BS EN 60204-33:2011

BSI Standards Publication

Safety of machinery — Electrical equipment of machines

Part 33: Requirements for semiconductor fabrication equipment

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National foreword

This British Standard is the UK implementation of EN 60204-33:2011. It is identical to IEC 60204-33:2010.

The CENELEC common modifications have been implemented at the appropriate places in the text. The start and finish of each common modification is indicated in the text by tags [C〉 〈C].

The UK participation in its preparation was entrusted to Technical Committee MCE/3, Safeguarding of machinery.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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EUROPEAN STANDARD

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English version

Safety of machinery -
Electrical equipment of machines -
Part 33: Requirements for semiconductor fabrication equipment
(IEC 60204-33:2009, modified)

Sécurité des machines -
Equipement électrique des machines -
Partie 33: Exigences pour les équipements de fabrication des semi-conducteurs
(CEI 60204-33:2009, modifiée)

Sicherheit von Maschinen -
Elektrische Ausrüstungen von Maschinen -
Teil 33: Anforderungen an Fertigungsausrüstungen für Halbleiter
(IEC 60204-33:2009, modifiziert)

This European Standard was approved by CENELEC on 2011-02-28. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of the International Standard IEC 60204-33:2009, prepared by IEC TC 44, Safety of machinery - Electrotechnical aspects, together with common modifications prepared by the Technical Committee CENELEC TC 44X, Safety of machinery: electrotechnical aspects, was submitted to the formal vote and was approved by CENELEC as EN 60204-33 on 2011-02-28.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2012-02-28
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2014-02-28

This European Standard has been prepared under Mandate M/396 given to CENELEC by the European Commission and the European Free Trade Association and covers essential requirements of EC Directive 2006/42/EC. See Annex ZZ.

Annexes ZA and ZZ have been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60204-33:2009 was approved by CENELEC as a European Standard with agreed common modifications as given below.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60034-11	2004	Rotating electrical machines - Part 11: Thermal protection	EN 60034-11	2004
IEC 60038	-	IEC standard voltages	-	-
IEC 60073	2002	Basic and safety principles for man-machine interface, marking and identification - Coding principles for indicators and actuators	EN 60073	2002
IEC 60364-4-41 (mod)	2005	Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock	HD 60364-4-41 + corr. July	2007 2007
IEC 60364-4-43 (mod)	2008	Low voltage electrical installations - Part 4-43: Protection for safety - Protection against overcurrent	HD 60364-4-43	2010
IEC 60364-6 (mod)	2006	Low voltage electrical installations - Part 6: Verification	HD 60364-6	2007
IEC 60417	Data-base	Graphical symbols for use on equipment	-	-
IEC 60445 (mod)	2006	Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals and conductor terminations	EN 60445	2007
IEC 60446	2007	Basic and safety principles for man-machine interface, marking and identification - Identification of conductors by colours or alphanumerics	EN 60446	2007
IEC 60447	2004	Basic and safety principles for man-machine interface, marking and identification - Actuating principles	EN 60447	2004
IEC 60529	1989	Degrees of protection provided by enclosures (IP Code)	EN 60529 + corr. May	1991 1993
IEC 60617	Data-base	Graphical symbols for diagrams	-	-
IEC 60695-11-10	1999	Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods	EN 60695-11-10	1999
IEC 60950-1 (mod)	2005	Information technology equipment - Safety - Part 1: General requirements	EN 60950-1 + A11	2006 2009

Publication	Year	Title	EN/HD	Year
IEC 61010-1	2001	Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements	EN 61010-1 + corr. June	2001 2002
IEC 61032	1997	Protection of persons and equipment by enclosures - Probes for verification	EN 61032	1998
IEC 61310	series	Safety of machinery - Indication, marking and actuation	EN 61310	series
IEC 61310-1	2007	Safety of machinery - Indication, marking and actuation - Part 1: Requirements for visual, acoustic and tactile signals	EN 61310-1	2008
IEC 61508	series	Functional safety of electrical/electronic/programmable electronic safety-related systems	EN 61508	series
IEC 61557-3	2007	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. - Equipment for testing, measuring or monitoring of protective measures - Part 3: Loop impedance	EN 61557-3	2007
IEC 61558-1	2005	Safety of power transformers, power supplies, reactors and similar products - Part 1: General requirements and tests	EN 61558-1 + corr. August	2005 2006
IEC 61558-2-6	2009	Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V - Part 2-6: Particular requirements and tests for safety isolating transformers and power supply units incorporating safety isolating transformers	EN 61558-2-6	2009
IEC 61800-5-1	2007	Adjustable speed electrical power drive systems - Part 5-1: Safety requirements - Electrical, thermal and energy	EN 61800-5-1	2007
IEC 62061	2005	Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems	EN 62061 + corr. February	2005 2010
ISO 12100-2	2003	Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles	EN ISO 12100-2	2003
ISO 13849	series	Safety of machinery - Safety-related parts of control systems	EN ISO 13849	series
ISO 13849-1 [1)]	1999	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design	-	-

[1)] Superseded by ISO 13849-1:2006 "*Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design*".

Publication	Year	Title	EN/HD	Year
ISO 13851	2002	Safety of machinery - Two-hand control devices - Functional aspects and design principles	-	-

Annex ZZ
(informative)

Coverage of Essential Requirements of EC Directives

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and within its scope the standard covers only the following essential requirements out of those given in Annex I of EC Directive 2006/42/EC:

- 1.2.1
- 1.2.2
- 1.2.3
- 1.2.4.1
- 1.2.4.3
- 1.2.4.4
- 1.2.6
- 1.5.1
- 1.5.4
- 1.6.3 (for isolation of electrical supplies)
- 1.6.4 (for access to electrical equipment)
- 1.7.1.1
- 1.7.1.2
- 1.7.2 (for residual risks of an electrical nature)
- 1.7.4.2(e)

Compliance with this standard provides one means of conformity with the specified essential requirements of the Directive concerned.

WARNING: Other requirements and other EC Directives may be applicable to the products falling within the scope of this standard.

CONTENTS

INTRODUCTION

IEC 60204-33 has been created to reflect the unique needs of electrical safety within the semiconductor manufacturing environment. This includes the specialized clean room environment in which semiconductors are fabricated as well as the specialized nature of the semiconductor fabrication equipment itself. IEC 60204-33 ensures a level of safety consistent with IEC 60204-1 while still permitting the flexibility needed in the design and operation of semiconductor fabrication equipment. It has been drafted to satisfy the electrical safety needs of the semiconductor industry.

This standard is not intended to address those functional aspects of semiconductor fabrication equipment that do not relate directly to safety.

Note relating to SEMI: SEMI is the global industry association serving the manufacturing supply chains for the microelectronic, display and photovoltaic industries. SEMI maintains offices in Austin, Beijing, Brussels, Hsinchu, Moscow, San Jose, Seoul, Shanghai, Singapore, Tokyo, and Washington, D.C. The SEMI Standards Program, established in 1973, covers all aspects of semiconductor process equipment and materials, from wafer manufacturing to test, assembly and packaging, in addition to the manufacture of flat panel displays, photovoltaic systems and micro-electromechanical systems (MEMS). More than 2,100 volunteers worldwide participate in the program, which is made up of 19 global technical committees. Visit **www.semi.org/standards** for further details about SEMI Standards. Some information contained in this document was derived from SEMI S22 and S2. Republished with permission from Semiconductor Equipment and Materials International, Inc. (SEMI) © 2009

SAFETY OF MACHINERY – ELECTRICAL EQUIPMENT OF MACHINES –

Part 33: Requirements for semiconductor fabrication equipment

1 Scope

This part of IEC 60204 applies to electrical and electronic equipment associated with semiconductor fabrication equipment for the manufacture, measurement, assembly, and test of semiconductors.

NOTE 1 In this standard, the term electrical includes electrical, electronic, and programmable electronic matters (i.e. electrical equipment means electrical, electronic, and programmable electronic equipment).

NOTE 2 In the context of this standard, the term person refers to any individual and includes those persons who are assigned and instructed by the user or his agent(s) in the installation, use, and care of the fabrication equipment in question.

The electrical equipment covered by this standard commences at the point of connection of the supply to the electrical equipment (see 5.1), and includes proper instruction for its safe installation.

NOTE 3 For the requirements for the electrical supply installation in buildings, see IEC 60364 series.

This part is applicable to the electrical equipment or parts of the electrical equipment that operate with nominal supply voltages not exceeding 1 000 V for alternating current (a.c.) and not exceeding 1 500 V for direct current (d.c.), and with nominal supply frequencies not exceeding 200 Hz. For higher voltages or frequencies, special requirements may be needed.

NOTE 4 Electrical equipment within which derived voltages exceed these supply voltage limits is within the scope of this standard.

Included are requirements for protective measures against electrical safety hazards as well as electrical interlock circuits that protect against non-electrical hazards. However, it does not cover all the requirements that are needed or required by other standards or regulations in order to safeguard persons from hazards other than electrical hazards (e.g. chemical hazards, mechanical hazards, radiation hazards). Each type of machine has unique requirements to be accommodated to provide adequate safety.

Additional and special requirements can apply to the electrical equipment of fabrication equipment that:

- use, process, or produce potentially explosive material;
- are used in potentially explosive and/or flammable atmospheres;
- have special risks when producing or using certain materials;
- are hoisting machines (which are covered by IEC 60204-32).

This standard does not include specifications for performance or functional characteristics of the fabrication equipment.

This standard does not deal with the possible effects on human health that can result from emissions (for example EMFs, noise) from the fabrication equipment.

This standard does not specify requirements for electromagnetic compatibility (EMC).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-11:2004, *Rotating electrical machines – Part 11: Thermal protection*

IEC 60038: *IEC standard voltages*

IEC 60073:2002, *Basic and safety principles for man-machine interface, marking and identification – Coding principles for indication devices and actuators*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-4-43:2008, *Low-voltage electrical installations – Part 4-43: Protection for safety – Protection against overcurrent*

IEC 60364-6:2006, *Low-voltage electrical installations – Part 6: Verification*

IEC 60417, *Graphical symbols for use on equipment*

IEC 60445:2006, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals and conductor terminations*

IEC 60446:2007, *Basic and safety principles for man-machine interface, marking and identification – Identification of conductors by colours or alphanumerics*

IEC 60447:2004, *Basic and safety principles for man-machine interface, marking and identification – Actuating principles*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60617, *Graphical symbols for diagrams*

IEC 60695-11-10:1999, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60950-1:2005, *Information technology equipment – Safety – Part 1: General requirements*

IEC 61010-1:2001, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

IEC 61032:1997, *Protection of persons and equipment by enclosures – Probes for verification*

61310 (all parts): *Safety of machinery – Indication, marking and actuation*

IEC 61310-1:2007, *Safety of machinery – Indication, marking and actuation – Part 1: Requirements for visual, acoustic and tactile signals*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety related systems*

IEC 61557-3:2007, *Electrical safety in low voltage distribution systems up to 1000 V a.c. and 1500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 3: Loop impedance*

IEC 61558-1:2005, *Safety of power transformers, power supplies, reactors and similar products – Part 1: General requirements and tests*

IEC 61558-2-6:2009, *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V – Part 2-6: Particular requirements and tests for safety isolating transformers and power supply units incorporating safety isolating transformers*

IEC 61800-5-1:2007, *Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy*

IEC 62061:2005, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

ISO 12100-2:2003, *Safety of machinery – Basic concepts, general principles for design – Part 2: Technical principles*

ISO 13849 (all parts): *Safety of machinery – Safety-related parts of control systems*

ISO 13849-1:1999, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

ISO 13851:2002, *Safety of machinery – Two-hand control devices – Functional aspects and design principles*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
actuator
part of a device to which an external manual action is to be applied

NOTE 1 The actuator may take the form of a handle, knob, push-button, roller, plunger, etc.

NOTE 2 There are some actuating means that do not require an external actuating force but only an action.

NOTE 3 See also 3.40.

3.2
ambient temperature
temperature of the air or other medium where the equipment is to be used

[IEV 826-01-04]

3.3
appliance coupler
means enabling the connection and disconnection at will, of a cord to an appliance or other equipment and consisting of a connector and an appliance inlet

NOTE 1 An appliance inlet integrated in an appliance or equipment is an appliance inlet the shroud and base of which is formed by the housing of the appliance or equipment.

NOTE 2 An appliance inlet incorporated in an appliance or an equipment is a separate appliance inlet built-in or fixed to an appliance or equipment.

3.4
automatic disconnection
interruption of one or more of the line conductors by the automatic operation of a protective device in case of a fault

3.5
barrier
part providing protection against direct contact from any usual direction of access

[IEV 826-03-13]

3.6
basic insulation
insulation of hazardous-live-parts which provides basic protection

[IEV 195-06-06]

3.7
cable tray
cable support consisting of a continuous base and raised edges and no covering

NOTE A cable tray may be perforated or non-perforated.

[IEV 826-06-08]

3.8
cable trunking system
system of closed enclosures comprising a base with a removable cover intended for the complete surrounding of insulated conductors, cables, cords and for the accommodation of other electrical equipment

[IEV 826-06-04]

3.9
concurrent
acting in conjunction; used to describe a situation wherein two or more control devices exist in an actuated condition at the same time (but not necessarily synchronously)

3.10
conduit
part of a closed wiring system of circular or non-circular cross-section for insulated conductors and/or cables in electrical installations, allowing them to be drawn in and/or replaced

NOTE Conduits should be sufficiently close-jointed so that the insulated conductors and/or cables can only be drawn in and not inserted laterally.

[IEV 826-06-03]

3.11
control device
device connected into the control circuit and used for controlling the operation of the machine (for example position sensor, manual control switch, relay, contactor, magnetically operated valve)

3.12
controlgear
switching devices and their combination with associated control, measuring, protective, and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures, and supporting structures, intended for the control of electrical energy consuming equipment

[IEV 441-11-03, modified]

3.13
controlled stop
stopping of machine motion with electrical power to the machine actuators maintained during the stopping process

3.14
class II equipment
equipment with

- basic insulation as provision for basic protection, and
- supplementary insulation as provision for fault protection

or in which

- basic and fault protection are provided by reinforced insulation

[IEC 61140, 7.3]

3.15
danger zone
in the case of high voltage installations, systems, and equipment, area limited by the minimum clearance around hazardous-live-parts without complete protection against direct contact

NOTE Entering the danger zone is considered to be the same as touching hazardous-live-parts.

[IEC 61140, 3.35, modified]

3.16
direct contact
contact of persons with live parts

NOTE For high-voltage installations, systems, and equipment, entering the danger zone is considered to be the same as touching hazardous live parts.

3.17
direct opening action (of a contact element)
achievement of contact separation as the direct result of a specified movement of the switch actuator through non-resilient members (for example not dependent upon springs)

[IEC 60947-5-1, K.2.2]

3.18
double insulation
insulation comprising both basic insulation and supplementary insulation

3.19
duct
enclosed channel designed expressly for holding and protecting electrical conductors, cables, and busbars

NOTE Conduits (see 3.9), cable trunking systems (see 3.7) and underfloor channels are types of duct.

3.20
electrical equipment
material, fittings, devices, components, appliances, fixtures, apparatus, and the like used as part of, or in connection with the use of electricity by semiconductor fabrication equipment

NOTE See also 3.27.

3.21
emergency stop device
manually actuated control device used to initiate an emergency stop function

[ISO 13850, 3.2]

3.22
emergency off
EMO
function which, when activated, will place the fabrication equipment into a safe shutdown condition, without generating any additional hazards

3.23
enclosed electrical equipment area
room or location for electrical equipment to which access is intended to be restricted to skilled or instructed persons by the opening of a door or the removal of a barrier by the use of a key or tool and which is clearly marked by appropriate warning signs

3.24
enclosure
part providing protection of equipment against certain external influences and, in any direction, protection against direct contact

[IEV 826-03-12]

NOTE The definition taken from the existing IEV needs the following explanations within the scope of this standard:

a) Enclosures provide protection of persons against access to hazardous parts.

b) Barriers, shaped openings, or any other means suitable to prevent or limit the penetration of the specified test probes, whether attached to the enclosure or formed by the enclosed equipment, are considered as part of the enclosure, except where they can be removed without the use of a key or tool.

c) An enclosure may be:

- a cabinet or box, either mounted on the machine or separate from the machine;
- a compartment consisting of an enclosed space within the machine structure.

3.25
equipotential bonding
provision of electric connections between conductive parts, intended to achieve equipotentiality

[IEV 195-01-10]

3.26
exposed conductive part
conductive part of electrical equipment, which can be touched and which is not live under normal operating conditions, but which can become live under fault conditions

[IEV 826-03-02, modified]

3.27
extraneous conductive part
conductive part, for example of the fabrication equipment, not forming part of the electrical equipment

3.28
fabrication equipment
machinery, associated electrical equipment, apparatus, process modules or devices used to manufacture, measure, assemble and test semiconductor products but not including any product (e.g., substrates, semiconductors)

NOTE See also 3.20.

3.29
failure
termination of the ability of an item to perform a required function

NOTE 1 After failure the item has a fault.

NOTE 2 "Failure" is an event, as distinguished from "fault", which is a state.

[IEV 191-04-01, modified]

NOTE 3 In practice, the terms fault and failure are often incorrectly used synonymously.

3.30
fault
state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

NOTE 1 A fault is often the result of a failure of the item itself, but may exist without prior failure.

NOTE 2 In English the term “fault” and its definition are identical with those given in IEV 191-05-01. In the field of machinery, the French term “défaut” and the German term “Fehler” are used rather than the terms “panne” and “Fehlzustand” that appear with this definition.

3.31
functional bonding
equipotential bonding necessary for proper functioning of electrical equipment

3.32
harm
physical injury or damage to health

[ISO 12100-1, 3.5]

3.33
hazard
potential source of physical injury or damage to health

NOTE 1 The term hazard can be qualified in order to define its origin (for example mechanical hazard, electrical hazard) or the nature of the potential harm (for example electric shock hazard, cutting hazard, toxic hazard, fire hazard).

NOTE 2 The hazard envisaged in this definition:

– either is permanently present during the intended use of the machine (for example motion of hazardous moving elements, electric arc during a welding phase, unhealthy posture, noise emission, high temperature);

– or can appear unexpectedly (for example: explosion, crushing hazard as a consequence of an unintended/unexpected start-up, ejection as a consequence of a breakage, fall as a consequence of acceleration/deceleration).

[ISO 12100-1, 3.6, modified]

3.34
hazardous electrical power
power levels equal to or greater than 240 VA

3.35
hazardous-live-part
live part which under certain conditions, can give a harmful electric shock

[IEV 195-06-05]

NOTE For the purposes of this standard voltages greater than 30 V r.m.s., 42,4 V peak, or 60 V d.c. are considered to have the possibility of a harmful electric shock.

3.36
hazardous situation
circumstance in which a person is exposed to at least one hazard. The exposure can immediately or over a period of time result in harm

[ISO 12100-1, 3.9]

3.37
hazardous voltage
voltage greater than 30 V r.m.s., 42,4 V peak, or 60 V d.c.

