Devices**

Devices that produce high frequency currents in the protective earth may produce touch voltages that are dangerous to persons and livestock.

**NOTES:**

1. The touch voltages may be as much as 100 V but the manufacturer's advice should be sought when installing this type of device. These high frequency voltages may not be detectable using normal 50 Hz test instruments. An oscilloscope and ballast resistor is required.
2. Attention is drawn to the safety requirements for electronic equipment in AS62103.

**5.5 Earthing Arrangements**

**5.5.1 Main Earthing Conductor**

**5.5.1.1 Arrangement**

An earthing conductor, deemed to be the main earthing conductor, shall be taken from the main earthing terminal/connection or bar at the main switchboard to an earth electrode complying with Clause 5.3.6.

The main earthing conductor shall be run in as direct a manner as possible and shall not be directly connected to the terminal of any accessory, luminaire, or appliance.

**Exceptions:**

1. The main earthing conductor may be taken to an earth bar within a customer's substation forming part of the electrical installation.
2. The main earthing conductor may be taken to an earthing conductor or terminal provided by the distributor or, if required by the distributor, to a distributor neutral bar within the electrical installation.

**NOTE:** An earthing conductor or terminal provided by the distributor may include a special earthing conductor, the conductive sheath of a supply cable, or a neutral bar at a substation.

**5.5.1.2 Connection to Earth Electrode**

The connection of the main earthing conductor to the earth electrode shall: (a) be accessible for visual inspection and for the purposes of testing; **NOTES:**

1. Where necessary, access by means of an underground pit with its cover accessible above ground is considered acceptable, provided adequate space is available for the connection of test leads and the pit is suitably identified as to its purpose.
2. Where the reinforcing steel is used as the earth electrode, this testing condition is deemed to be satisfied by the provision of a test point on the main earthing electrode. (b) be made by means of a suitable device, in accordance with the manufacturer's specification, that provides adequate electrical conductivity; (c) provide protection against mechanical damage likely to occur to the main earthing conductor or the connection to the electrode at the location, in accordance with Clause 5.5.5.2; and (d) be suitably protected against corrosion in accordance with Clause 5.5.5.3.

**NOTE:** For location of earth electrodes, see Clause 5.3.6.4.

**5.5.1.3 Labelling**

The main earthing conductor shall have a permanent label attached at the connection to the earth electrode with a legible warning against disconnection in the following form:

**WARNING: MAIN ELECTRICAL EARTHING CONDUCTOR—DO NOT DISCONNECT.**

**Exception:** Where the method of connection to the electrode precludes disconnection, this requirement need not apply.

**5.5.1.4 Resistance**

The resistance of the main earthing conductor, measured between the main earthing terminal/connection or bar and the earth electrode, including the connection to the earth electrode, shall be not more than 0.5 Ω.

**5.5.2 Protective Earthing Conductors**

**5.5.2.1 Arrangement**

All protective earthing conductors shall be directly connected to the main earthing conductor or to another point on an earthing system that is connected to the main earthing conductor. Protective earthing conductors shall not normally carry load current.

The connection shall be made at one or a combination of the following points:

(a) An earthing terminal/connection or bar at the main switchboard provided specifically for the connection of earthing conductors and that is directly connected to the main earthing conductor. (b) Any point on the main earthing conductor. (c) An earthing terminal/connection or bar at a distribution board provided specifically for the connection of protective earthing conductors and arranged to comply with Clause 5.5.2.2. (d) Any point on a protective earthing conductor providing facilities for earthing at a distribution board and arranged to comply with Clause 5.5.2.2.

**NOTES:**

1. Examples of earthing connections are shown in Figure 5.3.
2. Refer to Clause 5.5.3.1 where the earthing system in an outbuilding is to be treated as a separate MEN installation.

**5.5.2.2 Restricted Connections**

**5.5.2.2.1 Circuits**

The protective earthing conductor for a circuit that is incorporated in the same cable sheath or wiring enclosure as the associated live conductors for the circuit shall only be used for the earthing of equipment supplied from the circuit.

**Exception:** This does not preclude an unenclosed common protective earthing conductor being used for a number of different circuits.

