

8 Equipotential bonding

8.1 General

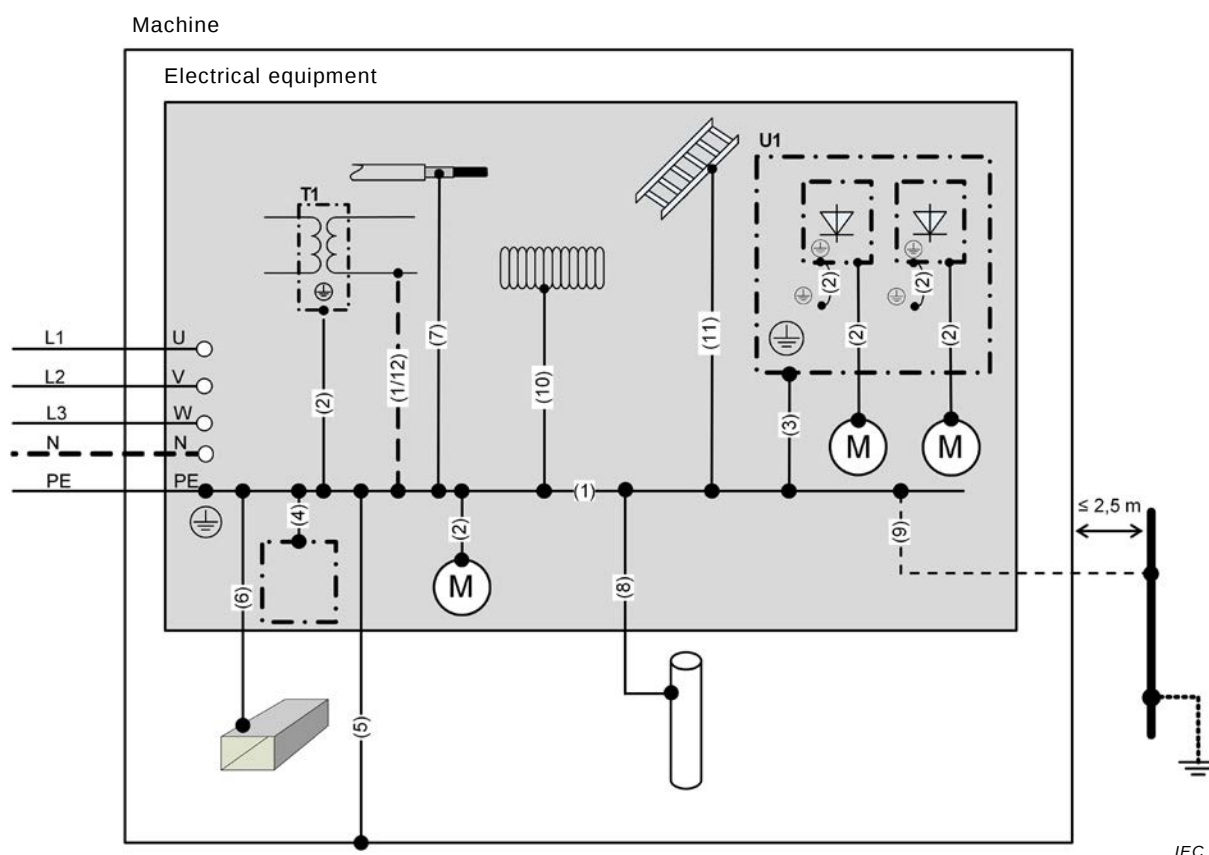
This Clause 8 provides requirements for protective bonding and functional bonding. Figure 4 illustrates those concepts.

Protective bonding is a basic provision for fault protection to enable protection of persons against electric shock (see 6.3.3 and 8.2).

The objective of functional bonding (see 8.4) is to reduce:

- the consequence of an insulation failure which could affect the operation of the machine;
- electrical disturbances to sensitive electrical equipment which could affect the operation of the machine;
- induced currents from lightning which could damage the electric equipment.

Functional bonding is achieved by connection to the protective bonding circuit, but where the level of electrical disturbances on the protective bonding circuit is not sufficiently low for proper functioning of electrical equipment, it can be necessary to use separate conductors for protective and functional bonding.