3.38
indirect contact
contact of persons with exposed conductive parts which have become live under fault conditions

[IEV 826-03-06, modified]

3.39
inductive power supply system
system of inductive power transfer, consisting of a track converter and a track conductor, along which one or more pick-up(s) and associated pick-up converter(s) can move, without any galvanic or mechanical contact, in order to transfer electrical power for example to a mobile machine

NOTE The track conductor and the pick-up are analogous to the primary and secondary of a transformer respectively.

3.40
(electrically) instructed person
person adequately advised or supervised by an electrically skilled person to enable him or her to perceive risks and to avoid hazards which electricity can create

[IEV 826-09-02, modified]

3.41
interlock
arrangement of devices operating together to:

- prevent hazardous situations, or
- prevent damage to equipment or material, or
- prevent specified operations, or
- ensure correct operations

3.42
live part
conductor or conductive part intended to be energized in normal use, including a neutral conductor, but, by convention, not a PEN conductor

NOTE This term does not necessarily imply a risk of electric shock.

[IEV 826-03-01]

3.43
machine actuator
power mechanism used to effect motion within the fabrication equipment

NOTE See also 3.1.

3.44
machinery
machine
assembly of linked parts or components, at least one of which moves, with the appropriate machine actuators, control and power circuits, joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material

The term "machinery" also covers an assembly of machines which, in order to achieve the same end, are arranged and controlled so that they function as an integral whole

[ISO 12100-1, 3.1, modified]

NOTE The term "component" is used here in a general sense and it does not refer only to electrical components.

3.45
maintenance
activities intended to keep fabrication equipment in proper working order

NOTE See also 3.60.

3.46
marking
signs or inscriptions for the purpose of identifying equipment, components and/or devices, which can include certain features thereof

3.47
neutral conductor
N
in a star-connected three-phase system, conductor connected to the common point and capable of contributing to the transmission of electrical energy and in a single-phase system, a conductor connected to the side that is commonly at the same potential as the protective earth

[IEV 826-01-03, modified]

NOTE The neutral point is only defined for a.c. systems.

3.48
obstacle
part preventing unintentional direct contact, but not preventing direct contact by deliberate action

[IEV 826-03-14]

3.49
operator
person who interacts with the fabrication equipment in order for it to perform its intended function

NOTE 1 Operator functions are distinct from maintenance and repair functions.

NOTE 2 Performance of operator functions does not require the knowledge or ability of a skilled or instructed person.

3.50
overcurrent
current exceeding the rated value

NOTE For conductors, the rated value is the current-carrying capacity.

[IEV 826-05-06, modified]

3.51
overload (of a circuit)
time/current relationship in a circuit which is in excess of the rated full load of the circuit when the circuit is not under a fault condition

NOTE *Overload* should not be used as a synonym for *overcurrent*.

3.52
plug/socket combination
component and a suitable mating component, appropriate to terminate conductors, intended for connection or disconnection of two or more conductors

NOTE Examples of plug/socket combination include:

– connectors which fulfil the requirements of IEC 61984;
– a plug and socket-outlet, a cable coupler, or an appliance coupler in accordance with IEC 60309-1;
– a plug and socket-outlet in accordance with IEC 60884-1 or an appliance coupler in accordance with IEC 60320-1.

3.53
protective bonding
equipotential bonding for protection against electric shock

NOTE Measures for protection against electric shock can also reduce the risk of burns or fire.

3.54
protective bonding circuit
protective conductors and conductive parts connected together to provide protection against electric shock in the event of an insulation failure

3.55
protective conductor
conductor required for protective bonding by some measures for protection against electric shock for electrically connecting any of the following parts:

- exposed conductive parts;
- extraneous conductive parts;
- main earthing terminal (PE)

[IEV 826-04-05, modified]

NOTE "some measures" includes for example protection by automatic disconnection of supply.

3.56
protective interlock circuit
type of safety circuit, the purpose of which is to prevent the operation of hazardous functions under specified conditions, and which starts at the point where the safety-related signals are generated and ends at the components used to eliminate the hazard or reduce the risk

3.57
readily accessible
capable of being reached without requiring the use of tools, keys, portable ladders or platforms, climbing over or removing obstacles or barriers

3.58
reference designation
distinctive code which serves to identify unambiguously an item in the documentation and on the electrical equipment

3.59
reinforced insulation
insulation of hazardous-live-parts which provides a degree of protection against electric shock equivalent to double insulation

NOTE Reinforced insulation may comprise several layers which cannot be tested singly as basic insulation or supplementary insulation.

[IEV 195-06-09]

3.60
repair
activities intended to return to proper working order fabrication equipment that has failed (see also 3.45)

3.61
residual current device
RCD
mechanical switching device designed to make, carry and break currents under normal conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions

NOTE 1 A residual current device can be a combination of various separate elements designed to detect and evaluate the residual current and to make and break current.

NOTE 2 A GFCI (ground-fault circuit interrupter) is a specific kind of RCD.

[IEV 442-05-02, modified]

3.62
risk
combination of the probability of occurrence of harm (i.e. physical injury or damage to health) and the severity of that harm

[ISO 12100-1, 3.11, modified]

3.63
safeguard
guard or protective device provided as a means to protect persons from a hazard

3.64
safeguarding
protective measure using safeguards to protect persons from the hazards which cannot reasonably be eliminated or from the risks which cannot be sufficiently reduced by inherently safe design measures

[ISO 12100-1, 3.20]

NOTE Protective interlocks are examples of safeguarding.

3.65
safety circuit
circuit that carries out a safety function that is intended to maintain the safe condition of the fabrication equipment or prevent an increase of the risks under single fault conditions

NOTE Safety circuits include protective interlock circuits and emergency off (EMO) circuits.

3.66
servicing level
level on which persons stand when operating or maintaining the electrical equipment

3.67
short-circuit current
overcurrent resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

[IEV 441-11-07]

3.68
short-circuit rating of the electrical equipment
maximum input current from the supply, resulting from a short-circuit fault, that the equipment can withstand under defined conditions

NOTE 1 This necessitates adequate co-ordination of protective devices within the equipment such that the short-circuit ratings of all the overcurrent protective devices in the equipment are at least equal to the prospective fault current at their points of connection within the equipment and adequate protection is provided by those devices.

NOTE 2 Where multiple input supplies are used for the electrical equipment (fabrication equipment) short-circuit current ratings are determined for each respective supply.

3.69
(electrically) skilled person
person with relevant training, education and experience to enable him or her to perceive risks and to avoid hazards associated with electricity

[IEV 826-09-01, modified]

3.70
supplementary insulation
independent insulation applied in addition to basic insulation, for fault protection

[IEV 195-06-08]

3.71
supplier
entity (for example manufacturer, contractor, installer, integrator) who provides the fabrication equipment or its associated equipment or services

NOTE The user organization may also act in the capacity of a supplier to itself.

3.72
switching device
device designed to make and/or break the current in one or more electric circuits

[IEV 441-14-01, modified]

NOTE A switching device may perform one or both of these actions.

3.73
touch voltage
voltage between conductive parts when touched simultaneously by a person

[IEV 195-05-11, modified]

3.74
uncontrolled stop
stopping of machine motion by removing electrical power to the machine actuators

NOTE This definition does not imply any particular state of other stopping devices, for example mechanical or hydraulic brakes.

3.75
uninterruptible power supply
UPS
power source that is capable of supplying power to the electrical equipment after power from the facilities has been discontinued

3.76
user
entity who utilizes the fabrication equipment and its associated electrical equipment

4 General requirements

4.1 General considerations

The risks associated with the hazards relevant to the electrical equipment shall be assessed as part of the overall requirements for risk assessment of the fabrication equipment. This will enable the determination of adequate risk reduction, and the necessary protective measures for persons who can be exposed to those hazards, while still maintaining an acceptable level of performance of the fabrication equipment.

Hazardous situations can result from, but are not limited to, the following causes:

- failures or faults in the electrical equipment resulting in the possibility of electric shock or electrical fire;
- failures or faults in control circuits (or components and devices associated with those circuits) resulting in the malfunctioning of the fabrication equipment that can increase risk;
- disturbances or disruptions in power sources as well as failures or faults in the electrical equipment resulting in the malfunctioning of the fabrication equipment that can increase risk;
- loss of continuity of circuits that depend upon sliding or rolling contacts, resulting in a failure of a safety function;
- electrical disturbances (for example electromagnetic, electrostatic either from outside the electrical equipment or internally generated, resulting in the malfunctioning of the fabrication equipment that can increase risk);
- release of stored energy (either electrical or mechanical) resulting in, for example, electric shock, unexpected movement that can cause injury;

- surface temperatures that can cause injury.

Safety measures are a combination of the measures incorporated at the design stage and those measures required to be implemented by the user.

During the design and development process, hazards and the risks arising from them shall be identified. Where the hazards cannot be removed and/or the risks cannot be sufficiently reduced by inherently safe design measures, protective measures (for example safeguarding,) shall be provided to reduce the risk. Additional means (for example awareness means) shall be provided where further risk reduction is necessary. In addition, working procedures that reduce risk can be necessary.

Ⓒ 4.2 Selection of electrical equipment

Electrical components and devices that are used as part of a safety related system and those that handle hazardous voltage or hazardous electrical power shall be suitable for their intended use, be applied in accordance with their supplier's instructions and conform to relevant IEC standards where such exist. Ⓒ

4.3 Electrical supply

4.3.1 General

The electrical equipment shall operate correctly when connected to its specified electrical supply. The specifications for the supply shall include the following where appropriate:

- a.c. supply voltage with plus and minus tolerances;
- d.c. supply voltage with plus and minus tolerances.

The term "correct operation" in this context does not consider the quality of the fabricated product.

Interruptions in the facilities electrical supply shall not result in hazardous conditions.

4.4 Physical environment and operating conditions

4.4.1 General

The electrical equipment shall be suitable for use in the physical environment and operating conditions specified by the manufacturer of the fabrication equipment including the following environmental parameters:

- ambient air temperature range;
- limitations on altitude of installation;
- humidity of operating installation;
- electromagnetic environment.

NOTE 1 The generic EMC standards IEC 61000-6-1 or IEC 61000-6-2 and IEC 61000-6-3 or IEC 61000-6-4 give general EMC emission and immunity limits.

NOTE 2 IEC/TR 61000-5-2 gives guidelines for earthing and cabling of electrical and electronic systems aimed at ensuring EMC. If specific product standards or product family EMC standards exist (for example, IEC 61496-1, IEC 61800-3, IEC 60947-5-2, IEC 61326 series) they take precedence over generic standards.

4.4.2 Contaminants

Electrical equipment shall be adequately protected against the ingress of solid bodies and liquids likely to be present in the environment in which the electrical equipment is intended to be used. Electrical equipment shall be adequately protected against or resistant to degradation resulting from foreseeable chemical exposures.

4.4.3 Ionizing and non-ionizing radiation

When electrical equipment can be subject to radiation (e.g. microwave, ultraviolet, lasers, X-rays), additional measures shall be taken to avoid failures of the electrical equipment that can result in a hazardous situation.

4.4.4 Vibration, shock, and bump

Effects of vibration, shock and bump (including those generated by the fabrication equipment and those created by the physical environment) that can result in a hazardous situation shall be avoided by the selection of suitable electrical equipment, by mounting it away from the source of disturbance, or by provision of anti-vibration mountings.

4.5 Transportation and storage

Unless the manufacturer specifies different temperature and humidity ranges, the equipment shall withstand temperatures from –25 °C to +55 °C and for short periods not exceeding 24 h, +70 °C, and relative humidity from 10 % to 90 %.

NOTE Electrical equipment susceptible to damage at low temperatures includes PVC insulated cables.

Suitable means should be provided to prevent damage from humidity, vibration, and shock.

4.6 Provisions for handling

Heavy and bulky electrical equipment shall be provided with suitable means for handling, for example by mechanical handling equipment.

4.7 Installation

Electrical equipment shall be installed in accordance with the electrical equipment supplier's instructions.

5 Incoming supply conductor terminations and devices for disconnecting and switching off

5.1 Incoming supply conductor terminations

5.1.1 General

It is recommended that, where practicable, there should be a single point of connection for the incoming electrical supply. Where another supply is necessary for certain parts of the electrical equipment (for example, electronic equipment that operates at a different voltage), that supply should be derived, as far as is practicable, from devices (for example, transformers, converters) forming part of the electrical equipment. For large complex fabrication equipment comprising a number of widely-spaced subsystems working together in a co-ordinated manner, there can be a need for more than one incoming supply depending upon the site supply arrangements (see 5.3.1).

5.1.2 Termination of the supply conductors

Unless the electrical equipment is cord and plug connected (see 5.3.2 d)), it is recommended that the supply conductors be terminated at the supply disconnecting device.

5.1.3 Neutral conductor

Where a neutral conductor is used it shall be clearly indicated in the technical documentation of the fabrication equipment, such as in the installation diagram and in the circuit diagram, and a separate insulated terminal, labelled N or "Neutral" in accordance with 16.1, shall be provided for the neutral conductor.

There shall be no connection between the neutral conductor and the protective bonding circuit nor shall a combined PEN terminal be provided.

EXCEPTION: A connection may be made between the neutral terminal and the PE terminal at the point of the connection of the power supply for TN-C systems.

5.1.4 Terminal identification

All terminals for the incoming supply connection shall be clearly identified with one of the following:

- “U”,”V”, and “W”
- “L1”, “L2”, and “L3"

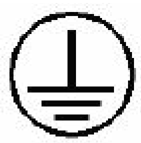
For the identification of the external protective conductor terminal, see 5.2.

5.2 Terminal for connection to the external protective earthing system

For each incoming supply, a terminal shall be provided in the vicinity of the associated phase conductor terminals for connection to the external protective earthing system or to the external protective conductor, depending upon the supply distribution system.

NOTE This is intended to facilitate the provision of an external protective earthing system or external protective conductor in association with the incoming supply conductors.

The terminal shall be of such a size as to enable the connection of an external protective copper conductor with a cross-sectional area in accordance with Tables C.1 to C.5. At each incoming supply point, the terminal for connection of the external protective earthing system or the external protective conductor shall be marked or labelled with the letters PE and/or the symbol IEC 60417-5019 (2006-08) (see IEC 60445):



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5.3 Supply disconnecting (isolating) device

5.3.1 General

A supply disconnecting device shall be provided:

- for each incoming source of supply to the fabrication equipment;

  NOTE The incoming supply can be connected directly to the machine or via a feeder system. Feeder systems can include conductor wires, conductor bars, slip-ring assemblies, flexible cable systems (reeled, festooned) or inductive power supply systems.

- for the output of each UPS, in accordance with 5.3.7.

Each supply disconnecting device shall remove electrical power from the load side of the disconnecting device when it is opened (for example for work on the fabrication equipment, including the electrical equipment).

Where two or more supply disconnecting devices are provided, interlocks shall be provided as necessary to prevent a hazardous situation.

When two or more supply disconnecting devices are present each shall be provided with marking such as “WARNING: Risk of Electric Shock or Burn. Disconnect all [number of feed locations] sources of electrical supply prior to maintenance or repair”

5.3.2 Type

The supply disconnecting device shall be one of the following types:

a) a switch-disconnector, with or without fuses, utilization category AC-23B or DC-23B;

b) a disconnector, with or without fuses, that has an auxiliary contact that in all cases causes switching devices to break the load circuit before the opening of the main contacts of the disconnector;

c) a circuit-breaker suitable for isolation;

d) a plug/socket combination under the following conditions:

   - the plug/socket combination shall be connected so that the part connected to the incoming supply is protected to at least IP2X or IPXXB, and either
   - the rated current does not exceed 16 A and total power rating does not exceed 3 kW; or
   - where the rated current exceeds 16 A or the total power rating does not exceed 3 kW,
   - it shall not be possible to connect or disconnect a plug/socket combination without adequate breaking capacity, during load conditions;
   - where a plug/socket combination with breaking capacity is used, it shall have a breaking capacity of at least the rated current of the machine at rated voltage. Where a plug/socket combination is used for disconnection under overload (e.g. locked rotor), the rating should be at least locked rotor current. In addition, the electrical equipment shall have a device for switching the machine on and off.

NOTE For switch-disconnectors and disconnectors, see IEC 60947-3. For circuit-breakers suitable for isolation, see IEC 60947-2.

5.3.3 Requirements

When the supply disconnecting device is one of the first three types specified in 5.3.2 (i.e. a switch-disconnector, a disconnector used in combination with switching devices, or a circuit-breaker), it shall fulfil all of the following requirements:

a) isolate the electrical equipment from the supply and have one OFF (isolated) and one ON position marked with "O" and "I" (symbols IEC 60417-5008 (2002-10) and IEC 60417-5007 (2002-10), see 10.2.2); a 'tripped' position is also permitted in the case of circuit-breakers;

b) have a visible contact gap or a position indicator which cannot indicate OFF (isolated) until all contacts are actually open and the requirements for the isolating function have been satisfied;

c) have an external operating means (for example handle);

d) be provided with a means (integral or external) permitting it to be locked only in the OFF (isolated) position (for example by padlocks). When so locked, remote as well as local closing shall be prevented;

e) disconnect all live conductors of its power supply circuit. However, for TN supply systems, the neutral conductor may or may not be disconnected except in countries where disconnection of the neutral conductor is compulsory. Where the neutral conductor can be disconnected it shall be disconnected simultaneously with the phase conductors;

   NOTE A TN system is one in which one point is directly earthed, with a protective conductor (PE) directly connected to that point. See Annex E and IEC 60364-1.

f) have a breaking capacity sufficient to interrupt the current of the largest motor when stalled together with the sum of the normal running currents of all other motors and/or loads that can be operated at any time.

5.3.4 Operating means

The operating means (for example, a handle) of the supply disconnecting device shall be readily accessible and located not more than 2 m above the servicing level. A height of between 0,6 m and 1,7 m is recommended.

NOTE The direction of operation is given in IEC 61310-3.

5.3.5 Supply disconnecting device mounting

The supply disconnecting device shall be installed in accordance with one or more of the following:

a) in its own electrical enclosure on or adjacent to the equipment for which it provides a disconnecting means;
b) near the top of the electrical enclosure for which it provides a disconnecting means;
c) anywhere below the top of the electrical enclosure for which it provides a disconnecting means provided that its incoming terminations are guarded to prevent accidental contact by personnel or by a tool dropped from above. Compliance can be demonstrated by verifying that a probe 3 mm in diameter and 15 mm long cannot contact live parts (see test probe 13 of IEC 61032).

EXCEPTION: Machines with a nominal power consumption of 1 500 W or less may be connected to a remotely mounted supply disconnecting device, provided that device is readily accessible and no more than 6 m from the machine.

5.3.6 Supply disconnecting device door interlock

Doors that provide access to live parts of the supply disconnecting device, shall be interlocked so that the door can only be opened when the supply disconnecting device is open and so that the supply disconnecting device can only be closed when the door is closed.