**5.5.2.2.2 Earthing of Equipment**

A protective earthing conductor that originates at a distribution board, in accordance with Clause 5.5.2.1, Item (c) or (d), shall not be used for the earthing of electrical equipment that is supplied from another switchboard.

**5.5.2.2.3 Earthing Facilities for Distribution Boards**

A protective earthing conductor that originates at a distribution board, in accordance with Clause 5.5.2.1, Item (c) or (d), shall not be used for the provision of earthing facilities for another distribution board.

**Exceptions:**

1. This requirement need not apply where earthing facilities for a distribution board originate from the same distribution board as the associated active conductors supplying the distribution board.
2. A common protective earthing conductor connected to the main earthing conductor in accordance with Clause 5.5.2.1, Item (a) or (b) may be arranged to provide earthing facilities at a number of distribution boards provided that:
   * the continuity of the protective earthing conductor shall not be dependent on a terminal at a distribution board; and
   * a direct connection shall be made between the common protective earthing conductor and any branch protective earthing conductor to a distribution board.

**5.5.3 Particular Methods of Earthing**

**5.5.3.1 Outbuildings**

Subcircuits supplied from DB2.

All parts of an electrical installation in or on an outbuilding that are required to be earthed in accordance with Clause 5.4 shall be earthed by one of the following methods:

(a) Individual Outbuildings: The earthing system in an individual outbuilding shall be either: (i) connected to a protective earthing conductor connected in accordance with Clause 5.5.2.1; (ii) connected as a separate MEN installation in accordance with Clauses 5.5.3.1 (c) and 5.5.3.2.

(b) Combined Outbuildings: The earthing system in a combined outbuilding shall be connected to a protective earthing conductor, connected in accordance with Clause 5.5.2.1, and shall not be connected as a separate MEN installation.

(c) Separate MEN Installation: 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.

The electrical installation in the outbuilding shall be regarded as a separate electrical installation, and shall be earthed in accordance with other relevant Clauses of this Standard. The following requirements and recommendations also apply: (i) There shall be not more than one MEN connection in any one individual outbuilding. (ii) The distribution board in the outbuilding shall be regarded as a main switchboard for the purpose of effecting the MEN connection. (iii) The earthing conductor between the distribution board in the outbuilding and the earth electrode shall be regarded as a main earthing conductor for the purposes of earthing of the electrical installation in the outbuilding. (iv) The submain supplying the outbuilding shall be run either: (A) directly from the main switchboard; or (B) from the main switchboard via distribution boards in one or more other outbuildings, to one distribution board only in the outbuilding. (v) Where the combined protective earthing and neutral (PEN) conductor supplying the distribution board in the outbuilding runs from the main switchboard via distribution boards in one or more other outbuildings, the terminals on such distribution boards shall not be depended on for continuity of the combined protective earthing and neutral (PEN) conductor. (vi) The combined protective earthing and neutral (PEN) conductor supplying the distribution board in the outbuilding should not be connected in parallel, by means of earthing or equipotential bonding conductors, with conductive pipes or structural metal within the electrical installation.

**NOTES:**

1. Refer to Figures 5.4 and 5.5 for examples of earthing of individual and combined outbuildings.
2. Particular care is needed where conductive pipes and such items as telecommunication cable sheaths, covered walkways, etc. may be continuous between separate buildings and thus establish a parallel earth/neutral path.

**5.5.3.2 Wiring Systems**

(a) Conductive Wiring Enclosures: Exposed conductive parts of wiring enclosures shall be earthed at the end adjacent to the switchboard or accessory at which the wiring enclosure originates.

(b) Conductive Sheaths, Armours, and Screens of Cables or Cords: The conductive sheathing, armouring or screening of cables or cords required to be earthed shall be earthed at the end adjacent to the switchboard or accessory at which the cable or cord originates.

**Exceptions:**

1. A conductive screen or braid embodied in a cable or flexible cord need not be earthed where:
   * it is separated from the live conductors by double insulation;
   * sheathed or covered overall with non-conductive material; and
   * all joints to and terminations of the screen or braid are suitably separated from exposed conductive and live parts.
2. A conductive cable sheathing, armouring, screening, or braiding need not be earthed where, in accordance with Clause 5.4, earthing is not required.