Protective bonding circuit:	
(1)	Interconnection of protective conductor(s) and the PE terminal
(2)	Connection of exposed conductive parts
(3)	Protective conductor connected to an electrical equipment mounting plate used as a protective conductor
(4)	Connection of conductive structural parts of the electrical equipment
(5)	Conductive structural parts of the machine
Parts connected to the protective bonding circuit which are not to be used as protective conductor:	
(6)	Metal ducts of flexible or rigid construction
(7)	Metallic cable sheaths or armouring
(8)	Metallic pipes containing flammable materials
(9)	Extraneous-conductive-parts, if earthed independently from the power supply of the machine and liable to introduce a potential, generally the earth potential, (see 17.2 d)), e.g.: metallic pipes, fences, ladders, handrails.
(10)	Flexible or pliable metal conduits
(11)	Protective bonding of support wires, cables tray and cable ladders
Connections to the protective bonding circuit for functional reasons:	
(12)	Functional bonding
Legend to reference designations:	
T1	Auxiliary transformer
U1	Mounting plate of electrical equipment

**Figure 4 – Example of equipotential bonding
for electrical equipment of a machine**

8.2 Protective bonding circuit

8.2.1 General

The protective bonding circuit consists of the interconnection of:

- PE terminal(s) (see 5.2);
- the protective conductors (see 3.1.51) in the equipment of the machine including sliding contacts where they are part of the circuit;
- the conductive structural parts and exposed conductive parts of the electrical equipment;

Exception: see 8.2.5.

- conductive structural parts of the machine.

All parts of the protective bonding circuit shall be so designed that they are capable of withstanding the highest thermal and mechanical stresses that can be caused by earth-fault currents that could flow in that part of the protective bonding circuit.

The cross-sectional area of every protective conductor which does not form part of a cable or which is not in a common enclosure with the line conductor shall be not less than

- 2,5 mm² Cu or 16 mm² Al if protection against mechanical damage is provided,
- 4 mm² Cu or 16 mm² Al if protection against mechanical damage is not provided.

NOTE The use of steel for a protective conductor is not excluded.

A protective conductor not forming part of a cable is considered to be mechanically protected if it is installed in a conduit, trunking or protected in a similar way. Conductive structural parts of equipment in accordance with 6.3.2.2 need not be connected to the protective bonding circuit. Conductive structural parts of the machine need not be connected to the protective bonding circuit where all the equipment provided is in accordance with 6.3.2.2.

Exposed conductive parts of equipment in accordance with 6.3.2.3 shall not be connected to the protective bonding circuit.

It is not necessary to connect exposed conductive parts to the protective bonding circuit where those parts are mounted so that they do not constitute a hazard because:

- they cannot be touched on large surfaces or grasped with the hand and they are small in size (less than approximately 50 mm × 50 mm); or
- they are located so that either contact with live parts, or an insulation failure, is unlikely.

This applies to small parts such as screws, rivets, and nameplates and to parts inside an enclosure, irrespective of their size (for example electromagnets of contactors or relays and mechanical parts of devices).

8.2.2 Protective conductors

Protective conductors shall be identified in accordance with 13.2.2.

Copper conductors are preferred. Where a conductor material other than copper is used, its electrical resistance per unit length shall not exceed that of the allowable copper conductor and such conductors shall be not less than 16 mm² in cross-sectional area for reasons of mechanical durability.

Metal enclosures or frames or mounting plates of electrical equipment, connected to the protective bonding circuit, may be used as protective conductors if they satisfy the following three requirements:

- their electrical continuity shall be assured by construction or by suitable connection so as to ensure protection against mechanical, chemical or electrochemical deterioration;
- they comply with the requirements of 543.1 of IEC 60364-5-54:2011;
- they shall permit the connection of other protective conductors at every predetermined tap-off point.

The cross-sectional area of protective conductors shall either be calculated in accordance with 543.1.2 of IEC 60364-5-54:2011, or selected in accordance with Table 1 (see 5.2). See also 8.2.6. and 17.2 (d) of this document.

Each protective conductor shall:

- be part of a multicore cable, or;
- be in a common enclosure with the line conductor, or;
- have a cross-sectional area of at least;
- 2,5 mm² Cu or 16 mm² Al if protection against mechanical damage is provided;
- 4 mm² Cu or 16 mm² Al if protection against mechanical damage is not provided.

NOTE 1 The use of steel for a protective conductor is not excluded.

A protective conductor not forming part of a cable is considered to be mechanically protected if it is installed in a conduit, trunking or protected in a similar way.

The following parts of the machine and its electrical equipment shall be connected to the protective bonding circuit but shall not be used as protective conductors:

- conductive structural parts of the machine;
- metal ducts of flexible or rigid construction;
- metallic cable sheaths or armouring;
- metallic pipes containing flammable materials such as gases, liquids, powder.
- flexible or pliable metal conduits;
- constructional parts subject to mechanical stress in normal service;
- flexible metal parts; support wires; cable trays and cable ladders.

NOTE 2 Information on cathodic protection is provided in 542.2.5 and 542.2.6 of IEC 60364-5-54:2011.

8.2.3 Continuity of the protective bonding circuit

Where a part is removed for any reason (for example routine maintenance), the protective bonding circuit for the remaining parts shall not be interrupted.