A tool or special device as prescribed by the supplier may be provided to permit skilled and instructed persons to defeat the interlock, provided that protection is provided against inadvertent contact with hazardous-live-parts inside the enclosure by the measures defined in 6.5.

EXCEPTION: Supply disconnecting device door interlocking need not be provided where protection is provided against inadvertent contact with hazardous-live-parts inside the enclosure by the measures defined in 6.5 for loads that:

- are rated less than 5 KVA, or
- consist of lighting circuits, or
- are cord and plug connected electrical equipment.

5.3.7 UPS disconnection

The output of each UPS that can supply greater than 30 V r.m.s., 42.4 V peak, 60 V d.c. or 240 VA, shall be disconnected when the main disconnecting device is opened or shall be provided with a disconnecting means that satisfies all the requirements for the supply disconnecting device in 5.3.1 to 5.3.5, or both. The UPS output wiring and terminals shall be labelled as “UPS Output”, or equivalent, at each connection point where the UPS wiring can be disconnected.

All power supplied from the UPS shall be disconnected when the emergency off actuator is activated.

EXCEPTION: power supplied from the UPS to safety related devices (including EMO circuits) and computer systems that perform functions such as data/alarm logging and error recovery is excepted from this requirement.

5.4 Additional disconnecting devices

Where it can be necessary to perform work on parts of the fabrication equipment (e.g. motors) when they are de-energized and isolated while leaving other parts of the electrical equipment energized, then a separate disconnecting device shall be provided for each part requiring separate isolation.

Such disconnecting devices should be:

- appropriate and convenient for the intended use;
- suitably located;
- readily identifiable as to which part or circuit(s) of the electrical equipment is served (e.g. by durable marking where necessary).

Means shall be provided to prevent unauthorized, inadvertent, and/or mistaken closure of these devices (e.g. provisions for locking).

Motors installed in a location from which the supply disconnecting device is not visible (for example in a chase or sub-fab) shall be provided with an additional means of disconnecting all unearthed conductors within sight of, and not more than 3 m distance from, the motor. These means of disconnecting shall meet the requirements of 5.3.1 to 5.3.5.

5.5 Protection against unauthorized, inadvertent and/or mistaken connection of plug/socket combination

When a plug/socket combination is used as a supply disconnecting means during maintenance or repair, in addition to meeting the requirements of 5.3.2 d), it shall either be capable of being kept under the exclusive supervision of the person carrying out the maintenance or repair, or it shall be provided with a lockable means to ensure it remains in a disconnected state.

6 Protection against electric shock

6.1 General

The electrical equipment shall provide protection of persons against electric shock from:

- direct contact;
- indirect contact.

NOTE It is considered that some of the protection of skilled persons is provided by their training and experience.

Skilled and instructed persons are those having appropriate technical training and experience to be aware of hazards to which they are exposed. Skilled and instructed persons shall be protected against inadvertent and unexpected hazards in accordance with 6.5.

The recommended measures for this protection are given in 6.2, 6.3, 6.4, and 6.5.

6.2 Protection against direct contact

6.2.1 General

For each circuit or part of the electrical equipment, the measures of either 6.2.2 or 6.2.3 and, where applicable, 6.2.4 shall be applied.

When the electrical equipment is located in places open to persons other than skilled and instructed persons, measures of either 6.2.2 with a minimum degree of protection against direct contact corresponding to IP2X/IPXXB (see IEC 60529), or 6.2.3 shall be applied.

6.2.2 Protection by enclosures

Opening an enclosure other than that of the supply disconnecting device (see 5.3.6) that contains hazardous-live-parts (i.e. opening doors, lids, covers, and the like) shall be possible only under one of the following conditions:

a) The use of a key or tool is necessary for access.

NOTE he necessity to use a key or tool is intended to restrict access to skilled or instructed persons.

Skilled and instructed persons shall be protected against inadvertent contact with hazardous-live-parts inside the enclosure by the measures defined in 6.5.

b) The disconnection of hazardous-live-parts inside the enclosure before the enclosure may be opened. This shall either be accomplished by a mechanical and/or electrical interlock so that the door can only be opened when the hazardous supply is disconnected and so that the hazardous supply can only be connected when the door is closed. If an electrical interlock is used it shall meet all the requirements of Clause 9 for a protective interlock circuit.

EXCEPTION: a special device or tool as prescribed by the supplier may be provided to permit skilled and instructed persons to defeat the interlock, provided that protection is provided against inadvertent contact with hazardous-live-parts inside the enclosure by the measures defined in 6.5.

Any hazardous-live-parts that are not disconnected shall be marked with a warning sign in accordance with 17.2, except for the supply terminals of the supply disconnecting device when it is mounted alone in a separate enclosure.

c) Opening without the use of a key or a tool and without disconnection of hazardous-live-parts shall be possible only when all hazardous-live-parts are protected against direct contact to at least IP2X or IPXXB (see IEC 60529). Where protection is removable, either it shall require a tool for its removal or all live parts protected by it shall be automatically disconnected when the protection is removed.

6.2.3 Protection by insulation of live parts

Live parts protected by insulation shall be completely covered with insulation that can only be removed by destruction. Such insulation shall be capable of withstanding the mechanical, chemical, electrical, and thermal stresses to which it can be subjected under normal operating conditions.

NOTE Paints, varnishes, lacquers, and similar products alone are generally considered to be inadequate for protection against electric shock under normal operating conditions.

6.2.4 Protection against residual voltages

Live parts having a residual voltage greater than 60 V after the supply has been disconnected shall be discharged to 60 V and 20 J or less within a time period of 10 s after disconnection of the supply voltage provided that this rate of discharge does not interfere with the proper functioning of the fabrication equipment.

Electrical equipment that cannot be discharged to this level in 10 s is exempted from this requirement if the following conditions are satisfied:

- the conductors supplied with stored energy cannot be accessed without the removal of a panel that requires a tool to remove; and
- the panel that is removed to access those conductors is marked specifying the discharge time required for the discharge conditions to be less than both 60 V and 20 J; and
- the discharge time does not exceed 5 min.

In the case of plugs or similar devices, the withdrawal of which results in the exposure of conductors (for example pins), the discharge time shall not exceed 1 s, otherwise such conductors shall be protected against direct contact to at least IP2X or IPXXB. If neither a discharge time of 1 s nor a protection of at least IP2X or IPXXB can be achieved, additional switching devices or an appropriate warning device (for example a warning notice in accordance with 16.1) shall be applied.

NOTE Voltage supplied by a UPS is considered to be a battery source and is not considered to be a residual voltage.

6.3 Protection against indirect contact

6.3.1 General

Protection against indirect contact (3.38) is intended to prevent hazardous situations due to an insulation fault between live parts and exposed conductive parts.

For each circuit or part of the electrical equipment, at least one of the following measures in accordance with 6.3.2 to 6.3.3 shall be applied:

- measures to prevent the occurrence of a touch voltage (6.3.2), or
- automatic disconnection of the supply before the time of contact with a touch voltage can become hazardous (6.3.3).

NOTE 1 The risk of harmful physiological effects from a touch voltage depends on the value of the touch voltage and the duration of possible exposure.

NOTE 2 For classes of electrical equipment and protective provisions, see IEC 61140.

6.3.2 Prevention of the occurrence of a touch voltage

6.3.2.1 General

Measures to prevent the occurrence of a touch voltage include the following:

- provision of class II equipment or by equivalent insulation;
- electrical separation.

6.3.2.2 Protection by provision of class II equipment or by equivalent insulation

This measure is intended to prevent the occurrence of touch voltages on the accessible parts through a fault in the basic insulation. See IEC 60364-4-41.

NOTE Examples of this measure include:

- class II electrical devices or apparatus (see 3.14);
- switchgear and controlgear assemblies having total insulation in accordance with IEC 61439-1.

6.3.2.3 Protection by electrical separation

6.3.2.3.1 General

Electrical separation of an individual circuit is intended to prevent a hazardous touch voltage through contact with exposed conductive parts that can be energized by a fault in the basic insulation of the live parts of that circuit. In order to provide this type of protection either the requirement of both sub-clauses 6.3.2.3.2 and 6.3.2.3.3 shall be satisfied or the requirements for electrical separation in IEC 60364-4-41 shall be satisfied.

6.3.2.3.2 Isolated power systems

The circuit to be protected by electrical separation shall have a high impedance between its conductors and the incoming supply connection to the equipment and a high impedance to earth. Impedance of one megohm or more is considered to be sufficiently high. This can be achieved by the use of isolation transformers or power supplies that have no direct electrical connection between their primary conductors and their secondary conductors.

NOTE 1 An isolation transformer with one conductor of the secondary connected to ground is not an isolated power system.

NOTE 2 Auto transformers do not provide electrical isolation.

NOTE 3 Isolated power systems are commonly used to reduce sources of electronic noise by not deliberately referencing the output circuit conductors to earth (ground).

6.3.2.3.3 Requirements for isolated circuits

Isolated circuits shall meet the following requirements:

- the transformer or power supply, and any components (devices) connected to their output, shall be clearly labeled adjacent to the isolated circuit(s) or on the enclosure to warn operators and service personnel of the unearthed condition, and
- earth fault detection lights, an insulation monitoring device, or a device that interrupts the circuit automatically in the event of an earth fault (for example, a ground-fault circuit-interrupter (GFCI)), shall be installed.

6.3.3 Protection by automatic disconnection of supply

This protective measure consists of the interruption of one or more of the line conductors by the automatic operation of a protective device in case of an insulation fault. It is intended to prevent a hazardous situation by interrupting the supply within a sufficiently short time to limit the duration of a touch voltage to a time within which that voltage is not hazardous. While the use of TN systems is preferred because of the lower touch voltage on exposed and extraneous conductive parts in the event of an earth fault, TT systems in accordance with the relevant parts of IEC 60364 may be used where the distribution system provides no PEN or PE conductor.

Requirements for TN supply systems are given in Annex A. A protective circuit impedance in accordance with 18.2.5 can be considered sufficiently low to meet the requirements of Annex A.

NOTE 1 A TT supply system is one in which one point is directly earthed but the protective conductor (PE) of the equipment is not directly connected to that earth point of the electrical supply system. See Annex E and IEC 60364-1.

Requirements for TT supply systems are given in Annex B.

NOTE 2 TN supply systems are commonly preferred over TT supply systems.

NOTE 3 In Japan TT supply systems are commonly used.

NOTE 4 This protective measure can necessitate co-ordination between:

- the type of supply and earthing system;
- the impedance values of the different elements of the protective bonding system;
- the characteristics of the protective devices that detect insulation fault(s).

This protective measure comprises both protective bonding of exposed conductive parts (see 8.2.3), and one of the following:

a) overcurrent protective devices for automatic disconnection of the supply on detection of an insulation fault in TN systems, or

b) residual current protective devices to initiate the automatic disconnection of the supply on detection of an insulation fault from a live part to exposed conductive parts or to earth in TT systems, or

c) insulation monitoring or residual current protective devices to initiate automatic disconnection of IT systems. Except where a protective device is provided to interrupt the supply in the case of the first earth fault, an insulation monitoring device shall be provided to indicate the occurrence of a first fault from a live part to exposed conductive parts or to earth. This insulation monitoring device shall initiate an audible and/or visual signal which shall continue as long as the fault persists.

Where automatic disconnection is provided in accordance with a), and disconnection within the time specified in Clause A.1 cannot be assured, supplementary bonding shall be provided as necessary to meet the requirements of Clause A.3.

6.4 Protection by the use of PELV

6.4.1 General requirements

The use of PELV (protective extra-low voltage) is intended to protect persons against electric shock from indirect contact and limited area direct contact (see 8.2.5).

PELV circuits shall satisfy all of the following conditions:

a) the nominal voltage shall not exceed:

- 25 V a.c. r.m.s. or 60 V ripple-free d.c. when the fabrication equipment is normally used in dry locations and when large area contact of live parts with the human body is not expected; or
- 6 V a.c. r.m.s. or 15 V ripple-free d.c. in all other cases;

NOTE *Ripple-free* is conventionally defined for a sinusoidal ripple voltage as a ripple content of not more than 10 % r.m.s.

b) one side of the circuit or one point of the source of the supply of that circuit shall be connected to the protective bonding circuit;

c) live parts of PELV circuits shall be electrically separated from other live circuits. Electrical separation shall be not less than that required between the primary and secondary circuits of a safety isolating transformer (see IEC 61558-1 and IEC 61558-2-6);

d) conductors of each PELV circuit shall be physically separated from those of any other circuit. When this requirement is impracticable, the insulation provisions of 13.1.3 shall apply;

e) plugs and socket-outlets for a PELV circuit shall conform to the following:

- plugs shall not be able to enter socket-outlets of other voltage systems;
- socket-outlets shall not admit plugs of other voltage systems.

6.4.2 Sources for PELV

The source for PELV shall be one of the following:

- a safety isolating transformer in accordance with IEC 61558-1 and IEC 61558-2-6;
- a source of current providing a degree of safety equivalent to that of the safety isolating transformer (for example a motor generator with winding providing equivalent isolation);
- an electrochemical source (for example a battery) or another source independent of a higher voltage circuit (for example a diesel-driven generator);
- an electronic power supply conforming to appropriate standards specifying measures to be taken to ensure that, even in the case of an internal fault, the voltage at the outgoing terminals cannot exceed the values specified in 6.4.1.

6.4.3 Design to minimise risks of live working

The electrical equipment shall be designed to minimize the need to calibrate, modify, repair, test, adjust, or maintain equipment while it is energized, and to minimize the need for work to be performed on components near exposed hazardous energized circuits.

Appropriate safety procedures (e.g., use of appropriate personal protective equipment and barriers) for troubleshooting, shall be described in the instructions for use. See 17.2.

6.5 Protection of skilled persons and instructed persons against inadvertent contact with hazardous-live-parts

6.5.1 General

Inadvertent contact to circuits that are not PELV shall be prevented by design. Persons shall not be inadvertently exposed to electrical or mechanical hazards while performing manual adjustments. Adequate access shall be provided for maintenance and repair. Where maintenance and repair personnel need to access the electrical equipment while it is energized, live parts (other than PELV) shall be protected against inadvertent contact by the provision of obstacles. Obstacles shall be provided where it is necessary to reach over, under, around, or close to electrical hazards. They shall also be provided where dropped objects or failure of liquid fittings could result in short circuits or arcing.

6.5.2 Obstacles

Obstacles that are used to protect against inadvertent contact shall be made of non-conductive material or if made of conductive material they shall be earthed. They shall be of substantial construction sufficient to withstand foreseeable abuse.

6.5.3 Probe holes

When necessary for electrical testing, probe holes shall be provided in the obstacles. These probe holes shall be located over test points and designed to protect against inadvertent contact with live parts. They should also provide adequate access for a test probe where it is needed and they shall be identified in the information for use (see 17.2). Where obstacles are of conductive material the perimeter of the probe holes shall be insulated.

7 Protection of equipment

7.1 General

This Clause details the measures to be taken to protect equipment against the effects of:

- overcurrent including the effect of a short circuit;
- overload and/or loss of cooling of motors;
- abnormal temperature;
- loss of or reduction in the supply voltage;
- overspeed of machines/machine elements;
- earth fault/residual current;
- incorrect phase sequence;
- overvoltage due to lightning and switching surges.

7.2 Overcurrent protection

7.2.1 General

Overcurrent protection shall be provided in all circuits that can be supplied with hazardous electrical power under normal operations or single fault conditions where current can exceed either the rating of any component or the current carrying capacity of the conductors, whichever is the lesser value. The ratings or settings to be used are detailed in 7.2.9.

7.2.2 Supply conductors

The supplier of the electrical equipment is not responsible for providing the overcurrent protective device for the supply conductors to the electrical equipment.

The supplier of the electrical equipment shall state on the installation documentation the data necessary for selecting the overcurrent protective device (see 7.2.9 and 17.4).

7.2.3 Neutral conductor protection

In TN or TT systems, neutral conductors shall not be disconnected without disconnecting the associated live conductors. Where the cross-sectional area of the neutral conductor is at least equal to or equivalent to that of the phase conductors, it is not necessary to provide overcurrent detection for the neutral conductor nor automatic disconnection for that conductor. For a neutral conductor with a cross-sectional area smaller than that of the associated phase conductors, the measures detailed in 431.2.1 of IEC 60364-4-43 shall apply.

In IT systems, it is recommended that the neutral conductor is not used. However, where a neutral conductor is used, the recommendations detailed in 431.2.2 of IEC 60364-4-43 are applicable.

NOTE An IT system is a distribution system that is not directly earthed. See Annex F.

7.2.4 Socket outlets and their associated conductors

Where general purpose socket outlets are provided for supplying power to maintenance equipment, overcurrent protective devices shall be provided in the unearthed live conductors of each circuit feeding such socket outlets in accordance with 7.2.9.

7.2.5 Lighting circuits

All unearthed conductors of circuits supplying lighting shall be protected against the effects of short circuits by the provision of overcurrent devices independent of those protecting other circuits in accordance with 7.2.9.

7.2.6 Transformers

Transformers shall be protected against overcurrent in accordance with the transformer manufacturer’s instructions and with 7.2.9. If the manufacturer's instructions differ from the requirements of 7.2.9, the more stringent requirements shall apply.

7.2.7 Location of overcurrent protective devices

An overcurrent protective device shall be located at the point where a reduction in the cross-sectional area of each conductor or another change reduces the current-carrying capacity of the conductor such that it is not protected by the upstream protective device, except where all the following conditions are satisfied:

- the current carrying capacity of the conductor is at least equal to that of the load;
- the part of the conductor between the point of reduction of current-carrying capacity and the position of the overcurrent protective device is no longer than 3 m;

- the conductor is installed in such a manner as to reduce the possibility of a short-circuit, for example, protected by an enclosure or duct.

7.2.8 Overcurrent protective devices

7.2.8.1 General

The short-circuit rating of overcurrent protective devices shall be at least equal to the prospective fault current at their point of connection when the equipment is connected to an incoming supply as specified by the equipment manufacturer. Where the short-circuit current to an overcurrent protective device can include additional currents other than from the supply (for example from motors, from power factor correction capacitors), those currents shall be taken into consideration.

The characteristics of two series connected OCPDs devices shall be coordinated so that the let-through energy (I^2t) of the two devices in series does not exceed that which can be withstood without damage to the overcurrent protective device on the load side and to the conductors protected by that device. This can be determined by tests and/or by calculation.

NOTE 1 See for example Annex A of IEC 60947-2. Other techniques for the evaluation can be found in, for example, SEMI S.22, UL 508A.

NOTE 2 The use of such a co-ordinated arrangement of overcurrent protective devices can result in the operation of both overcurrent protective devices.

NOTE 3 Circuit breakers are commonly preferred to fuses.

Overcurrent protective devices include fuses and circuit-breakers. Electronic devices designed to reduce or to limit the current in protected circuits may also be used.