**5.5.3.3 Electrical Equipment Supplied by Flexible Cord or Flexible Cable**

The exposed conductive parts of electrical equipment supplied by flexible cord or flexible cable shall be earthed by connection to a protective earthing conductor incorporated with the associated live conductors in the sheath, braid, or enclosure of the supply cord or cable.

**5.5.3.4 Switchboards**

Electrical equipment mounted on the conductive framework of a switchboard may be earthed in accordance with Clause 5.3.2.3(c).

**5.5.3.5 Unprotected Consumer Mains**

Exposed conductive parts associated with consumer mains not provided with short-circuit protection on the supply side shall be earthed by a conductor or by direct connection to an earth bar such that either has a current-carrying capacity not less than that of the main neutral conductor. Unprotected consumer mains are those that are not protected by a service protective device as shown in Figure 2.1.

**NOTE:** Short-circuit of an unprotected active conductor to a switchboard surround, riser bracket, etc. will cause the earthing conductor to continuously carry the maximum fault current available through those consumer mains. Reduced sizes for protective earthing conductors in other situations are permitted because the fault current is of limited duration.

This conductor shall be connected to: (a) the main neutral conductor or bar [see Figure 5.6(A)]; or (b) the main earthing terminal/connection or bar, in which case, in accordance with Clause 5.3.5.2, the cross-sectional area of the MEN connection shall be not less than that of the main neutral conductor [see Figure 5.6(B)].

**Exception:** Where double insulation of the consumer mains conductors is maintained up to the supply terminals of the service protective device(s), and short-circuit protection is provided by that device, this requirement need not apply [see Figure 5.6(C)].

**NOTES:**

1. A system that is deemed to provide double insulation for aerial conductors would include use of XLPE type X-90UV cable to AS/NZS 3560 with insulated strain clamps and double insulated connectors to AS/NZS 4396.
2. Exposed conductive parts associated with consumer mains include: (a) switchboard cases, surrounds, and enclosures; (b) wiring enclosures; (c) boxes and accessories; and (d) supports for aerial conductors.
3. A distributor's upstream service protective device may provide short-circuit protection of consumer mains.

**5.5.4 Continuity**

**5.5.4.1 General**

Earthing conductors shall be suitably protected against mechanical and chemical deterioration and electrodynamic forces. Star or cutting washers or similar devices that effectively cut through paint or similar coatings are considered to be an acceptable method of ensuring earth continuity across bolted or clamped joints between metal equipment panels or framework that have painted or coated surfaces.

**5.5.4.2 Conductive Wiring Enclosures**

Conductive wiring enclosures and associated fittings that are required to be earthed, including those used as an earthing medium, shall be mechanically and electrically continuous. The impedance of such a wiring enclosure earthing arrangement shall be in accordance with Clause 5.7.

**5.5.4.3 Conductive Sheaths, Armours, and Screens of Cables**

Conductive sheaths, armours, and screens of cables and associated fittings that are required to be earthed, including those used as an earthing medium, shall be mechanically and electrically continuous. The impedance of such cable components and associated fittings providing earth continuity shall be in accordance with that required for a copper earthing conductor determined in accordance with Clause 5.3.3.

**5.5.4.4 Connecting Devices**

Where electrical equipment is connected to the installation wiring by a connection in the form of a plug and socket-outlet, appliance plug, or similar connecting device, any connection of exposed conductive parts to earth shall be:

(a) made automatically, before the live connections are made, when any plug portion is inserted in the corresponding socket-outlet; and

(b) broken automatically, not before the live connections are broken, when any plug portion is withdrawn from the corresponding socket-outlet.

**5.5.5 Installation**

**5.5.5.1 General**

All earthing conductors and other forms of earthing medium shall be installed in a manner that provides adequate protection against likely mechanical damage, inadvertent interference, and chemical deterioration.

**NOTE:** In areas of high lightning activity, the provisions of AS/NZS 1768 should be considered.

**5.5.5.2 Protection Against Mechanical Damage**

Earthing conductors shall be protected against becoming displaced, damaged, or cut by means of one or a combination of the following methods appropriate to the expected conditions or mechanical damage at the point of installation:

(a) Fixing by means of clamps, clips, saddles, clouts, or similar devices that shall not pass between the strands of the conductor or damage the conductor. (b) Guarding by metallic barriers or other robust material.