Connection and bonding points shall be so designed that their current-carrying capacity is not impaired by mechanical, chemical, or electrochemical influences. Where enclosures and conductors of aluminium or aluminium alloys are used, particular consideration should be given to the possibility of electrolytic corrosion.

Where the electrical equipment is mounted on lids, doors, or cover plates, continuity of the protective bonding circuit shall be ensured and a protective conductor (see 8.2.2) is recommended. Where a protective conductor is not provided, fastenings, hinges or sliding contacts designed to have a low resistance shall be used (see 18.2.2, Test 1).

The continuity of conductors in cables that are exposed to damage (for example flexible trailing cables) shall be ensured by appropriate measures (for example monitoring).

For requirements for the continuity of conductors using conductor wires, conductor bars and slip-ring assemblies, see 12.7.2.

The protective bonding circuit shall not incorporate a switching device, an overcurrent protective device (for example switch, fuse), or other means of interruption.

Exception: links that cannot be opened without the use of a tool and that are located in an enclosed electrical operating area may be provided for test or measurement purposes.

Where the continuity of the protective bonding circuit can be interrupted by means of removable current collectors or plug/socket combinations, the protective bonding circuit shall be interrupted by a first make last break contact. This also applies to removable or withdrawable plug-in units (see also 13.4.5).

8.2.4 Protective conductor connecting points

All protective conductors shall be terminated in accordance with 13.1.1. The protective conductor connecting points are not intended, for example, to attach appliances or parts.

Each protective conductor connecting point shall be marked or labelled as such using the symbol IEC 60417-5019:2006-08 as illustrated in Figure 5:

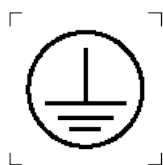


Figure 5 – Symbol IEC 60417-5019: Protective earth

or with the letters PE, the graphical symbol being preferred, or by use of the bicolour combination GREEN-AND-YELLOW, or by any combination of these.

8.2.5 Mobile machines

On mobile machines with on-board power supplies, the protective conductors, the conductive structural parts of the electrical equipment, and those extraneous-conductive-parts which form the structure of the machine shall all be connected to a protective bonding terminal to provide protection against electric shock. Where a mobile machine is also capable of being connected to an external incoming power supply, this protective bonding terminal shall be the connection point for the external protective conductor.

NOTE When the supply of electrical energy is self-contained within stationary, mobile, or movable items of equipment, and when there is no external supply connected (for example when an on-board battery charger is not connected), there is no need to connect such equipment to an external protective conductor.

8.2.6 Additional requirements for electrical equipment having earth leakage currents higher than 10 mA

Where electrical equipment has an earth leakage current that is greater than 10 mA AC or DC in any protective conductor, one or more of the following conditions for the integrity of each section of the associated protective bonding circuit that carries the earth leakage current shall be satisfied:

- a) the protective conductor is completely enclosed within electrical equipment enclosures or otherwise protected throughout its length against mechanical damage;
- b) the protective conductor has a cross-sectional area of at least 10 mm² Cu or 16 mm² Al;
- c) where the protective conductor has a cross-sectional area of less than 10 mm² Cu or 16 mm² Al, a second protective conductor of at least the same cross-sectional area is

provided up to a point where the protective conductor has a cross-sectional area not less than 10 mm² Cu or 16 mm² Al. This can require that the electrical equipment has a separate terminal for a second protective conductor.

- d) the supply is automatically disconnected in case of loss of continuity of the protective conductor;
- e) where a plug-socket combination is used, an industrial connector in accordance with IEC 60309 series, with adequate strain relief and a minimum protective earthing conductor cross-section of 2,5 mm² as part of a multi-conductor power cable is provided.

A statement shall be given in the instructions for installation that the equipment shall be installed as described in this 8.2.6.

NOTE A warning label may also be provided adjacent to the PE terminal to state that the protective conductor current exceeds 10mA.

8.3 Measures to restrict the effects of high leakage current

The effects of high leakage current can be restricted to the equipment having high leakage current by connection of that equipment to a dedicated supply transformer having separate windings. The protective bonding circuit shall be connected to exposed conductive parts of the equipment and, in addition, to the secondary winding of the transformer. The protective conductor(s) between the equipment and the secondary winding of the transformer shall comply with one or more of the arrangements described in 8.2.6.

8.4 Functional bonding

Protection against maloperation as a result of insulation failures can be achieved by connecting to a common conductor in accordance with 9.4.3.1.1.

For recommendations regarding functional bonding to avoid maloperation due to electromagnetic disturbances, see 4.4.2 and Annex H.

Functional bonding connecting points should be marked or labelled as such using the symbol IEC 60417-5020:2002-10 (see Figure 6).

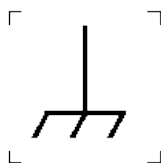


Figure 6 – Symbol IEC 60417-5020: Frame or chassis