7.2.8.2 Additional requirements for fuses

When fuses are provided they shall be in fixed fuse holders.

7.2.8.3 Additional requirements for circuit-breakers

All circuit breakers shall have the OFF (isolated) position and ON position clearly marked with "O" and "I" (symbols IEC 60417-5008 (2002-10) and IEC 60417-5007 (2002-10), see 10.2.2).

Actuating directions shall be in accordance with the following:

a) Circuit breakers that are mounted on a vertical surface and vertically oriented shall be mounted with the handle up for the “ON” position.
b) Circuit breakers that are mounted on a vertical surface and horizontally oriented shall be mounted with the handle to the right for the “ON” position.
c) Circuit breakers that are mounted in two columns, horizontally oriented, shall be mounted with the handles toward the centre for the “ON” position; or clearly marked indicating the “ON” and “OFF” positions.
d) Circuit breakers that are mounted on a horizontal surface shall be mounted with the handle to the right for the “ON” position.

7.2.9 Rating and setting of overcurrent protective devices

The rated current of fuses or the setting current of other overcurrent protective devices (overcurrent protection) should be selected as low as practicable but adequate for the anticipated overcurrents (for example during starting of motors or energizing of transformers). When selecting those protective devices, consideration shall be given to the protection of switching devices against damage due to overcurrents (for example welding of the switching device contacts).

Overcurrent protection shall be limited as follows.

a) Conductors and plug/socket combinations shall have overcurrent protection that does not exceed their rating.

b) The overcurrent protection of other devices or components, with the exception of motors, shall not exceed 125 % of the current rating of the device or component or 125 % of maximum nominal load.

c) Non-process lighting circuits shall have overcurrent protection at not greater than 15 A.

d) Transformers that operate at 50/60 Hz shall be protected in accordance with Table 1 or Table 2 as appropriate.

Table 1 – Protection of transformers without thermal protection

Transformer primary rating	Transformer secondary rating	Maximum primary protection percentage of rating	Maximum secondary protection percentage of rating
Any rating	≥ 9 A	250	125
Any rating	< 9 A	250	167
≥ 9 A	Any rating	125	Not required
< 9 A and > 2 A	Any rating	167	Not required
≤ 2 A	Any rating	300	Not required

Table 2 – Protection of transformers with thermal protection

Transformer impedance	Maximum primary protection percent of rating (see Note)	Maximum secondary protection percent of rating (see Note)
≤ 6 %	600	125
> 6 % and < 10 %	400	125
NOTE Where the rating does not match a standard overcurrent device rating, the next standard size is permitted.		

In all cases, the next larger standard size of overcurrent device from the calculated value may be used to satisfy this requirement.

7.3 Protection of motors against overheating

7.3.1 General

Protection of motors against overheating shall be provided for each motor consuming more than 240 VA.

Protection of motors against overheating can be achieved by:

- overload protection (7.3.2), or

NOTE 1 Overload protective devices detect the time and current relationships (I^2t) in a circuit that are in excess of the rated full load of the circuit and initiate appropriate control responses.

- over-temperature protection (7.3.3),

NOTE 2 Temperature detection devices sense over temperature and initiate appropriate control responses.

Automatic restarting of any motor after the operation of protection against overheating shall be prevented where this can cause a hazardous situation or damage to the machine.

Motor installation shall provide for proper cooling to maintain temperature within the motor rating.

7.3.2 Overload protection

Where overload protection is provided, detection of overload(s) shall be provided in each live conductor except for the neutral conductor. For motors having single-phase or d.c. power supplies, detection in only one unearthed live conductor is permitted.

Where overload protection is achieved by switching off, the switching device shall switch off all live conductors. The switching of the neutral conductor is not necessary for overload protection.

Unless suitable overload protection for the motor is provided by power conversion equipment, overload protection shall be provided external to the power conversion equipment.

Where motors with special duty ratings are required to start or to brake frequently (for example, motors for rapid traverse, locking, rapid reversal, sensitive drilling) it can be difficult to provide overload protection with a time constant comparable with that of the winding to be protected. Appropriate protective devices designed to accommodate special duty motors or over-temperature protection (see 7.3.3) can be necessary.

For motors that cannot be overloaded (for example torque motors, motion drives that either are protected by mechanical overload protection devices or are adequately dimensioned), overload protection is not required.

7.3.3 Over-temperature protection

The provision of motors with over-temperature protection in accordance with IEC 60034-11 is recommended in situations where the cooling can be impaired. Depending upon the kind of motor, protection under stalled rotor or loss of phase conditions is not always ensured by over-temperature protection, and additional protection should then be provided.

Over-temperature protection is also recommended for motors that cannot be overloaded (for example torque motors, motion drives that either are protected by mechanical overload protection devices or are adequately dimensioned), where the possibility of over-temperature exists (for example due to reduced cooling).

7.4 Motor overspeed protection

Overspeed protection shall be provided where overspeeding could otherwise cause a hazardous situation. Overspeed protection shall initiate appropriate control responses and shall prevent automatic restarting.

The overspeed protection should operate in such a manner that the maximum permissible speed of the motor or its load is not exceeded.

NOTE This protection can consist, for example, of a centrifugal switch or speed limit monitor.

7.5 Abnormal temperature detection

Resistance heating or other circuits that are capable of attaining or causing abnormal temperatures (for example, due to short-time rating or loss of cooling medium) shall be provided with suitable detection to initiate an appropriate control response.

Where abnormal temperature can cause a hazardous situation, protective interlock functions shall be provided in accordance with 9.4.1.

7.6 Protection against supply interruption or voltage reduction and subsequent restoration

Where a supply interruption or a voltage reduction can cause a hazardous situation, damage to the fabrication equipment, undervoltage protection shall be provided by, for example, switching off the machine at a predetermined voltage level.

Where the operation of the fabrication equipment can allow for an interruption or a reduction of the voltage for a short time period, delayed undervoltage protection may be provided. The operation of the undervoltage device shall not impair the operation of any stopping control of the fabrication equipment.

Upon restoration of the voltage or upon switching on the incoming supply, automatic or unexpected restarting of the fabrication equipment shall be prevented where such a restart can cause a hazardous situation.

Where only a part of the fabrication equipment is affected by the voltage reduction or supply interruption, the undervoltage protection shall initiate appropriate control responses to ensure co-ordination with other parts of the equipment, to protect against any potentially hazardous situations resulting in the equipment.

7.7 Earth fault/residual current protection

In addition to providing overcurrent protection for automatic disconnection as described in 6.3, earth fault/residual current protection can be provided to reduce damage to electrical equipment due to earth fault currents less than the detection level of the overcurrent protection.

The setting of the devices should be as low as possible consistent with correct operation of the electrical equipment.

7.8 Phase sequence protection

Where an incorrect phase sequence of the supply voltage can cause a hazardous situation or damage to the fabrication equipment, suitable protection shall be provided, such as a hardware device or phase marking and appropriate warnings or cautions.

7.9 Protection against overvoltages due to lightning and to switching surges

Protective devices can be provided to protect against the effects of overvoltages due to lightning or to switching surges.

Where provided:

- devices for the suppression of overvoltages due to lightning shall be connected to the incoming terminals of the supply disconnecting device.
- devices for the suppression of overvoltages due to switching surges shall be connected across the terminals of all electrical equipment requiring such protection.

7.10 Electrolytic capacitors

Where practicable capacitors that are greater than 25,4 mm (1,0 in) in diameter or are capable of storing more than 4 J should:

a) be self-vented or protected from rupture by equivalent means. Capacitor vents should be unobstructed for a minimum of 5,1 mm (0,2 in);

b) have containment provisions within the capacitor itself or be shielded such that vapours or debris will not become hazardous to personnel;

c) have terminals that are insulated or protected from short circuits by tools. Lacquer and sealing compounds shall not be relied upon to provide protection.

EXCEPTION: These recommendations need not apply to capacitors that are components of a product conforming to an IEC product standard (e.g., capacitors that are included in an Adjustable Speed Drive conforming to IEC 61800-5-1).

8 Equipotential bonding

8.1 General

This Clause provides requirements for both protective bonding and functional bonding. Figure 1 illustrates those concepts.

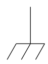
Protective bonding is a basic provision for fault protection to enable protection of persons against electric shock from indirect contact (see 6.3.3 and 8.2).

The objective of functional bonding (see 8.3) is to minimize:

- the consequence of an insulation failure which could affect the operation of the machine ;
- the consequences of electrical disturbances to sensitive electrical equipment which could affect the operation of the machine.

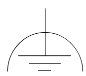
Normally functional bonding is achieved by connection to the protective bonding circuit, but where the level of electrical disturbances on the protective bonding circuit is not sufficiently low for proper functioning of electrical equipment, it can be necessary to connect the functional bonding circuit to a separate functional earthing conductor (see Figure 1). Functional bonding to enhance the immunity of the electrical equipment against conducted and radiated RF disturbance can include:

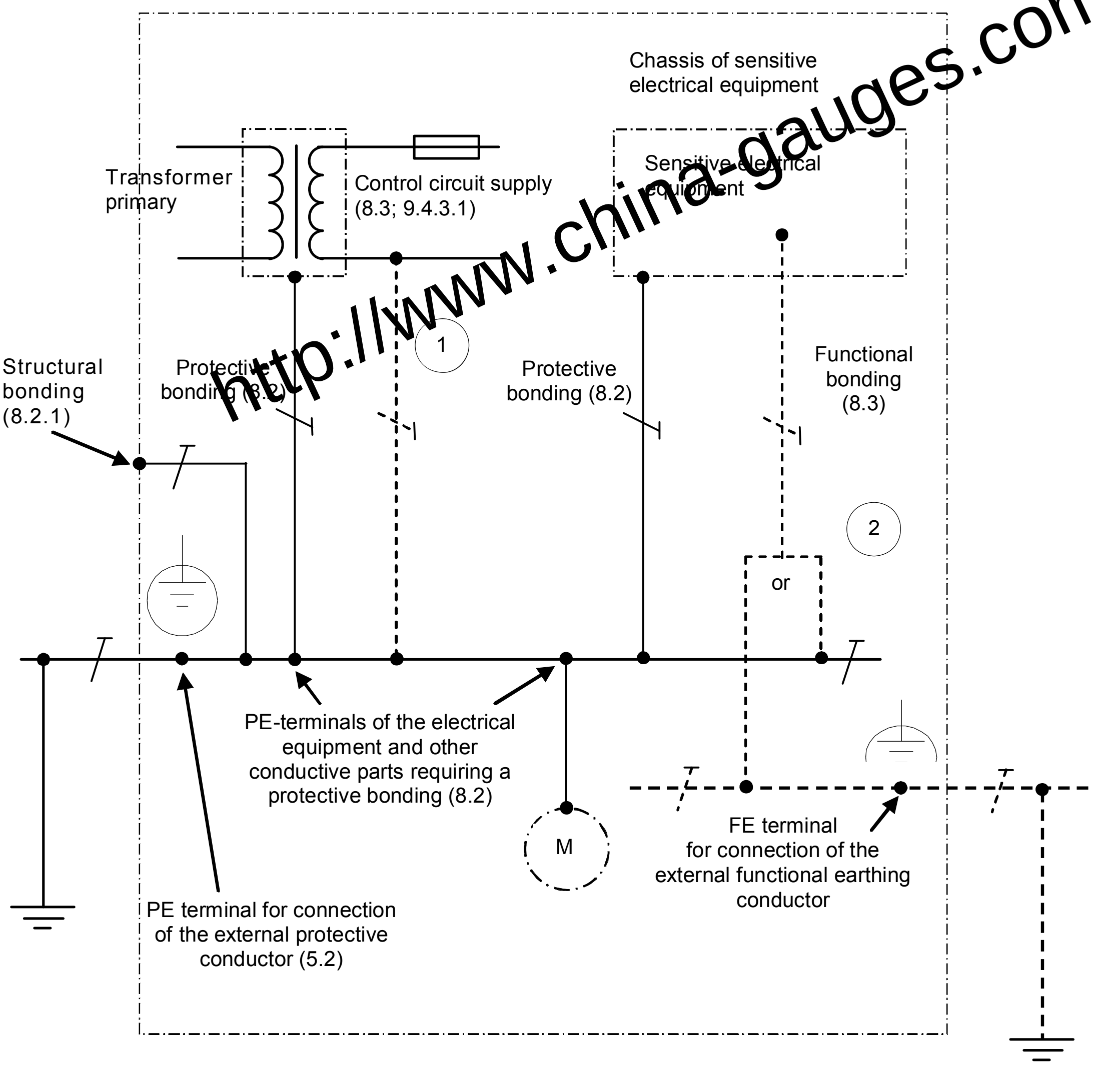
a) connection of sensitive electrical circuits to the chassis:
   - such terminations should be marked or labelled with the symbol IEC 60417-5020 (2002-10):



   - connection of the chassis to earth (PE) using a conductor with low RF impedance and as short as practicable;

b) connection of sensitive electrical equipment or circuits directly to the PE circuit or to a functional earthing conductor (FE) (see Figure 1), to minimize common mode disturbance. The FE terminal should be marked or labelled by the symbol IEC 60417-5018 (2002-10):





------------- Optional connections

(1) Functional bonding (8.3)
including protective bonding (8.2)

(2) Functional bonding only (8.3) either to the protective conductor or to the functional earthing conductor

NOTE The functional earthing conductor was previously referred to as 'noiseless earth conductor' and the 'FE' terminal was previously designated 'TE' (see IEC 60445).

IEC 2178/09

Figure 1 – Example of equipotential bonding for electrical equipment

8.2 Protective bonding circuit

8.2.1 General

8.2.1.1 Overview

The protective bonding circuit consists of:

- PE terminal(s) (see 5.2);
- the protective conductors in the electrical equipment including sliding contacts where they are part of the circuit;
- the exposed conductive parts and conductive structural parts of the electrical equipment;
- those extraneous conductive parts which form the structure of the semiconductor fabrication equipment.

8.2.1.2 Thermal and mechanical stresses

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.

NOTE 1 Particular attention is necessary to ensure sufficient mechanical integrity of the protective bonding circuit in the case of equipment having high earth leakage currents.

NOTE 2 Earth leakage current is defined as “current flowing from the live parts of an installation to earth, in the absence of an insulation fault” (IEV 442-01-24). This current may have a capacitive component including that resulting from the deliberate use of capacitors.

8.2.1.3 Current-carrying capacity

All parts of the protective bonding circuit shall have sufficient current-carrying capacity to withstand the fault current that can occur in that part of the protective bonding circuit.

NOTE Bonding conductors in accordance with 8.2.2 are considered to meet this requirement.

8.2.1.4 Supplementary bonding conductor

Where a conductive structural part can become the path for fault currents, it shall have an impedance sufficiently low to ensure a fault clearing time to satisfy the requirements of Annex A or be provided with a supplementary protective bonding conductor. An impedance lower than 0,1 is considered to be sufficiently low.

A supplementary protective bonding conductor connecting two exposed conductive parts shall have a conductance not less than that of the smaller protective conductor connected to the exposed conductive parts.

A supplementary protective bonding conductor connecting exposed conductive parts to extraneous conductive parts shall have a conductance not less than that of the cross-sectional area of the corresponding protective conductor.

NOTE 1 Derived from 544.2 of IEC 60364-5-54:2002.

NOTE 2 See 6.3.3.

8.2.1.5 IT distribution

If an IT distribution system is used, the structure shall be part of the protective bonding circuit in conjunction with insulation monitoring. In large fabrication equipment this can involve the provision of an earth fault supervision system.

NOTE See 6.3.3 c).

8.2.1.6 Parts that need not be bonded

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.

NOTE This exemption applies, for example, to bolts, rivets, nameplates and cable clips.

Conductive structural parts of electrical equipment in accordance with 6.3.2.2 need not be connected to the protective bonding circuit. Extraneous conductive parts which form the structure of the fabrication equipment need not be connected to the protective bonding circuit where all the electrical equipment provided is in accordance with 6.3.2.2.

8.2.1.7 Parts that shall not be bonded

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

8.2.2 Protective conductors

Protective conductors shall be identified in accordance with 13.4.2.

Copper conductors are preferred.

The cross-sectional area of protective conductors shall comply with the requirements of Tables C.1 to C.5.

Where a conductor material other than copper is used, its electrical resistance per unit length shall not exceed that of the allowable copper conductor.

NOTE In Europe, there are no harmonised standards for non-copper cables with cross-sectional areas less than 16 mm^2.

Metal ducts of flexible or rigid construction and metallic cable sheaths shall not be used as protective conductors. Nevertheless such metal ducts and the metal sheathing of all connecting cables (for example cable armouring, lead sheath) shall be connected to the protective bonding circuit.

8.2.3 Continuity of the protective bonding circuit

8.2.3.1 General

All exposed conductive parts shall be connected to the protective bonding circuit in accordance with 8.2.1.

EXCEPTION: see 8.2.1.6 and 8.2.1.7.

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

8.2.3.2 Integrity of bonding points

Connection and bonding points shall be so designed that their current-carrying capacity is not impaired by environmental influences including for example mechanical, chemical, or electrochemical.

NOTE Where enclosures and conductors of aluminium or aluminium alloys are used, particular consideration should be given to the possibility of electrolytic corrosion.

8.2.3.3 Door-mounted electrical equipment

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. Otherwise fastenings, hinges or sliding contacts designed to have a low resistance shall be used (see 18.3).

8.2.3.4 Continuity of the protective conductor

The continuity of the protective conductor in cables that are exposed to damage (for example flexible trailing cables) shall be ensured by appropriate measures. Where this cannot be achieved, the continuity shall be monitored.

8.2.4 Exclusion of switching devices from the protective bonding circuit

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

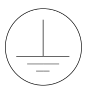
No means of interruption of the protective bonding circuit shall be provided except under one of the following circumstances:

a) Links for test or measurement purposes that cannot be opened without the use of a tool and that are located in an enclosed electrical equipment area.
b) Chassis that need to be floating for normal operation are permitted where access within enclosures can be achieved only after the chassis are connected to the protective earth by automatic means. Such means shall be able to continue to perform its function in the presence of a single fault or failure.
c) Where the continuity of the protective bonding circuit can be interrupted by means of 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).

8.2.5 Protective conductor connecting points

All protective conductors shall be terminated in accordance with 13.1.1. The protective conductor connecting points shall have no other function and are not intended, for example, to attach or connect appliances or parts.

Each protective conductor connecting point shall be marked or labelled as such using the symbol IEC 60417-5019 (2002-10):



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.

8.2.6 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 fabrication 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 fabrication equipment to an external protective conductor.

8.2.7 Limitation of touch current on cord and plug connected equipment

The maximum current through a resistor of 1 500 connected between any exposed (accessible) part of cord and plug connected equipment and the protective earthing conductor of the supply shall not exceed 3,5 mA.

For the verification that this requirement is met 18.3 applies.

EXCEPTION: Equipment with touch current exceeding 3,5 mA is acceptable if the equipment is fully compliant with an applicable IEC product safety standard that explicitly permits a higher leakage current.