(c) Installing in a wiring enclosure, in accordance with Clause 3.10.2.

**5.5.5.3 Protection Against Corrosion**

Earthing conductors, and any associated fixing devices, shall be protected from corrosion, including the effects of moisture or contact with dissimilar metals.Earthing conductors and associated fittings and fixing devices shall comply with the following requirements:

(a) Underground and Damp Situations: All joints and terminations installed in an underground location or other damp situation shall be sealed to prevent the entry of moisture. All associated fittings and fixing devices in such locations shall be constructed of, or protected by, corrosion-resistant material. (b) Exposed to the Weather: All joints, terminations, fittings, and fixtures in locations exposed to the weather shall be constructed of, or protected by, corrosion-resistant material in such a manner that will prevent the entry of moisture affecting the conductor.

**5.5.5.4 Aerial Earthing Conductors**

Aerial earthing conductors shall be:

(a) supported in accordance with Clause 3.12.5; and

(b) identified in accordance with Clause 3.8.3.4.

**5.5.5.5 Buried Earthing Conductors**

(a) Installation Conditions: A bare or insulated earthing conductor buried directly in the ground or installed in an underground enclosure shall be subject to the depth of laying and mechanical protection requirements appropriate to the method of installation for a sheathed conductor, in accordance with Clause 3.11.

(b) Bare Earthing Conductors: In addition, bare earthing conductors shall be buried directly in the ground or installed in an underground enclosure only where they are copper not less than 25 mm².

(c) Walls and Partitions: An earthing conductor that passes through a wall or partition shall not be considered as a buried earthing conductor.

**5.5.6 Connections**

**5.5.6.1 Conductors**

Connections in earthing conductors shall comply with Clause 3.7.

**5.5.6.2 Constructional Components**

The exposed conductive parts of electrical equipment may be earthed by the connection of a protective earthing conductor to a constructional bolt, stud, screw, or similar terminal arrangement forming an integral part of the electrical equipment.

Such earthing shall be in accordance with the following requirements:

(a) The terminal shall be mechanically and electrically continuous with the exposed conductive part to be earthed.

(b) The protective earthing conductor shall be capable of being removed from the terminal without:

(i) reducing the effectiveness of the bolt, stud, or screw as a constructional medium in any way; or

(ii) causing any parts of the electrical equipment to lose their relative rigidity.

A stud that also serves for securing a terminal cover may be used for the connection provided that it complies with items (c) and (d).

(c) The removal of any covers or parts that are likely to be removed to:

(i) obtain access to terminals; or

(ii) adjust the electrical equipment or parts thereof, shall not disturb or reduce the effectiveness of the earthing connection.

(d) The bolt, stud, or screw shall not be used to:

(i) fix the electrical equipment in position; or

(ii) adjust the position of the electrical equipment or any part of it.

**5.6 Equipotential Bonding**

**5.6.1 General**

Equipotential bonding is intended to minimize the risks associated with the occurrence of voltage differences between exposed conductive parts of electrical equipment and extraneous conductive parts.

Such voltage differences can arise from a range of sources including the following: (a) A fault external to the installation, either on an incoming extraneous conductor (such as a water or gas pipe, etc.) or on the supply neutral and protective earthing system. (b) Distribution system load current in the soil passing through a swimming pool. (c) Telecommunication system voltages on equipment adjacent to exposed conductive parts. (d) Lightning discharges either directly within the installation or affecting the incoming extraneous conductor or the supply mains.

**5.6.2 Arrangement**

**5.6.2.1 General**

Equipotential bonding arrangements shall be provided in accordance with Clauses 5.6.2.2 to 5.6.2.6 to avoid any potential differences that may occur between electrical equipment connected to the electrical installation earthing system and any conductive piping (including taps etc.) that may independently be in contact with the mass of earth (see Figures 5.7 and 5.8 for arrangement details).

Additional equipotential bonding requirements apply for: (a) Patient areas of hospitals, medical and dental practices and dialyzing locations, in accordance with AS/NZS 3003. (b) Explosive atmospheres, in accordance with Clause 7.7. (c) Telecommunications installations, in accordance with AS/NZS 3015. (d) Film, video and television sites, in accordance with AS/NZS 4249. (e) Photovoltaic arrays, in accordance with AS/NZS 5033. (f) Grid connected inverters, in accordance with AS/NZS 4777.1. (g) Generating systems, in accordance with Clause 7.3. (h) Separated circuits, in accordance with Clause 7.4.

**5.6.2.2 Conductive Water Piping**

Conductive water piping that is both: (a) installed and accessible within the building containing the electrical installation; and (b) continuously conductive from inside the building to a point of contact with the ground, shall be bonded to the earthing system of the electrical installation.

Any equipotential bonding of conductive water piping shall be effected by means of an equipotential bonding conductor connected to the main earthing conductor or earth terminal or bar. The connection of the bonding conductor to the conductive water piping shall be as close as practicable to the entry of the conductive water piping to the building.

**NOTES:**

1. The main earthing conductor may be continued beyond the earth electrode connecting device to form the equipotential bonding conductor to the conductive water piping. A separate connection to the earth electrode does not constitute a connection to the main earthing conductor and does not comply with this Clause.
2. Item (b) above includes any conductive path through an item of equipment, e.g. a water heater.

**5.6.2.3 Other Conductive Piping Systems**

Conductive piping systems associated with fire sprinklers, gas, water, or flammable liquid that are unavoidably in contact with the exposed conductive parts of wiring enclosures, cable components, or other electrical equipment shall be connected to such equipment by means of an equipotential bonding conductor.

**Exception:** Bonding need not be provided where the piping system is effectively earthed by connection to an associated item of electrical equipment, e.g. pipes connected to electric hot water systems.

**5.6.2.4 Conductive Cable Sheaths and Conductive Wiring Enclosures**

The conductive sheath, armour, or conductive wiring enclosure of conductors operating at above extra-low voltage shall comply with one of the following: (a) The conductive sheath, armour, or conductive wiring enclosure of conductors shall be bonded to any conductive pipes containing flammable agents, such as gas or oil, with which they are in contact. The bonding shall be arranged to prevent appreciable voltage differences at points of contact. or (b) Where it is impracticable to achieve the bonding specified in Item (a), the conductive cable sheath, armour, or conductive wiring enclosures shall be separated from any non-earthed conductive pipes containing flammable agents. This separation shall overlap the points of crossing by 25 mm in all directions and be: (i) a rigid spacing of 25 mm in air; or (ii) a 6 mm thickness of durable insulating material.

**5.6.2.5 Showers and Bathrooms**

Any conductive reinforcing within a concrete floor or wall of a room containing a shower or bath shall be bonded to the earthing system of the electrical installation.

An equipotential bonding conductor, in accordance with Clause 5.6.3, shall be connected between the reinforcing material and any part of the earthing system. For a combined outbuilding, each structure within that outbuilding that contains a shower or bathroom shall contain its own individual bonding connection to the conductive reinforcing within that structure.

Providing the reinforcement is electrically continuous across the whole of the combined outbuilding (refer to Note 3), one bonding conductor connecting the reinforcement to the earth bar or link of the switchboard that supplies all of the combined outbuilding is satisfactory.

**NOTES:**

1. This requirement is intended to avoid any potential differences that may occur between conductive material connected to, or in contact with, the electrical installation earthing system or earthed electrical appliances and the concrete floor or wall.
2. A conductive grille or reinforcement mesh laid in the floor and connected to the equipotential bonding conductor may also be used.
3. Conductive tie-wires used during construction of reinforced concrete structures are considered to be an adequate electrical bond between the conductive reinforcing components. Provided that the reinforcement is satisfactorily electrically connected together, one point of connection of the bonding conductor to the reinforcement is sufficient.
4. In existing electrical installations, the bonding requirement of this Clause for concrete floors and walls containing conductive reinforcing need not apply, but should be adopted wherever practicable.