8.3 Functional bonding

Connection to a common conductor in accordance with 9.4.3.1 can contribute to protection against incorrect operation as a result of insulation failures.

For recommendations regarding functional bonding to avoid incorrect operation due to electromagnetic disturbances, see 4.4.2.

8.4 Measures to limit the effects of high leakage current

The effects of high leakage current can be restricted to the electrical equipment having high leakage current by connection of that electrical equipment to a dedicated supply transformer having separate windings. The protective bonding circuit shall be connected to exposed conductive parts of the fabrication equipment and, in addition, to the secondary winding of the transformer.

9 Control circuits, emergency off (EMO), and protective interlock circuits

9.1 Control circuits

9.1.1 Control circuit supply

It is recommended that, where practicable, circuits be supplied from power supplies or control transformers. Such transformers shall have separate windings.

NOTE This will limit currents under fault and surge conditions, and can provide enhanced EMC filtering.

Safety circuits should be designed using non-hazardous voltage and power levels consistent with the correct operation of the control circuit.

9.1.2 DC circuits derived from an a.c. supply

Where d.c. circuits derived from an a.c. supply are connected to the protective bonding circuit (see 8.2.1), it is recommended that they be supplied from a separate winding of a transformer.

NOTE Switch-mode units fitted with transformers having separate windings in accordance with IEC 61558-2-16 meet this recommendation.

9.1.3 Start functions

Start functions shall operate by energizing the relevant circuit (see 9.3.2).

9.1.4 Stop functions

There are three categories of stop functions that can be used for all or part of the fabrication equipment as follows:

- stop category 0: stopping of operation(s) by immediate removal of power to the machine actuators (i.e., an uncontrolled stop – see 3.74);
- stop category 1: a controlled stop of operation(s) (see 3.13) with power available to the machine actuators to achieve the stop and then removal of power when the stop is achieved;
- stop category 2: a controlled stop of operation(s) with power left available to the machine actuators.

9.1.5 Operating modes

Fabrication equipment can have one or more operating modes determined by the type of its application. When a hazardous situation can result from a mode selection, it shall be restricted by suitable means (for example key operated switch, access code).

NOTE The use of these means is intended to restrict access to skilled or instructed persons, and to prevent inadvertent selection.

Mode selection by itself shall not initiate operation of the fabrication equipment. A separate actuation of a start control shall be required.

For each specific operating mode, the relevant safety functions and/or protective measures shall be implemented.

Indication of the selected operating mode shall be provided (for example the position of a mode selector, the provision of an indicating light, a visual display indication on a user interface screen).

9.1.6 Multiple control stations

Where fabrication equipment has more than one control station, measures shall be provided to ensure that initiation of commands from different control stations does not lead to a hazardous situation.

Where this requires that only one of the control stations can be enabled at a given time, a hardware-based device or a circuit in accordance with 9.4 shall be used to ensure that only one of the control stations can be enabled at a given time. An indication of which operator control station is in control of the fabrication equipment shall be provided at suitable locations as determined from a risk assessment of the fabrication equipment.

Where more than one control station is provided, stop commands from any control station shall be effective unless otherwise indicated by the risk assessment of the fabrication equipment.

NOTE Multiple points of remote host control are under consideration for automated manufacturing.

9.2 Emergency Off (EMO)

9.2.1 General

Fabrication equipment shall have an emergency off circuit which when activated, will place the fabrication equipment into a safe shutdown condition, without generating any additional hazards.

EXCEPTION 1: for single phase fabrication equipment that is supplied at less than 250 V line to ground, with a total load not more than 2,4 KVA, and having only electrical hazards, an "emergency off" circuit is not required provided that the supply disconnecting device is within 3 m of the normal position of the operator.

EXCEPTION 2: equipment that is not intended to stand-alone but is intended to be incorporated within an overall integrated system need not have a separate emergency off circuit. The equipment's installation manual shall provide clear instructions to the equipment installer to connect the equipment to the integrated system's emergency off circuit.

NOTE 1 A safe shutdown condition involves disconnecting sources of hazardous energy and removing or suitably containing hazardous production materials. These hazardous energies and materials include but are not limited to those that can cause electrical, chemical, mechanical, and radiation hazards.

NOTE 2 The EMO can fulfil the requirement to provide an emergency stop function.

9.2.2 Circuits to be de-energized

Activation of the emergency off circuit shall de-energize all hazardous voltage and all power greater than 240 VA in the electrical equipment except for voltage and power needed for the EMO circuit function and for reset following an EMO shutdown where that power is contained within the main electrical enclosure.

EXCEPTION: safety related devices (such as fire suppression systems) and computer systems performing data logging need not be de-energized by the EMO circuit.

All components that remain energised at hazardous voltage or power following EMO activation shall be clearly labelled and identified in the user documentation, and protected against inadvertent contact.

9.2.3 Requirements for EMO circuits

The emergency off circuit shall:

a) not include controls that enable it to be defeated or bypassed;
b) not re-energize systems that can create a hazardous situation upon resetting of the EMO device;
c) shut down the fabrication equipment by de-energizing control components;
d) be designed in accordance with 9.4.2 and its components selected in accordance with 4.2.

9.3 Operations other than emergency off

9.3.1 General

The necessary safety functions and/or protective measures (for example, protective interlock circuits (see 9.4.2) shall be provided for safe operation.

Measures shall be taken to prevent operation of the fabrication equipment in an unintended or unexpected manner after any stopping of the fabrication equipment (for example due to locked-off condition, power supply fault, battery replacement, lost signal condition with cableless control).

9.3.2 Start

The start of an operation shall be possible only when all of the relevant safety functions and/or protective measures are in place and are operational except for conditions as described in 9.5.

On fabrication equipment where safety functions and/or protective measures cannot be applied for certain operations, manual control of such operations shall require the use of hold-to-run controls, and/or enabling devices, as appropriate.

Suitable protective interlock circuits shall be provided to secure correct sequential starting where an incorrect start sequence can result in an unacceptable risk.

9.3.3 Stop

The selection of stop category(ies) is dependent on the requirements of the fabrication equipment.

Stop functions shall override related start functions (see 9.3.2).

Reset of the stop function shall not initiate any hazardous situation.

9.3.4 Other control functions

9.3.4.1 Hold-to-run controls

Hold-to-run controls shall require continuous actuation of the control device(s) to sustain operation.

NOTE Hold-to-run control can be accomplished by two-hand control devices.

9.3.4.2 Two-hand control

Requirements for two-hand controls are given in ISO 13851. Three types of two-hand control function are defined in ISO 13851, the selection of which is determined by the risk assessment. These have the following features:

Type I: this type requires:

- the provision of two control devices and their concurrent actuation by both hands;
- continuous concurrent actuation during the hazardous situation;
- operation of the fabrication equipment shall cease upon the release of either one or both of the control devices when hazardous situations are still present.

A Type I two-hand control device is not considered to be suitable for the initiation of hazardous operation.

Type II: a type I control requiring the release of both control devices before operation of the fabrication equipment can be reinitiated.

Type III: a type II control requiring concurrent actuation of the control devices as follows:

- it shall be necessary to actuate the control devices within a certain time limit of each other, not exceeding 0,5 s;
- where this time limit is exceeded, both control devices shall be released before operation of the fabrication equipment can be initiated.

9.3.4.3 Enabling control

Enabling control (see also 10.9) is a manually activated control function that:

a) when activated allows operation of the fabrication equipment to be initiated by a separate start control, and
b) when de-activated
   1) initiates a stop function, and
   2) prevents initiation of operation of the fabrication equipment.

Enabling control shall be so arranged as to minimize the possibility of defeating, for example by requiring the de-activation of the enabling control device before operation of the fabrication equipment can be reinitiated. It should not be possible to defeat the enabling function by simple means (such as taping a button down).

9.3.5 Cableless control

This Subclause deals with the functional requirements of control systems employing cableless (for example radio, infra-red) techniques for transmitting commands and signals between a control system and operator control station(s).

NOTE Some of these application and system considerations can also be applicable to control functions employing serial data communication techniques where the communications link uses a cable (for example coaxial, twisted-pair, optical fibre).

Cableless controls shall not be used where malfunction or improper operation of the control can impact the safety of the system.

Each cableless operator control station shall carry an unambiguous indication of which fabrication equipment is intended to be controlled by that operator control station.

9.4 Protective interlocks

9.4.1 General

When a single failure can result in an unacceptable level of risk, a protective interlock circuit or other suitable means shall be provided to protect against the consequences of that failure.

Protective interlock circuits shall be designed using non-hazardous voltage and power levels, consistent with the correct operation of the circuit.

9.4.2 Protective interlock circuit design

9.4.2.1 General

A protective interlock circuit shall be designed such that, upon activation, the relevant parts of the fabrication equipment are automatically brought to a safe condition.

It is recommended that safety-related control functions be in accordance with IEC 62061 or ISO 13849-1 and have an appropriate level of safety integrity or safety performance which has been determined from the safety requirements specification.

NOTE Devices whose primary function is to protect the electrical equipment (for example circuit breakers, fuses) are not considered to be parts of protective interlock circuits.

9.4.2.2 Resetting

The manual or automatic resetting of an protective interlocking circuit shall not initiate fabrication equipment operation where it can result in a hazardous situation.

9.4.2.3 Indication of activation

When a protective interlock circuit is activated it shall provide an indication at the main operator work station.

NOTE 1 It is recommended that the indication identifies the cause of the activation.

NOTE 2 It can be useful to provide additional indication at other locations.

EXCEPTION: If a protective interlock triggers the emergency off (EMO) circuit, or otherwise removes power to the user interface, indication of activation is not mandatory.

9.4.2.4 Device considerations

It is preferred that protective interlock circuits rely on electromechanical devices, however, solid state devices may be used if they have been evaluated for suitability for their application, in accordance with appropriate standard(s). The evaluation for suitability should take into account reliability, and abnormal conditions such as overvoltage, undervoltage, power supply interruption, transient overvoltage, ramp voltage, electromagnetic susceptibility, electrostatic discharge, thermal cycling, humidity, dust, vibration, jarring, or interfacing to a network.

9.4.2.5 Software

Software used in protective interlock functions or devices shall be in accordance with IEC 61508, IEC 62061, or ISO 13849 (all parts).

EXCEPTION: Software based (including embedded software) protective interlock circuits that do not meet these requirements may be used only if they protect against hazardous situations that cannot result in human injury requiring medical attention.

NOTE 1 Both ISO 13849-1 and IEC 62061 refer to IEC 61508-3 for application guidance on software based devices in safety-related circuits such as protective interlock circuits.

NOTE 2 IEC/TR 62513 gives guidance for the use of communication systems in safety-related applications.

9.4.2.6 Overriding of protective interlocks

The protective interlock circuit shall be designed to minimize the need to override protective interlocks for maintenance or repair purposes.

When it is necessary to provide protective interlock circuits that can be overridden, an intentional operation shall be required to override them. When a protective interlock circuit is overridden in accordance with the user instructions, the combination of the engineering means and the methods specified by the instructions shall be sufficient to ensure that risks to personnel are adequately reduced while the protective interlock is overridden. Means shall be provided to protect against unexpected commands from control systems when protective interlocks are in the overridden mode.

All protective interlock circuits shall be designed such that the fabrication equipment cannot be returned to normal operation before they are restored.

Protective interlock circuits that safeguard personnel shall not be defeatable without the use of a tool.

9.4.2.7 Circuit design

Protective interlock circuits shall switch control devices on the unearthed side of the circuit.

Protective interlocks circuits shall eliminate hazardous situations by de-energizing circuit components rather than energizing them.

9.4.2.8 Additional protective interlock circuits

Means to connect additional protective interlock circuits shall be provided when necessary for safe use of the fabrication equipment, for example when necessary for interfacing to other equipment.

NOTE Provisions for the selection, installation and configuration of Presence Sensing Protective Equipment can be found in IEC/TS 62046.

9.5 Suspension of safety functions and/or protective measures

Where it is necessary to suspend safety functions and/or protective measures (for example for setting or maintenance purposes), protection shall be ensured by:

- disabling all other operating (control) modes that might endanger personnel in the area affected by the suspended safety function; and
- other relevant means (see 4.11.9 of ISO 12100-2:2003), that can include, for example, one or more of the following:
  - initiation of operation by a hold-to-run device or by a similar control device;
  - a portable control station with an emergency stop device and, where appropriate, an enabling device. Where a portable control station is in use, initiation of motion shall only be possible from that control station;
  - limitation of the speed or the power of motion;
  - limitation of the range of motion.

10 Operator interfaces

10.1 General

10.1.1 General device requirements

This clause contains requirements for devices mounted outside or partially outside control enclosures.

As far as is practicable, those devices shall be selected, mounted, and identified or coded in accordance with relevant parts of IEC 61310.

The possibility of inadvertent operation shall be minimized by for example, positioning of devices, suitable design, provision of additional protective measures. Particular consideration shall be given to the selection, arrangement, programming and use of operator input devices such as touchscreens, keypads and keyboards for the control of hazardous fabrication equipment operations. Additional information is given in IEC 60447.

10.1.2 Location and mounting

As far as is practicable, control devices shall be:

- readily accessible for operation, repair and maintenance;
- mounted in such a manner as to minimize the possibility of damage from activities such as material handling.

The actuators of operator hand-operated control devices shall be installed so that they are not less than 0,6 m above the servicing level and are within easy reach of the normal working position of the operator.

All controls shall be located so that personnel are not placed in a hazardous situation when operating them.

The actuators of foot-operated operator control devices shall be selected and installed so that they are within easy reach of the normal working position of the operator.

10.1.3 Degree of protection

The degree of protection (see IEC 60529) together with other appropriate measures shall afford protection against:

- the effects of aggressive liquids, vapours, or gases likely to be present in the physical environment of the operator interface;
- the ingress of contaminants (for example particulate matter).

In addition, the operator interface control devices shall have a minimum degree of protection against direct contact of IPXXD (see IEC 60529).

10.1.4 Portable and pendant control stations

Portable and pendant control stations and their control devices shall be so selected and arranged as to minimize the possibility of inadvertent fabrication equipment operations caused by shocks and vibrations (for example if the control station is dropped or strikes an obstruction) (see also 4.4.5).

10.2 Push-buttons

10.2.1 Colours

Push-button actuators shall be colour-coded in accordance with Table 3 (see also 9.2).

The colours for START/ON actuators should be WHITE, GREY, BLACK or GREEN with a preference for WHITE. RED shall not be used.

The colour RED shall be used for emergency stop and emergency off actuators.

The colours for STOP/OFF actuators should be BLACK, GREY, or WHITE with a preference for BLACK. GREEN shall not be used. RED is permitted, but it is recommended that RED is not used near an emergency operation device.

WHITE, GREY, or BLACK are the preferred colours for push-button actuators that alternately act as START/ON and STOP/OFF push-buttons. The colours RED, YELLOW, or GREEN shall not be used.

WHITE, GREY, or BLACK are the preferred colours for push-button actuators that cause operation while they are actuated and cease the operation when they are released (for example hold-to-run). The colours RED, YELLOW, or GREEN shall not be used.

Reset push-buttons shall be BLUE, WHITE, GREY, or BLACK. Where they also act as a STOP/OFF button, the colours WHITE, GREY, or BLACK are preferred with the main preference being for BLACK. GREEN shall not be used.

Where the same colour WHITE, GREY, or BLACK is used for various functions (for example WHITE for START/ON and for STOP/OFF actuators) a supplementary means of coding (for example shape, position, symbol) shall be used for the identification of push-button actuators.

Table 3 – Colour-coding for push-button actuators and their meanings

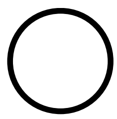
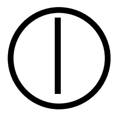
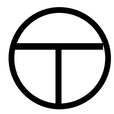
Colour	Meaning	Explanation	Examples of application
RED	Emergency	Actuate in the event of a hazardous situation or emergency	Emergency stop Initiation of emergency function (see also 10.2.1)
YELLOW	Abnormal	Actuate in the event of an abnormal condition	Intervention to suppress abnormal condition Intervention to restart an interrupted automatic cycle
BLUE	Mandatory	Actuate for a condition requiring mandatory action	Reset function

Colour	Meaning	Explanation	Examples of application
GREEN	Normal	Actuate to initiate normal conditions	(See 10.2.1)
WHITE			START/ON (preferred) STOP/OFF
GREY	No specific meaning assigned	For general initiation of functions except for emergency stop	START/ON STOP/OFF
BLACK			START/ON STOP/OFF (preferred)

10.2.2 Markings

In addition to the functional identification as described in 16.3, it is recommended that push-buttons be marked, near to or preferably directly on the actuators, with the symbols shown in Table 4.

Table 4 – Symbols for push-buttons

START or ON	STOP or OFF	Push-buttons acting alternately as START or STOP buttons and as ON or OFF buttons	Push-buttons acting as START or ON buttons when pressed and as STOP or OFF buttons when released (i.e. hold-to-run)
IEC 60417-5007 (2002-10)	IEC 60417-5008 (2002-10) 	IEC 60417-5010 (2002-10) 	IEC 60417-5011 (2002-10) 

10.3 Indicator lights

10.3.1 General

Indicator lights are used for the following purposes.

- Indication: to attract attention or to indicate that a certain task should be performed. The colours RED, YELLOW, BLUE, and GREEN are normally used in this mode; for flashing indicator lights and displays, see 10.3.3.
- Confirmation: to confirm a command, or a condition, or to confirm the termination of a change or transition period. The colours BLUE and WHITE are normally used in this mode and GREEN may be used in some cases.

Indicator lights shall be selected and installed in such a manner as to be visible from the necessary locations (see also IEC 61310-1).

Indicator light circuits used for warning lights shall be fitted with facilities to check the operability of these lights.

Indicator lights that provide warnings shall be clearly visible to those who need to receive and act on that warning. It is recommended that indicator lights that have functional purposes other than warnings be visible from locations that are consistent with their use.

NOTE Indicator lights used for other purposes, for example to give information or to indicate the status of a production process, are not considered in this subclause.

10.3.2 Colours

Unless otherwise agreed between the supplier and the user, indicator lights shall be colour-coded with respect to the condition (status) of the fabrication equipment in accordance with Table 5.

Table 5 – Colours for indicator lights and their meanings with respect to the condition of the fabrication equipment

Colour	Meaning	Explanation	Action by operator
RED	Emergency	Critical condition	Immediate action to deal with critical condition (for example switching off the machine supply, being alert to the critical condition)
YELLOW	Abnormal	Abnormal condition Impending critical condition	Monitoring and/or intervention (for example by re-establishing the intended function)
BLUE	Mandatory	Indication of a condition that requires action by the operator	Mandatory action
GREEN	Normal	Normal condition	Optional
WHITE	Neutral	Other conditions; may be used whenever doubt exists about the application of RED, YELLOW, GREEN, BLUE	Monitoring

10.3.3 Flashing lights and displays

For further distinction or information and especially to give additional emphasis, flashing lights and displays can be provided for the following purposes:

- to attract attention;
- to request immediate action;
- to indicate a discrepancy between the command and actual state;
- to indicate a change in process (flashing during transition).

It is recommended that higher frequency flashing lights or display be used for higher priority information (see IEC 60073 for recommended flashing rates and pulse/pause ratios).

Where flashing lights or displays are used to provide higher priority information, audible warning devices should also be provided.

10.4 Illuminated push-buttons

Illuminated push-button actuators shall be colour-coded in accordance with Tables 3 and 5. Where it is not clear from the Tables what colour is required, WHITE may be used. The colour RED for the emergency stop actuator shall not depend on the illumination of its light.

10.5 Rotary control devices

Devices having a rotational member, such as potentiometers and selector switches, shall have means of prevention of rotation of the stationary member. Friction alone shall not be considered sufficient.

10.6 Start devices

Actuators used to initiate a start function or the movement of fabrication equipment elements (for example slides, spindles, carriers) shall be selected and mounted so as to minimize inadvertent operation. However, mushroom-type actuators may be used for two-hand control (see also ISO 13851).

10.7 Emergency off devices

Emergency off devices shall:

a) have a palm or mushroom head type of actuator, coloured red;

b) permit activation by the heel of the palm;

c) have a yellow background;

d) be clearly labelled “Emergency Off” or “EMO” which shall be clearly legible from the viewing location;

e) be located or shrouded to minimize accidental activation. If shrouding is used it shall still permit activation by the heel of the palm;

f) be self-latching;

g) be readily accessible from operating locations at the fabrication equipment, regularly scheduled maintenance locations at the fabrication equipment and reasonably foreseeable repair locations at the fabrication equipment;

h) be located at the fabrication equipment, at each operating location at the fabrication equipment and within 3 m (10 feet) from any regularly scheduled maintenance location at the fabrication equipment;

i) have direct opening contacts.

10.8 Emergency stop devices

In some applications it can be necessary to provide an emergency stop for motions, in addition to the EMO. In this case the emergency stop actuator shall be differentiated from the EMO, for example by the words “Emergency Stop”.

NOTE Requirements for the emergency stop function are given in ISO 13850.

10.9 Enabling control device

When an enabling control device is provided as a part of a system, it shall signal the enabling control to allow operation when actuated in one position only. In any other position, operation shall be stopped or prevented.

Enabling control devices shall be selected and arranged so as to minimize the possibility of defeating.

Enabling control devices shall be selected that have the following features:

- for a two-position type:
  - position 1: off-function of the switch (actuator is not operated);
  - position 2: enabling function (actuator is operated);
- for a three-position type:
  - position 1: off-function of the switch (actuator is not operated);
  - position 2: enabling function (actuator is operated in its mid-position);
  - position 3: off-function (actuator is operated past its mid-position);
  - when returning from position 3 to position 2, the enabling function is not activated.

NOTE 1 The enabling control function is described in 9.3.4.3.

NOTE 2 Use of two-position type enabling control devices can be inappropriate in some applications (for example, manual control of a robot).

11 Controlgear: location, mounting, and enclosures

11.1 General requirements

All controlgear shall be located and mounted so as to facilitate:

- its accessibility and maintenance;

- its protection against the external influences or conditions under which it is intended to operate;
- operation and maintenance of the fabrication equipment.

NOTE This clause does not consider the ability of the equipment to withstand the activation of external fire suppression systems.

11.2 Location and mounting

11.2.1 Accessibility and maintenance

11.2.1.1 General

All items of controlgear that are intended to be field-replaceable shall be placed and oriented so that they can be identified without moving them or the wiring or dismantling electrical equipment or parts of the fabrication equipment.

For items that require checking for correct operation or that are liable to need replacement, those actions should be possible without dismantling other electrical equipment or parts of the fabrication equipment (except opening doors or removing covers, barriers or obstacles). Terminals not part of controlgear components or devices shall also conform to these requirements.

All controlgear shall be mounted so as to facilitate its operation and maintenance. Where a special tool is necessary to adjust, maintain, or remove a device, such a tool shall be supplied.

Ⓒ All controlgear shall be mounted so as to facilitate its operation and maintenance from the front. Where a special tool is necessary to adjust, maintain, or remove a device, such a tool shall be supplied. Where access is required for regular maintenance or adjustment, the relevant devices shall be located between 0,4 m and 2,0 m above the servicing level. It is recommended that terminals be at least 0,2 m above the servicing level and be so placed that conductors and cables can be easily connected to them. Ⓒ

11.2.1.2 Mounting on doors and swing panels

Devices other than human interface devices and cooling devices should not be mounted on doors or on normally removable access covers of enclosures.

When components that handle hazardous voltage and hazardous power are mounted on swing panels or doors, the swing panels or doors that have those components mounted on them shall swing open adequately to provide access. The wiring that flexes when opening the swing panel or door shall pass the flexing test described in 18.13 or shall be provided with additional mechanical protection against damage caused by flexing at all points where it is flexed.

11.2.1.3 Plug/socket combinations

Where control devices are connected through plug-in arrangements, their association shall be made clear by type (shape) or marking. Plug-in devices that are handled during normal operation or maintenance shall be provided with non-interchangeable features where the lack of such a facility can result in an unacceptable risk.

11.2.1.4 Test points

Test points for connection of test equipment, where provided, shall be:

- mounted so as to provide unobstructed access;
- clearly identified to correspond with the documentation (see 17.3);
- adequately insulated;
- sufficiently spaced.

11.2.2 Physical separation or grouping

It is recommended that terminals that are supplied with hazardous voltage be grouped separately from those that are not supplied with hazardous voltage.

Creepage and clearance distances shall meet the criteria of basic insulation between conductors supplied with hazardous voltage and the earthed electrical enclosure for the working voltages involved (see Table C.8).

11.2.3 Heating effects

Heat generating components (for example heat sinks, power resistors) shall be so located that the temperature of each component in the vicinity remains within its permitted limit.

This can be verified by a temperature test (see 18.9).

11.3 Degrees of protection

The electrical controlgear shall be adequately protected against ingress of solid foreign objects and substances in the environment in which the electrical controlgear is intended to be used.

NOTE 1 Requirements for protection against electric shock are given in Clause 6.

NOTE 2 The degrees of protection against ingress of solid foreign objects and water are specified in IEC 60529. Additional protective measures can be necessary against other liquids.

11.4 Enclosures for electrical equipment

11.4.1 General

Enclosures shall be constructed to be capable of withstanding the mechanical, electrical, chemical and thermal stresses as well as the effects of humidity and other environmental factors that are likely to be encountered in normal conditions.

11.4.2 Fasteners

Fasteners used to secure doors and covers should be of the captive type.

11.4.3 Windows

Windows provided for viewing internally mounted indicating devices shall be of a material suitable to withstand mechanical stress and chemical attack.

11.4.4 Doors

It is recommended that enclosure doors be not wider than 0,9 m and have vertical hinges, with an angle of opening of at least 95°.

11.4.5 Openings

Where openings in enclosures are provided (for example, for cable access), including those towards the floor or foundation or to other parts of the fabrication equipment, means shall be provided to ensure that such openings do not impair the degree of protection specified for the electrical equipment. Openings for cable entries shall be easily re-opened on site.

Where there are holes in an enclosure for mounting purposes, it can be necessary to provide means to ensure that after mounting the holes do not impair the required protection.

11.4.6 High surface temperatures

Electrical equipment that, in normal or abnormal operation, can attain a surface temperature sufficient to cause a risk of fire or harmful effect to an enclosure material:

- shall be located within an enclosure that will withstand, without risk of fire or harmful effect, such temperatures as can be generated; and
- shall be mounted and located at a sufficient distance from adjacent equipment so as to allow safe dissipation of heat (see also 11.2.3); or
- shall be otherwise screened by material that can withstand, without risk of fire or harmful effect, the heat emitted by the equipment.

NOTE A warning label in accordance with 16.2 can be necessary.

11.4.7 Containment of molten material or burning insulation

Electrical enclosures shall prevent the emission of molten material or burning insulation under fault conditions, including from the bottom of the enclosure. Baffling or equivalent construction techniques can be used to satisfy this requirement.

11.4.8 Enclosures that can be fully entered

Enclosures which readily allow a person to fully enter shall be provided with means to allow escape, for example panic bolts on the inside of doors. Enclosures intended for such access, for example for resetting, adjusting, maintenance, shall have an unobstructed width of at least 0,7 m and an unobstructed height of at least 2,1 m.

11.4.9 Clearance for access to electrical equipment

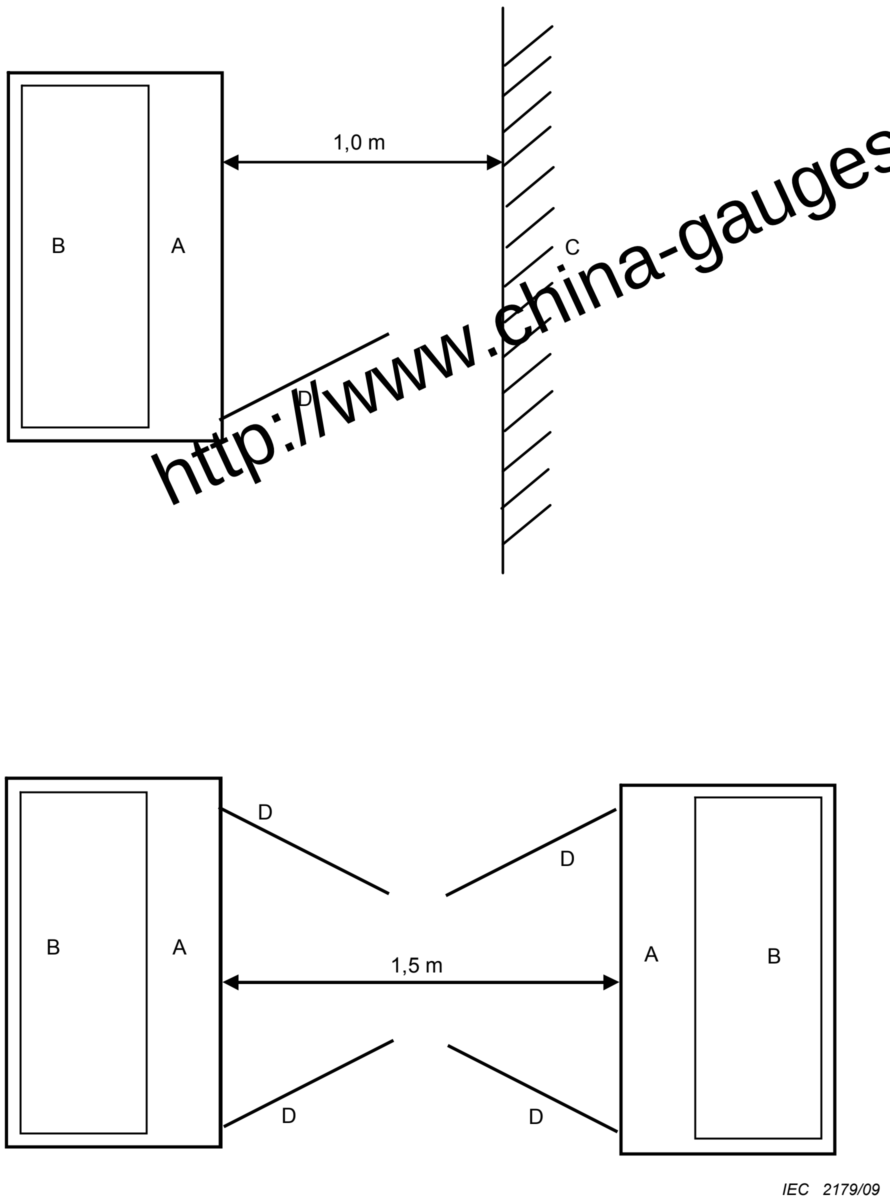
In cases where:

- electrical equipment is likely to be live during access; and
- energized parts are exposed when the enclosure is open,

there shall be a space free of obstructions of 1,0 m in front of the enclosure. In cases where such parts are present on both sides of the access way, the unobstructed space shall be at least 1,5 m. See Figure 2.

NOTE 1 These dimensions are derived from ISO 14122 series.

NOTE 2 In some applications, it can be necessary to provide means to prevent inadvertent closing of the door.



Key

A enclosure for electrical equipment

B electrical equipment within enclosure

C wall or other obstruction

D door of enclosure

Figure 2 – Clearance in front of enclosures

12 Conductors and cables

12.1 General requirements

Conductors and cables shall be selected so as to be suitable for the operating conditions (for example voltage, current, protection against electric shock, grouping of cables) and external influences (for example ambient temperature, presence of water or corrosive substances, mechanical stresses (including stresses during installation), fire hazards) that can exist.

NOTE Further information is given in CENELEC HD 516 S2 "Guide to use of low-voltage harmonized cables".

All conductors shall be constructed of materials compatible with the materials and ratings of the devices they will be connected to and the environment in which they will be used.

Wire conductors should be constructed of copper.

It is recommended that conductor applications be in accordance with Annex C.

12.2 Insulation

12.2.1 General

The insulation of each conductor shall be suitable for the application, taking into account:

a) voltage and currents;
b) mechanical strength;
c) thermal rating;
d) worst-case environment;
e) presence of chemicals;
f) radiation;
g) resistance to flame spread;
h) damage that can result from normal use;
i) reasonably foreseeable misuse;
j) protective devices for clearing faults;
k) wiring practice (see Clause 13).

It is important to give special attention to the integrity of a circuit having a safety-related function.

Natural rubber and materials containing asbestos shall not be used as insulation.

12.2.2 Fire propagation and fume emissions

Where the insulation of conductors and cables (for example PVC) can constitute hazards due to the propagation of a fire or the emission of toxic or corrosive fumes, additional protection should be provided or alternative insulation should be considered.

12.2.3 Printed circuit boards

Printed circuit boards shall be made of flame-retardant material with a flammability rating of V-1 or better (see IEC 60695-11-10).

NOTE IEC 60695-11-10 is derived from UL 94.

12.3 Current-carrying capacity

Conductors shall meet the following requirements:

a) be applied in accordance with its rating and the suppliers instructions;
b) be sized in accordance with Annex C except for conductors that have been demonstrated to be adequate for their application by testing in accordance with a relevant IEC standard.

12.4 Conductor and cable voltage drop

It is recommended that the voltage drop from the point of supply to the load does not exceed 5 % of the nominal voltage under normal operating conditions. In order to satisfy this recommendation, it can be necessary to use conductors having a larger cross-sectional area than that derived from Annex C.

12.5 Flexible cables

12.5.1 General

Cables that are subjected to severe duties shall be of adequate construction to protect against:

- damage due to excessive flexing;
- abrasion due to mechanical handling and dragging across rough surfaces;
- kinking due to operation without guides;
- stress resulting from guide rollers and forced guiding, being wound and re-wound on cable drums.

NOTE 1 Cables for such conditions are specified in relevant national standards.

NOTE 2 The operational life of the cable will be reduced where unfavourable operating conditions such as high tensile stress, small radii, bending into another plane and/or where frequent duty cycles coincide.

NOTE 3 See 17.2, j) 3).

12.5.2 Flexible cables inside enclosures or ducts

Flexible cords, cables and power cord sets which meet all the requirements of 12.5.1 are permitted inside electrical enclosures for internal wiring:

a) when equipped with an attachment plug and powered from a receptacle outlet inside the electrical enclosure to connect one or more assemblies to primary power inside the enclosure; and
b) when the insulation on the individual conductors of the flexible cord or cable are suitable for the application without depending on the outer sheath (jacket) insulation; and
c) when the flexible cord, power cord set, receptacles, and appliance coupler are all used in accordance with their ratings; and
d) when the cable type is appropriate for its method of installation.

12.5.3 Mechanical rating in cable handling systems

The cable handling system of the electrical equipment shall be so designed to keep the tensile stress of the conductors as low as is practicable during operation. Where copper conductors are used, the tensile stress applied to the conductors shall not exceed 15 N/mm^2 of the copper cross-sectional area. Where the demands of the application exceed the tensile stress limit of 15 N/mm^2, cables with special construction features should be used and the allowed maximal tensile stress should be agreed with the cable manufacturer.

The maximum stress applied to the conductors of flexible cables with material other than copper shall be within the cable manufacturer’s specification.

NOTE The following conditions affect the tensile stress on the conductors:

- acceleration forces;
- speed of motion;
- dead (hanging) weight of the cables;
- method of guiding;
- design of cable drum system.

13 Wiring practices

13.1 Connections and routing

13.1.1 General requirements

13.1.1.1 General

All connections, especially those of the protective bonding circuit, shall be secured against accidental loosening.

The means of connection shall be suitable for the cross-sectional areas and properties of the conductors being terminated.

13.1.1.2 Multiple conductors

The connection of two or more conductors to one terminal connecting point is permitted only in those cases where the terminal is stated by the manufacturer to be suitable for that purpose. However, only one protective conductor shall be connected to one terminal connecting point.

13.1.1.3 Soldered connections

Soldered connections shall be permitted only where terminals are provided that are suitable for soldering. The conductor shall be fixed so that reliance is not placed upon the soldering alone to maintain the conductor in position.

13.1.1.4 Terminals on terminal blocks

Terminals on terminal blocks shall be plainly marked or labelled to correspond with markings on the diagrams.

Where an incorrect electrical connection (for example, arising from replacement of devices) can be a source of risk the possibility of incorrect connection should be reduced as far as practicable by design measures in addition to the identification of conductors and/or terminations in accordance with 13.4.

13.1.1.5 Flexible conduits and cables

The installation of flexible conduits and cables shall be such that liquids will drain away from the fittings.

13.1.1.6 Retaining strands

Means of retaining strands of conductors and shields shall be provided when terminating conductors at devices or terminals that are not equipped with this facility. Solder shall not be used for that purpose.

13.1.1.7 Terminal blocks

Terminal blocks shall be mounted and wired so that the internal and external wiring does not cross over the terminals.

13.1.1.8 Integration of conductors

The integration of conductors into the fabrication equipment shall be such that their current carrying capacity is not unduly impaired by mechanical, chemical, thermal or any other influences.

NOTE Conductor derating can be necessary.

13.1.2 Conductor and cable runs

Conductors and cables shall be run from terminal to terminal without splices or joints. Connections using plug/socket combinations with suitable protection against accidental disconnection are not considered to be joints for the purpose of this Subclause.

Where it is necessary to connect and disconnect cables and cable assemblies, a sufficient extra length shall be provided for that purpose.

The terminations of cables shall be adequately supported to prevent mechanical stresses at the terminations of the conductors.

Wherever practicable, the protective conductor shall be placed close to the associated live conductors in order to decrease the impedance of the loop.

13.1.3 Conductors of different circuits

Conductors of different circuits may be laid side by side, may occupy the same duct (for example conduit, cable trunking system), or may be in the same multiconductor cable provided that the arrangement does not impair the safe functioning of the respective circuits.