**5.6.2.6 Swimming and Spa Pools**

**5.6.2.6.1 Bonding Arrangement**

An equipotential bonding conductor, in accordance with Clause 5.6.3, shall be connected between: (a) the conductive pool structure and the pool equipotential bonding conductor connection point specified in Clauses 5.6.2.6.2 and 5.6.2.6.3; (b) the items of electrical equipment specified in Clause 5.6.2.6.4; (c) the conductive fixtures and fittings specified in Clause 5.6.2.6.5; and (d) the earthing conductors associated with each circuit supplying the pool or spa, or the earthing bar at the switchboard at which the circuits originate.

The resistance of an equipotential bonding conductor connected between the items listed (a) to (d) shall not exceed 0.5 Ω.

**A bonding arrangement for pools and spas is provided in Figure 5.9.**

**5.6.2.6.2 Conductive Pool Structures**

Where the pool structure is conductive, all extraneous conductive parts, including the reinforcing metal of the pool shell or deck, shall be connected to a pool equipotential bonding conductor connection point complying with Clause 5.6.2.6.3. The connection point shall also be bonded to the earthing conductors associated with each circuit supplying the pool or spa, or the earthing bar at the switchboard at which the circuits originate.

**Where the pool structure is conductive, the connection point shall be installed and bonded to the installation earthing system regardless of other requirements specified in Clauses 5.6.2.6.4 and 5.6.2.6.5.**

**Exception:** This requirement need not apply where the reinforcing metal of the pool shell or deck is electrically continuous (0.5 Ω) to the reinforcing metal within the concrete floor of the electrical installation, and that reinforcing metal has been bonded to the earthing system of the electrical installation as required in Clause 5.6.2.5.

**NOTES:**

1. Connections to the conductive reinforcement of the pool will generally be subject to the effects of water during the construction phase and to subsequent dampness.
2. Conductive tie-wires used during construction of reinforced concrete pools are considered to be an adequate electrical bond between the conductive reinforcing components. Provided that the reinforcement is satisfactorily electrically connected together, one point of connection of the bonding conductor to the reinforcement is sufficient.

**5.6.2.6.3 Pool Equipotential Bonding Conductor Connection Point**

An equipotential bonding conductor connection point, as required by Clause 5.6.2.6.2, may be used as a connection point for the bonding arrangements required by Clauses 5.6.2.6.4 and 5.6.2.6.5.

The connection point shall be: (a) located in a position that will be accessible with space for connections to be made after pool construction (e.g. located adjacent to the pool equipment); (b) identified by marking of its location on the switchboard at which the circuits supplying the pool or spa originate, or other permanent location; (c) designed and constructed in accordance with Clause 3.7; (d) protected against mechanical damage in accordance with Clause 5.5.5.2; and (e) protected against corrosion in accordance with Clause 5.5.5.3.

**5.6.2.6.4 Electrical Equipment**

The following items associated with electrical equipment shall be equipotentially bonded: (a) The exposed conductive parts of any electrical equipment in the classified pool zones. (b) Any exposed conductive parts of electrical equipment in contact with the pool water, including water in the circulation or filtration system, e.g. filtration pumps and heating systems.

**NOTES:**

1. Where electrical appliances and luminaires are supplied as a separated circuit in accordance with Clause 7.4, all conductive parts of such electrical equipment are deemed to be separated from live parts by double insulation.
2. Underwater luminaire bezels should be made of plastics and any associated fixing screws be insulated or of insulating material.

**5.6.2.6.5 Conductive Fixtures and Fittings**

Where any items specified in Clauses 5.6.2.6.2 or 5.6.2.6.4 are required to be equipotentially bonded, the bonding shall be extended to any fixed conductive material (such as pool ladders, diving boards, conductive fences, pipework and reinforcing metal in a concrete slab) that is installed within arm's reach of the pool edge, and that is in contact with the general mass of earth either directly or indirectly.

**NOTES:**

1. The general mass of earth itself may not provide a low enough impedance to operate a protective device or be suitable as an electrical bond.
2. Refer to Clause 1.4.16 and Figure 1.1 for the zone of arm's reach and Clause 1.4.60 for the definition of equipotential bonding.