Where those circuits operate at different voltages, the conductors shall be separated by suitable barriers or shall be insulated for the highest voltage to which any conductor within the same duct is intended to be subjected, for example line to line voltage for unearthed systems and phase to earth voltage for earthed systems.

13.1.4 Conductors smaller than 50 mm^2

Conductors smaller than 50 mm^2 shall not be connected in parallel to the same terminations to attain the necessary current carrying capacity.

13.1.5 Temperature exposure of conductors

Conductors and their insulations shall not be exposed to temperatures greater than their temperature ratings for normal operating conditions and fault conditions.

13.1.6 Terminal temperatures

If a component terminal has a lower temperature rating than the conductor connecting to it, then the conductor should be sized to and provided with overcurrent protection to ensure its temperature does not exceed that of the terminal rating.

13.2 Multi-outlet assemblies

Multi-outlet assemblies are acceptable provided that they satisfy all the following criteria:

a) are permanently installed;

b) are manufactured for industrial use;

c) have an enclosure that passes the test in 18.11;

d) have an enclosure that is metal, V-0 rated plastic (see IEC 60695-11-10), or equivalent;

e) each receptacle shall have an individual protective conductor connection that passes the test in 18.3.

NOTE Series connection of the protective conductor from receptacle to receptacle should not be used (see IEC 60364-5-54).

13.3 Plug/socket combinations

Where plug/socket combinations are provided, they shall fulfil the following requirements.

a) Where a plug/socket combination has a protective bonding contact, it shall be a first make last break contact.

b) The component which remains live after disconnection shall have a degree of protection of at least IP2X or IPXXB, taking into account the required clearance and creepage distances. PELV circuits are excepted from this requirement.

   NOTE This generally means that only female cord connectors should be used to supply power, to prevent access to electrical contacts which are supplied with hazardous voltage.

c) Metallic housings of plug/socket combinations shall be connected to the protective bonding circuit. Plug/socket combinations carrying only PELV circuits are excepted from this requirement.

d) Where more than one plug/socket combination is provided in the same electrical equipment, the associated combinations shall be clearly identifiable. If misconnection is reasonably foreseeable and could result in a hazardous situation, then these plug/socket combinations shall be physically incapable of being misconnected. In any case, it is recommended that mechanical coding be used to prevent incorrect insertion.

e) Plug/socket combinations should be rated for at least 125 % of the maximum rated design load (current) intended for the circuit.

13.4 Identification of conductors

13.4.1 General requirements

Each conductor shall be identifiable at each termination in accordance with the technical documentation (see Clause 17).

It is recommended (for example to facilitate maintenance) that conductors be identified by number, alphanumeric, colour (either solid or with one or more stripes), or a combination of colour and numbers or alphanumeric. When numbers are used, they shall be Arabic; letters shall be Roman (either upper or lower case).

13.4.2 Identification of the protective conductor

The protective conductor shall be readily distinguishable by shape, location, marking, construction or colour. When identification is by colour alone, the bicolour combination GREEN-AND-YELLOW shall be used throughout the length of the conductor. This colour identification is strictly reserved for the protective conductor.

For insulated conductors, the bicolour combination GREEN-AND-YELLOW shall be such that on any 15 mm length one of the colours covers at least 30 % and not more than 70 % of the surface of the conductor, the other colour covering the remainder of the surface.

Where the protective conductor can be easily identified by its shape, location, or construction (for example a braided conductor, uninsulated stranded conductor), or where the insulated conductor is not normally accessible, colour coding throughout its length is not necessary but at least the ends shall be clearly identified by the graphical symbol IEC 60417-5019 (2002-10) or by the bicolour combination GREEN-AND-YELLOW.

NOTE This means, for example, that a protective conductor may be green if it is identified by some additional means, such as by the symbol IEC 60417-5019 (2002-10).

13.4.3 Identification of the neutral conductor by colour

Where a circuit includes a neutral conductor that is identified by colour alone, the colour used for this conductor shall be BLUE. In order to avoid confusion with other colours, it is recommended that an unsaturated blue be used, called here "light blue" (see IEC 60446). Where the selected colour is the sole identification of the neutral conductor, that colour shall not be used for identifying any other conductor where confusion is possible.

NOTE This means, for example, that a neutral conductor may be white if it is identified by some additional means, such as by the symbol N.

Where identification by colour is used, uninsulated conductors used as neutral conductors shall be either coloured by a stripe, 15 mm to 100 mm wide in each compartment or unit and at each accessible location, or coloured throughout their length.

13.4.4 Identification by colour

Where colour-coding is used for identification of conductors it is recommended that the colour be used throughout the length of the conductor either by the colour of the insulation or by colour markers at regular intervals and at the ends or accessible location.

For safety reasons, the colour GREEN or the colour YELLOW should not be used where there is a possibility of confusion with the bicolour combination GREEN-AND-YELLOW (see 13.4.2).

Colour identification using combinations of colours may be used provided there can be no confusion with GREEN-AND-YELLOW and that GREEN or YELLOW is not used except in the bicolour combination GREEN-AND-YELLOW.

White, grey or light blue shall not be used to identify any conductors other than the neutral.

Where colour-coding is used for identification of conductors, it is recommended that they be colour-coded as follows:

- BLACK: a.c. and d.c. circuits supplied with hazardous voltage.

13.4.5 Wiring inside enclosures

13.4.5.1 Protection of wiring

Conductors and cables shall not be subjected to physical stress that can cause damage.

Conductors inside enclosures shall be supported where necessary to keep them in place. Non-metallic ducts shall be permitted only when they are made with a flame-retardant insulating material having a minimum flammability rating of V-0.

NOTE Flammability ratings and tests are given in IEC 60695-11-10.

Wiring that carries hazardous voltage located inside enclosures shall be routed to avoid mechanical damage during maintenance or troubleshooting and shall be retained in position by appropriate means.

Wiring shall be protected from contact with liquids that can be present under reasonably foreseeable single fault conditions, unless the wiring is suitably rated to withstand contact with those liquids.

Wire guides may be used for wire routing. However, these guides shall be constructed so as not to adversely affect the insulation of the wires they secure.

13.4.5.2 Access

It is recommended that electrical equipment mounted inside enclosures be designed and constructed in such a way as to permit access to the wiring from the front of the electrical enclosure (see also 11.2.1). Where that is not practicable and control devices are connected from the rear of the enclosure, access doors or swing out panels shall be provided.

Connections to devices mounted on doors or to other movable parts shall be made using flexible conductors in accordance with 12.5 to allow for the frequent movement of the part. The conductors shall be anchored to the fixed part and to the movable part independently of the electrical connection (see also 8.2.3 and 11.2.1).

13.4.5.3 Wiring that extends beyond the enclosure

Terminal blocks or plug/socket combinations should be used for control wiring that extends beyond the enclosure.

Power cables and cables of measuring circuits may be directly connected to the terminals of the devices for which the connections were intended.

13.5 Wiring outside enclosures

13.5.1 General requirements

The means of introduction of cables or ducts with their individual glands, bushings, etc., into an enclosure shall ensure that the required degree of protection (IP rating) is achieved.

13.5.2 Plug/socket combinations external to electrical enclosures

Where plug/socket combinations are provided external to an electrical enclosure they shall satisfy the following requirements.

a) When installed correctly in accordance with e), plug/socket combinations shall be of such a type as to prevent unintentional contact with live parts at any time, including during insertion or removal of the connectors. The degree of protection shall be at least IPXXB. PELV circuits are excepted from this requirement.
b) Plug/socket combinations intended to be connected or disconnected during load conditions shall have sufficient load-breaking capacity. Where the plug/socket combination is rated at 30 A, or greater, it shall be interlocked with a switching device so that the insertion or removal is possible only when the switching device is in the OFF position.
c) Plug/socket combinations that are rated at more than 16 A shall have a retaining means to prevent unintended or accidental disconnection.
d) If unintended or accidental disconnection of plug/socket combinations can cause a hazardous situation, they shall have a retaining means and shall be clearly marked that they are not intended to be disconnected under load.
e) The component which remains live after disconnection shall have a degree of protection of at least IP2X or IPXXB, or in the case of voltages above 1 000 a.c. or 1 500 d.c., IP2XH or IPXXBH. Plug/socket combinations carrying only PELV circuits are excepted from this requirement.

13.5.3 Cables and conductors external to the electrical enclosure

Cables and conductors external to the electrical enclosure(s) shall be either enclosed in ducts or of a type suitable for installation without ducts.

13.5.4 Ducts

Ducts and their associated fittings shall be suitable for the anticipated physical environment in which they are installed.

13.5.5 Pendant control stations

Flexible conduit or flexible multi-conductor cable shall be used where it is necessary to employ flexible connections to pendant control stations. The weight of the pendant stations shall be supported by means other than the flexible conduit or the flexible multi-conductor cable, except where the conduit or cable is specifically designed for that purpose.

13.5.6 Strain relief

Cables or conductors that exit an electrical enclosure shall be provided with adequate strain relief to ensure a mechanical pull cannot dislodge the terminations. Compliance is verified by conducting a strain relief test in accordance with 18.6.

13.5.7 Protection of flexible cables

Flexible cables shall be protected to avoid insulation breakdown due to normal operating conditions, single fault conditions, or foreseeable misuse. Some of the factors that should be considered are:

a) moving machine parts,
b) brackets or cable guides,
c) abrasion,
d) exposure to liquids and gas,
e) exposure to radiation,
f) temperatures exceeding specifications,
g) bending radius of cables.

13.5.8 Clearance between cables and moving parts

Where cables are subject to movement or are routed close to moving parts, an adequate clearance between cables and moving parts shall be maintained.

NOTE A minimum clearance of 25 mm between the moving parts and the cables is recommended.

13.5.9 Clearance between flexible conduit and moving parts

Where flexible conduit is adjacent to moving parts, the construction and supporting means shall satisfy the following:

a) prevent damage to the flexible conduit under normal operating conditions;
b) prevent damage to the insulation on the wire inside the conduit under single fault conditions;
c) prevent the conduit from coming into contact with moving parts or structures that could cause damage to insulation.

13.5.10 Interconnection of electrical equipment

Conductors that are connected between subsystems at the time of installation should have wire bending space in accordance with Annex C.

It is recommended that the connections between those subsystems be made through terminals forming intermediate test points or plug/socket combinations. Such terminals or plug/socket combinations shall be conveniently placed, adequately protected, and shown on the relevant diagrams.

13.5.11 Dismantling for shipment

Where it is necessary that wiring be disconnected for shipment, terminals or plug/socket combinations shall be provided at the sectional points. Such terminals shall be suitably enclosed and plug/socket combinations shall be protected from the physical environment during transportation and storage.

13.6 Ducts, connection boxes and other boxes

13.6.1 General

The percentage fill in ducts should not exceed 50 % of the interior cross-sectional area of the duct.

NOTE All other limiting factors for conductors and cables should be taken into account. For example, temperature limitations can reduce the number of allowable conductors.

Non-flexible and flexible conduit and fittings shall be suitable for the anticipated conditions of use. Conduits shall be securely held in place.

Fittings shall be compatible with the conduit and appropriate for the application.

Fittings shall be secured by a means that requires a tool to remove.

Conduit bends shall be made in such a manner that the conduit is not damaged and the internal diameter of the conduit is not effectively reduced.

Connection boxes shall provide protection against the intrusion of substances that can damage insulation.

The size of the connection box shall be sufficient to allow dissipation of heat generated during normal operation.

Cable trays that are partially covered are not ducts or cable trunking systems. The cables used in them shall be of a type suitable for installation in cable trays.

13.6.2 Cable trunking systems

Cable trunking systems external to enclosures shall be rigidly supported and clear of all moving parts and be suitably protected for the environment.

Covers shall be shaped to overlap the sides; gaskets shall be permitted. Covers shall be attached to cable trunking systems by suitable means. On horizontal cable trunking systems, the cover shall not be on the bottom unless specifically designed for such installation.

NOTE Requirements for cable trunking and ducting systems for electrical installations are given in IEC 61084.

Where the cable trunking system is furnished in sections, the joints between sections shall fit tightly but need not be gasketed.

The only openings permitted shall be those required for wiring or for drainage and shall be in accordance with the IP rating. Cable trunking systems shall not have open but unused knockouts.

13.6.3 Fabrication equipment compartments and cable trunking systems

The use of compartments or cable trunking systems within fabrication equipment to enclose conductors is permitted provided the compartments or cable trunking systems are entirely enclosed and are isolated from the fittings of piping or reservoirs that contain fluids. Conductors run in enclosed compartments and cable trunking systems shall be so secured and arranged that they are not subject to damage.

13.6.4 Connection boxes and other boxes

Connection boxes and other boxes used for wiring purposes shall be accessible for maintenance. Those boxes shall provide protection against the ingress of solid bodies and liquids, taking into account the external influences under which the electrical equipment is intended to operate (see 11.3).

Those boxes shall not have open but unused knockouts nor any other openings and shall be so constructed as to exclude liquids and solids.

14 Electric motors and associated equipment

14.1 General requirements

This subclause applies to a.c. and d.c. motors rated 240 VA and larger.

Motor drive hardware such as belts and pulleys shall be adequately guarded so that maintenance and repair can be performed without putting personnel at risk of injury, taking into account the possible need for repair and maintenance of equipment in the vicinity.

If required for maintenance or repair, motors and motor drive hardware shall be accessible for lubrication, maintenance, and replacement.

Where the operation of a mechanical brake increases the potential for entrapment or hazardous situations, a method of brake release should be provided.

Where substances that can lead to increased risk of electric shock, fire, or damage to the motor can be present under reasonably foreseeable fault conditions, motors and their terminations shall be protected from ingress of such substances.

The motor and/or its load shall be marked with directional arrows, if incorrect direction of rotation can result in an increased risk.

Motors shall be marked with the manufacturer’s name and part number as well as voltage, current and supply frequency ratings.

EXCEPTION: Voltage, current and supply frequency ratings may be provided in support documentation if it can be traced to the manufacturer’s name and part number on the motor

14.2 Remotely installed motors

Remotely installed motors (motors that are not integrated into the fabrication equipment) shall have a means of disconnecting all unearthed conductors in sight of and within 3 m travel distance from the motor.

14.3 Motor dimensions

As far as is practicable, the dimensions of motors should conform to those given in the IEC 60072 series.

14.4 Motor mounting and compartments

Each motor and its associated couplings, belts, pulleys, or chains, shall be so mounted that they are adequately protected and are accessible when required for inspection, maintenance, adjustment and alignment, lubrication, and replacement. The motor mounting arrangement shall be such that all motor hold-down means can be removed and all terminal boxes are accessible.

Motors shall be so mounted that proper cooling can be achieved.

NOTE 1 Thermal classes are defined in IEC 60034-1.

NOTE 2 Ventilation for heat removal should be direct to the exterior of the fabrication equipment.

15 Accessories and lighting

15.1 Accessories

Where the fabrication equipment is provided with socket-outlets that are intended to be used for accessory equipment (for example hand-held power tools, test equipment), the socket-outlets shall fulfil all of the following requirements:

- socket-outlets accessible without the use of a key or tool shall be protected by a residual current device (RCD) at a level appropriate for personnel protection;
- socket-outlets shall be clearly marked with the voltage and current ratings;
- the continuity of the protective bonding circuit to the socket-outlet shall be ensured except where protection is provided by PELV;
- all unearthed conductors connected to the socket-outlet shall be protected against overcurrent in accordance with the provisions of Clause 7.

15.2 Local lighting of the fabrication equipment

15.2.1 General

Connections to the protective bonding circuit shall be in accordance with 8.2.2.

Switches or receptacles of local lighting shall not be located where liquids or other substances can increase the risk of electric shock.

15.2.2 Supply

The nominal voltage of the local lighting circuit shall not exceed 250 V between conductors. A voltage not exceeding 50 V between conductors is recommended.

Lighting circuits shall be supplied from one of the following sources (see also 7.2.5):

- a dedicated isolating transformer connected to the load side of the supply disconnecting device. Overcurrent protection shall be provided in the secondary circuit;
- a dedicated isolating transformer connected to the line side of the supply disconnecting device. That source shall be permitted for maintenance lighting circuits in control enclosures only. Overcurrent protection shall be provided in the secondary circuit (see also 5.3.5 and 13.1.3);
- a circuit within the fabrication equipment with dedicated overcurrent protection;
- an isolating transformer connected to the line side of the supply disconnecting device, provided with a dedicated primary disconnecting means (see 5.3.5) and secondary overcurrent protection, and mounted within the control enclosure adjacent to the supply disconnecting device (see also 13.1.3);

- an externally supplied lighting circuit (for example factory lighting supply). This shall only be permitted in enclosures, and for the fabrication equipment work light(s) where their total power rating is not more than 3 kW (see also 7.2.9).

EXCEPTION: where fixed lighting is out of reach of persons during normal operations, the provisions of this Subclause do not apply.

15.2.3 Protection

Local lighting circuits shall be protected in accordance with 7.2.5.

15.2.4 Fittings

Adjustable lighting fittings shall be suitable for the physical environment and exposure to liquids or other substances shall not increase the risk of electric shock or fire.

Where adjustable fittings are within reach of personnel during normal operation, the reflector shall be supported by mechanical means other than the lamp holder.

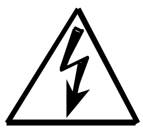
16 Marking, warning signs and reference designations

16.1 General

Warning signs, nameplates, markings, and identification plates shall be of sufficient durability to withstand the physical environment involved.

16.2 Electric shock hazard warning signs

Enclosures that contain hazardous voltages shall be marked with the graphical symbol IEC 60417-5036 (2002-10).



The warning sign shall be plainly visible on the enclosure door or cover.

NOTE 1 Consideration should be given to additional labelling at the location(s) of the electrical hazard.

NOTE 2 Additional requirements for safety labels used in the semiconductor manufacturing industry can be found in SEMI S1.

16.3 Functional identification

Human interface control devices, visual indicators, and displays (particularly those related to safety) shall be clearly and durably identified or marked with regard to their functions either on or adjacent to the item.

16.4 Equipment nameplate

A permanent nameplate should be attached to the main electrical enclosure of the fabrication equipment where it is plainly visible after installation. This nameplate shall include the following information:

a) the manufacturer’s name and address,

b) the equipment name, model, and serial number,

c) supply voltage,

d) number of phases,

e) number of wires,
f) frequency,
g) full-load current,
h) ampere rating of the largest motor or load,
i) short-circuit rating of the electrical equipment connected to each incoming supply,
j) ampere rating of the supply overcurrent protective device, where furnished as part of the electrical equipment, and
k) the electrical diagram number(s) or the number of the index to the electrical diagrams (bill of material).

The full-load current shown on the nameplate shall be not less than the running currents for all motors and other electrical equipment that can be in operation at the same time under normal conditions.

16.5 Reference designations

All enclosures, assemblies, devices, and components shall be plainly identified with the same reference designation as shown in the technical documentation.