**Exception:**

1. Where any fixed conductive material (such as pool ladders, diving boards, etc.) is installed within arm's reach of the pool edge and is electrically continuous (0.5 Ω) to the reinforcing metal of a concrete slab into which it is installed, and where that reinforcing metal is electrically continuous with the reinforcing metal of the pool shell or deck, then no additional bonding is required.
2. This requirement need not apply to fixed conductive parts and fittings that are not part of electrical equipment and have no individual accessible part greater than 100 mm in any dimension.

**5.6.2.7 Telephone and Telecommunication Earthing Systems**

The telephone and telecommunication earthing system may be connected in common with the electrical installation earthing system in order to minimize the risk associated with different voltages appearing on the two systems.

If the telephone and telecommunication earthing system is directly connected to the electrical installation earthing system, it shall be connected either: (a) to the electrical installation earthing system at an enclosed terminal provided for the purpose; or (b) directly to the earth electrode by an independent connecting device, and shall be clearly identified.

If an enclosed terminal is used, the following conditions shall apply: (i) The terminal shall be connected by means of a protective earthing conductor to the main earthing conductor of the electrical installation earthing system in accordance with the connection methods specified in Clause 5.5.2. (ii) The terminal shall not be installed within a switchboard. (iii) The terminal shall be installed in a convenient and readily accessible position. (iv) The minimum cross-sectional area of the protective earthing conductor used for the connection shall be 6 mm².

**NOTES:**

1. Requirements for the installation of telecommunications earthing systems in Australia are contained in AS/CA S009, Installation requirements for customer cabling (Wiring Rules).
2. Recommendations for New Zealand are contained in the TCF Premises Wiring Code of Practice.
3. Refer to Appendix F for further detail of the bonding arrangement.

**5.6.3 Bonding Conductors**

**5.6.3.1 General**

The selection and installation of equipotential bonding conductors shall be in accordance with the protective earthing conductor requirements in Clause 5.5.

**Exception:** The size of an equipotential bonding conductor shall be determined in accordance with Clause 5.6.3.2.

**5.6.3.2 Size**

The size of equipotential bonding conductors shall be determined from the requirements of this Clause 5.6.3, as appropriate to the particular bonding conductor application.

The equipotential bonding conductor need not be larger than the sizes specified below, provided the installation conditions are such that mechanical damage is unlikely to occur, and, in accordance with Clause 5.7.5, a larger size is not required to reduce the earth fault-loop impedance.

The size of equipotential bonding conductors shall be in accordance with the following:

(a) **Conductive piping, cable sheaths, and wiring enclosures:** The equipotential bonding conductor required in accordance with Clauses 5.6.2.2 to 5.6.2.4 shall have a cross-sectional area not less than 4 mm². (b) **Showers, bathrooms, swimming and spa pools:** The equipotential bonding conductors required to connect conductive parts of a shower, bathroom, swimming or spa pool in accordance with Clauses 5.6.2.5 and 5.6.2.6 shall have a cross-sectional area not less than 4 mm².

**Exception:** The cross-sectional area of the equipotential bonding conductor for a swimming or spa pool may be determined as for an earthing conductor, in accordance with Clause 5.3.3.4(c), where the equipotential bonding conductor is incorporated in a multi-core flexible cord supplying electrical equipment that is required to be removed for maintenance.

(c) **Telephone and telecommunication earthing systems:** The equipotential bonding conductors required to connect a telephone and telecommunication earthing system in accordance with Clause 5.6.2.7 shall have a cross-sectional area not less than 6 mm².

**NOTE:** Refer to the AS/NZS 60079 series for minimum sizes of equipotential bonding conductors in explosive atmospheres.

**5.7 Earth Fault-Loop Impedance**

**5.7.1 General**

Effective fault protection by means of automatic disconnection of supply is based on disconnecting supply from the section of the installation concerned in such a way as to limit the time/touch voltage relationship to safe values in the event of an insulation fault.

Automatic disconnection is dependent on the characteristics of the circuit protective device and the impedance of the earthing system. 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.

The impedance of the earthing system shall be limited to that which will generate sufficient current in the protective device to cause operation of that device within the required time, taking into consideration the characteristics of the circuit protection device and the impedance of the active conductor.

**NOTE:** Appendix B provides a detailed analysis of earth fault-loop impedance as an element of the method of protection by automatic disconnection of supply.

**5.7.2 Disconnection Times**

The maximum disconnection time for a 230 V supply voltage shall not exceed the following:

(a) 0.4 s for final subcircuits that supply: (i) socket-outlets having rated currents not exceeding 63 A; or (ii) hand-held Class I equipment; or (iii) portable equipment intended for manual movement during use.

(b) 5 s for other circuits where it can be shown that people are not exposed to touch voltages that exceed safe values. Refer to Appendix B, Paragraph B4.

**NOTES:**

1. Maximum disconnection times will vary for other operating voltages or installation conditions, such as wet locations, etc.
2. The fault current has to be of sufficient magnitude to cause automatic disconnection within the required times.
3. See Clauses 1.5 and 2.4.2.

**5.7.3 Earth Fault-Loop**

The path for the circulation of fault current, the earth fault-loop, in a MEN system comprises the following parts:

(a) The active conductor as far as the point of the fault, including supply mains, service line, consumer mains, submains (if any) and the final subcircuit. (b) The protective earthing conductor (PE), including the main earthing terminal/connection or bar and MEN connection. (c) The neutral-return path, consisting of the neutral conductor (N) between the main neutral terminal or bar and the neutral point at the transformer, including supply mains, service line and consumer mains. (d) The path through the neutral point of the transformer and the transformer winding.

**NOTE:** See Appendix B, Figure B5.

**5.7.4 Impedance**

The earthing system impedance and characteristics of protective devices shall be such that, if a fault of negligible impedance occurs anywhere in the electrical installation between an active conductor and an exposed conductive part or protective earthing conductor, automatic disconnection of the supply will occur within the specified time.

The following condition fulfills this requirement:

𝑍𝑠×𝐼𝑎≤𝑈𝑜

where:

𝑍𝑠​ = the impedance of the earth fault-loop comprising the source, the active conductor up to the point of the fault, and the return conductor between the point of the fault and the source

𝐼𝑎​ = the current required to cause the automatic operation of the disconnecting protective device within the required disconnection time

𝑈𝑜​ = the nominal a.c. r.m.s. voltage to earth (230 V)

**NOTES:**

1. Additional earthing requirements apply in patient areas of hospitals, medical and dental practices, and dialyzing locations. Refer to AS/NZS 3003.
2. The return path will comprise both protective earthing and neutral conductors.
3. Appendix B illustrates a method of complying with the requirements of this Clause based on the determination of the maximum length of a circuit in relation to the size of circuit conductors and type of protective device.
4. Guidance on the measurement of the earth fault-loop impedance of each circuit is given in Appendix B.
5. Table B.1 contains calculated examples of the maximum values of earth fault-loop impedance, 𝑍𝑠​, using approximate mean tripping currents for a limited range of miniature circuit-breakers (MCBs) (taken from AS/NZS 60898 and manufacturers' time/current characteristic curves) and fuses (taken from IEC 60269 series) and the appropriate disconnection time.

**5.7.5 Supplementary Equipotential Bonding**

In the event that a reduction in earth fault-loop impedance is required in order to ensure that the disconnection time of the protective device is sufficient to satisfy the requirements of Clause 5.7.2, bonding of extraneous conductive parts and their connection to the earthing system may be used.

**NOTE:** Other measures, such as selection of an alternative protective device, e.g. an RCD that has a lower automatic operating current, i.e., within the required disconnection time, may also be used to satisfy the requirements of Clause 5.7.2.

**5.8 Other Earthing Arrangements**

Where it is intended to provide fault protection by the method of electrical separation, protective earthing conductors and equipotential bonding conductors shall be arranged in accordance with the requirements of Clause 7.4.

The earthing arrangements of the following systems should be independent systems; however, if they are connected to the electrical installation earthing system they should not reduce the integrity of the electrical installation protective earthing system.

**Examples:** The following are examples of independent systems: (a) Lightning protection. (b) Static electricity protection. (c) Radio frequency interference (RFI)-screened installations. (d) Information technology installations. (e) Explosion protection systems. (f) Cathodic protection systems.

**NOTE:** Requirements for the installation of protective earthing and bonding conductors for the above systems may be contained in other Standards.