Components shall be identified on the mounting surface adjacent to the component, so the component can be identified from the documentation as described in Clause 17, unless engineering documentation provides a layout of the electrical enclosure with component identification.

17 Technical documentation

17.1 General

The information necessary for installation, operation, and maintenance of the electrical equipment shall be supplied in the appropriate forms, for example, drawings, diagrams, charts, tables, instructions. The information provided may vary with the complexity of the electrical equipment. For very simple electrical equipment, the relevant information may be contained in one document, provided that the document shows all the devices of the electrical equipment and enables the connections to the supply network to be made.

NOTE 1 The technical documentation provided with items of electrical equipment can form part of the documentation of the fabrication equipment.

NOTE 2 In some countries the requirement to use specific language(s) is covered by legal requirements.

17.2 Information to be provided

The information provided with the electrical equipment shall include:

a) a list of document(s) provided;
b) a clear, comprehensive description of the electrical equipment, installation and mounting, and the connection to the electrical supply(ies) including connection to the external protective bonding conductor;
c) electrical supply(ies) requirements at the point of connection to the equipment, including tolerances and permitted short term voltage deviations (see 4.3);
d) ambient air temperature range;
e) limitations on altitude of installation;
f) humidity of operating installation;
g) information on other aspects of the physical environment (for example: lighting, vibration, noise levels, atmospheric contaminants) where appropriate;
h) overview (block) diagram(s) where appropriate;

i) circuit diagram(s);

j) information (as applicable) on:

   1) programming, as necessary for use of the electrical equipment;

   2) sequence of operation(s);

   3) frequency of inspection;

   4) frequency and method of functional testing;

   5) guidance on the adjustment, maintenance, troubleshooting and repair, particularly of the protective devices and circuits; and

   6) recommended spare parts list;

   7) list of tools supplied;

   8) where an uninterruptible power supply (UPS) is used its function and wiring shall be clearly described in the manufacturers documentation;

k) a functional description of protective interlock circuits and other safeguards, which includes sufficient detail to explain their operation, calibration and test;

l) a description of the safeguarding and of the means provided where it is necessary to suspend the safeguarding (for example for setting or maintenance), as well as the measures to minimize the risk when the safeguarding is suspended (see 9.1.6);

m) instructions on the procedures for securing the fabrication equipment for safe maintenance, for example, locking off of energy isolation devices (see also 17.8);

n) information on handling, transportation and storage;

o) information regarding load currents, peak starting currents, as applicable;

p) information on the residual risks due to the protection measures adopted, indication of whether any particular training is required and specification of any necessary personal protective equipment;

q) explanation of all symbols used on human interface devices where such symbols are relied on for identification.

17.3 Requirements applicable to all documentation

A table identifying the reference designations (reference key) for the documentation system shall be provided. It is recommended that the document reference designation system be in accordance with IEC 61346 series.

17.4 Installation documents

17.4.1 General

The installation instructions shall give all the information necessary for complete installation and safe start up of the system.

17.4.2 Supply cables

The recommended position, type, and cross-sectional areas of the supply cables to be installed on site shall be clearly indicated.

17.4.3 Overcurrent protection devices

The data necessary for choosing the type, characteristics, rated currents, and setting of the overcurrent protective device(s) for the supply conductors to the electrical equipment shall be stated (see 7.2.2).

17.4.4 Ducts, cable trays, or cable supports

The size, purpose, and location of any ducts that are to be provided by the user shall be detailed.

The size, type, and purpose of ducts, cable trays, or cable supports between subsystems of the fabrication equipment that are to be provided by the user shall be detailed.

17.4.5 Diagrams

Where necessary, the diagram shall indicate where space is required for the removal, troubleshooting or maintenance of the electrical equipment.

NOTE 1 Examples of installation diagrams can be found in IEC 61082-1.

In addition, where it is appropriate an interconnection diagram (a diagram showing the interface connections) or table shall be provided. That diagram or table shall give full information about all external connections.

Where the electrical equipment is intended to be operated from alternative sources of electrical supply (for example different voltages), the interconnection diagram or table shall indicate any adaptations required for the use of each source of supply.

NOTE 2 Examples of interconnection diagrams/tables can be found in IEC 61082-1.

17.5 Overview diagrams and function diagrams

Where it is necessary to facilitate the understanding of the principles of operation, an overview diagram shall be provided. An overview diagram symbolically represents the electrical equipment together with its functional interrelationships without necessarily showing all of the interconnections.

NOTE 1 Examples of overview diagrams can be found in IEC 61082-1.

Function diagrams may be provided as either part of, or in addition to, the overview diagram.

NOTE 2 Examples of function diagrams can be found in IEC 61082-1.

17.6 Circuit diagrams

A circuit diagram(s) shall be provided. This diagram(s) shall show the electrical circuits in the fabrication equipment and its associated electrical equipment and draw attention to the protective interlock circuits and the EMO circuit. Any graphical symbol not shown in IEC 60617 shall be separately shown and described on the diagrams or supporting documents. The symbols and identification of components and devices should be consistent throughout all documents and on the electrical equipment.

Where appropriate, a diagram showing the terminals for interface connections (an interconnection diagram) shall be provided. That diagram may be used in conjunction with the circuit diagram(s) for simplification. The diagram should contain a reference to the detailed circuit diagram of each unit that is intended to be serviced, maintained, or repaired in the field.

NOTE It is common practice that switch symbols are shown on the electromechanical diagrams with all supplies turned off (for example electricity, air, water, lubricant).

Conductors shall be identified in accordance with 13.4.

Circuits shall be shown in such a way as to facilitate the understanding of their function as well as maintenance and fault location. Characteristics relating to the function of the control devices and components which are not evident from their symbolic representation shall be included on the diagrams adjacent to the symbol or referenced to a footnote.

17.7 Operating documentation

The technical documentation shall contain operating instructions detailing proper procedures for start-up and use of the electrical equipment. Particular attention should be given to the safety measures provided.

17.8 Maintenance documentation

17.8.1 General

The technical documentation shall contain instructions detailing proper procedures for adjustment, cleaning, maintenance and preventive inspection, replacement, and repair. Attention should be given to how these procedures can be performed safely. Recommendations on maintenance intervals and records should be part of those instructions. Where methods for the verification of proper operation are provided (for example software testing programs), the use of those methods shall be detailed.

NOTE Maintenance activities for which the user is not authorised by the manufacturer should be identified in the maintenance instructions. The specific maintenance instructions for these activities are not required by this subclause.

17.8.2 Identification of replacement parts

Parts that are intended to be replaced by the user (both planned consumables and all other parts that are reasonably likely to need replacement during the expected life of the equipment) should be identified in the user instructions together with information sufficient for their identification, acquisition and proper replacement.

18 Testing

18.1 General

18.1.1 Test schedule

Verification of conformance to the requirements of this standard includes the following:

a) verification that the electrical equipment complies with its technical documentation;
b) earthing continuity and continuity of the protective bonding circuit test;
c) dielectric test;
d) input current test;
e) temperature test;
f) protective interlock functional test;
g) EMO circuit functional test.

Other tests of this clause are required when applicable.

18.1.2 Test conditions

The tests outlined in this clause are to be performed by skilled or instructed persons who have knowledge of the techniques and the test apparatuses described herein. All test equipment should be appropriately calibrated.

Except where specified in this standard, the electrical equipment shall be tested under the conditions within the manufacturer's operating specifications which are least favourable to passing these tests. The parameters to be varied can include but are not limited to the following:

a) supply voltage,

b) supply frequency,

c) operating mode (e.g., full temperature conditions, motors in operation), and

d) adjustment of thermostats, regulating devices, or similar controls in operator-accessible areas.

The earthing (grounding) continuity tests and leakage current tests prescribed in Subclauses 18.2 and 18.3 shall be performed on fully assembled equipment. These tests are not required individually on unassembled components or sub-assemblies.

Tests may be performed on sub-assemblies independent of the complete fabrication equipment, provided that the tests simulate the least favourable conditions expected for the actual operation of the sub-assemblies when installed in the fabrication equipment.

18.2 Earthing continuity and continuity of the protective bonding circuit test

18.2.1 General

Either of the procedures prescribed in 18.2.3 or 18.2.4 may be performed.

Although extraneous conductive parts, which are not part of the electrical equipment but of the fabrication equipment, are connected to the protective bonding circuits, in testing it is inappropriate in some cases and not preferable in other cases for the electrical equipment to be connected to the extraneous conductive parts.

It is especially important that the extraneous conductive parts are not connected for the leakage test and the earthing continuity tests.

The additional possible parallel return paths that could be realized by the connection of the protective bonding circuit to the extraneous conductive parts could, during an earthing continuity test, mask deficient protective conductor circuits and connections which are necessary for an effective low impedance fault return path.

18.2.2 Test equipment

For procedure 1, a low range ohmmeter with a range to measure 0,10 with an accuracy of ± 1,0 %.

For procedure 2, a low voltage current source capable of 10 A, a current meter to measure 10 A with an accuracy of ± 1 %, and a voltmeter with a range to measure 0,01 V and an accuracy of ± 1 %.

18.2.3 Procedure 1

Disconnect the electrical equipment from the incoming supply. For electrical equipment installed with fixed wiring, disconnect the protective earthing conductor from the protective earthing conductor terminal. Measure the resistance between the protective earthing terminal and each conductive part (handle, monitor, doors, etc.) connected to the protective bonding circuit on the equipment using a low-range ohmmeter. Upon test completion, reconnect the protective earthing conductor to the protective earthing conductor terminal.

18.2.4 Procedure 2

Disconnect the electrical equipment from the incoming electrical supply. For electrical equipment installed with fixed wiring methods, disconnect the protective earthing conductor from the protective earthing conductor terminal. Connect the low voltage current source between the protective earthing conductor terminal and conductive part (handle, monitor, doors, etc.) connected to the protective bonding circuit on the electrical equipment frame or cover. With a current of 10 A injected, measure the voltage drop between each accessible metal part and the protective earthing conductor terminal. Calculate the resistance by dividing the measured voltage by the injected current. Upon test completion, reconnect the protective earthing conductor to the protective earthing conductor terminal.

NOTE Some standards (e.g., IEC 61010-1) specify this test to be performed using a current injection method using more than 10 A.

18.2.5 Acceptable results

The resistance between the protective earthing conductor terminal and each conductive part (handle, monitor, doors, etc.) connected to the protective bonding circuit shall not exceed 0,1 .

18.3 Touch current test for cord and plug connected electrical equipment

18.3.1 Application

This test is only required on cord and plug connected electrical equipment.

EXCEPTION: This test is not required on cord and plug connected equipment that is located in an enclosure within semiconductor fabrication equipment and is not intended to be disconnected during normal operation including maintenance.

18.3.2 Test equipment

True r.m.s. voltmeter with an accuracy of ± 1 %.

Impedance network consisting of a 1 500 Ω resistor shunted by a 0,15 µF capacitor.

18.3.3 Procedure

For equipment connected to the incoming supply with a plug/socket combination (cord-and-plug), ensure that the equipment is isolated (e.g., by placing the equipment on a wooden or other non-conductive surface). Connect the equipment to its rated source of supply with the protective earthing conductor(s) disconnected and operate it at the least favourable conditions specified by the manufacturer. Connect the impedance network between each accessible metal part and the protective earthing conductor of the supply.

NOTE The impedance network may be a separate assembly or incorporated within a touch current measuring instrument.

Measure the voltage drop across the impedance network. Calculate the touch current using the formula:

$$I_{\text{leakage}} = \frac{\text{Voltage}_{\text{measured}}}{1\,500}$$

18.3.4 Acceptable results

The maximum calculated touch current based on the measured voltage shall not exceed 3,5 mA for cord and plug connected equipment.

18.4 Dielectric test

18.4.1 Test equipment

Timer with accuracy of ± 5 s. Dielectric withstand tester with an output of 1 500 V a.c. or 2 121 V d.c. at an accuracy of ± 1 %, means of indicating test potential, as well as an audible or visual indicator of dielectric breakdown, or an automatic-reject feature for any unacceptable unit. In an alternating current test, the test equipment should include a transformer having sinusoidal output. This transformer should have a rating of 500 VA or greater unless it is provided with a voltmeter that directly measures the applied output potential.

18.4.2 Procedure

With the equipment disconnected from its incoming electrical supply, apply a dielectric withstand potential of 1 500 V a.c. or 2 121 V d.c. between energized metal parts of the primary circuit(s) and non-energised metal parts. Surge suppression components and devices, and electronic components that can be damaged may be disconnected from the circuit for this test provided that they have been voltage tested in accordance with their product standard. For this test, the following conditions shall be set:

a) the electrical equipment shall be at its maximum operating temperature;

b) switches shall be placed in the "on" position; and

c) circuits through contactors shall be completed by manually engaging the contacts or bypassing the contactor terminals.

Achieve the test potential gradually, starting from zero and holding at the maximum value for a period of 1 min.

NOTE A neutral conductor, if used in the circuit, is considered to be an energized conductor.

18.4.3 Acceptable results

The electrical equipment does not have a dielectric breakdown.

NOTE Breakdown is often indicated by an abrupt decrease or nonlinear advance of voltage as the voltage is increased. Similarly, a breakdown is often indicated by an abrupt increase in current. Partial discharge (corona) and similar phenomena are disregarded during application of the test voltage.

18.5 Strain relief test

18.5.1 General

This test is intended to verify that for cord-and-plug connected equipment, strain relief is provided to prevent mechanical stress such as a pull or twist being transmitted to terminals, or interior wiring.

Either procedure 1 or procedure 2 may be used to demonstrate compliance to this test.

18.5.2 Test equipment

Timer with accuracy of ± 5 s. A calibrated force gauge to apply a force of 156 N ± 1,56 N. A supporting surface on which to secure the equipment.

18.5.3 Procedure 1

Support the equipment on a surface so it will not move when the force is applied to the cord. Apply a direct pull of 156 N to the equipment supply cord from the least favourable angle. If necessary, use pulleys or other means to adjust the angle of force applied to the strain relief. Apply the force gradually and maintain the applied force for a period of 1 min.

18.5.4 Acceptable results for procedure 1

The supply cord shall not displace to the extent that stress could be applied to the internal connections.

18.5.5 Procedure 2

Support the equipment on a surface so it will not move when the force is applied to the cord. Disconnect the internal connections for the cord. Mark the external portion of the cord with tape where it meets the strain relief. Apply a direct pull of 156 N to the supply cord from the least favourable angle. If necessary, use pulleys or other means to adjust the angle of force applied to the strain relief on the equipment. Apply the force gradually and maintain the applied force for a period of 1 min.

18.5.6 Acceptable results for procedure 2

The tape shall not be displaced.

18.6 Power supply output short circuit test

18.6.1 Test equipment

A connection capable of short-circuiting the output of each power supply.

18.6.2 Procedure

Start with the power supply energised but unloaded. Short circuit each power supply output, one at a time.

EXCEPTION: A power supply that has been evaluated and tested to an appropriate standard in accordance with 4.2 need not be subjected to this test.

18.6.3 Acceptable results

A hazardous condition shall not exist within 8 h of the start of the test or the output short circuit hazard shall be eliminated by activation of a protective circuit or device.

18.7 Protective interlock circuit function test

18.7.1 Procedure

Each protective interlock is activated to perform its safety function by producing or simulating, as appropriate, the conditions under which it is designed to detect a potential unsafe condition.

18.7.2 Acceptable results

The following shall be confirmed:

a) protective interlocks, upon activation, automatically bring the fabrication equipment or relevant part of the fabrication equipment to a safe condition;
b) upon activation of the protective interlocks operator notification is provided;

   EXCEPTION: If a protective interlock triggers the emergency off (EMO) circuit, or otherwise removes power to the user interface, indication of activation is not mandatory.

c) resumption of normal operation of the equipment is prevented until a manual reset of the interlock circuit has been performed.

18.8 Capacitor stored energy discharge test (see 6.2.4)

18.8.1 Test equipment

Timer with accuracy of ± 1 s or better. DC voltmeter with accuracy of ± 1,0 % of the voltage across each capacitor to be tested.

18.8.2 Procedure

Test each capacitor that stores a hazardous energy (20 J or more). Monitor the voltage across the capacitor terminals continuously. Disconnect the electrical equipment from the supply. Record the voltage across the capacitor terminals after 10 s.

18.8.3 Acceptable results

The capacitor is discharged to less than 60 V and 20 J within 10 s of electrical equipment disconnection from the supply.

NOTE The following formula is provided to calculate the energy:

$$J = 1/2\ CV^2$$

where J is the energy in joules;

C is the capacitance in farads;

V is the voltage.

18.9 Temperature test

18.9.1 Test equipment

Timer with accuracy of ± 5 s. A thermometer with a full range of resolution and an accuracy of ± 0,1 °C.

18.9.2 Procedure

The equipment shall be operated at the manufacturer's maximum design load for 8 h or until thermal equilibrium is reached (whichever occurs first). Measure and record the ambient room temperature. Measure and record the temperatures of the various components and devices for comparison with Table 6. Subtract the measured ambient temperature from 40 °C or the maximum ambient temperature specified in the manufacturer's documentation, whichever is greater. Add this difference to each of the measured temperatures. Compare the result with Table 6.

18.9.3 Acceptable results

The results shall not exceed those in Table 6.

Table 6 – Acceptable temperature for parts of the electrical equipment

Parts of the electrical equipment	Temperature limit °C
Knife switch blade and contact jaws	55
Fuse and fuse clip	110
Insulated conductors	See Note 1 below
Field wiring terminals	See Note 1 below
Electrical equipment marked for 60 °C or 60/75 °C supply wires	60
Electrical equipment marked for 75 °C supply wires	75
Buses and connecting straps or bars	125
Capacitors	See Note 2 below
Power switching semiconductors	See Note 3 below
Printed wiring boards	See Note 4 below
Motors and transformers	See Note 5 below

NOTE 1 The temperature as marked on the conductor or otherwise the rated temperature designated by the conductor manufacturer.

NOTE 2 The temperature marked on the capacitor or otherwise the rated temperature designated by the conductor manufacturer.

NOTE 3 The case temperature for the applied power dissipation recommended by the semiconductor manufacturer.

NOTE 4 The operating temperature of the board as specified by the board manufacturer.

NOTE 5 The rated temperature of the motor or transformer as specified by the manufacturer, if provided. When not provided, use appropriate standards such as IEC 61010-1 for guidance.

18.10 Strength of electrical enclosures test; 30 N steady force test

18.10.1 General

This test verifies the protection provided by enclosures against contact with hazardous energized parts.

18.10.2 Test equipment

Force gauge. Test fingers (see Annex D).

18.10.3 Procedure

The enclosure walls and covers are to be subjected to a steady force of 30 N ± 3 N for a period of 5 s applied by means of a straight unjointed test finger to the part, on or within the complete electrical equipment, or on a separate sub-assembly.

18.10.4 Acceptable results

If the straight unjointed test finger penetrates the material or opening, it shall not be possible to touch any hazardous energized parts inside the enclosure with the jointed or unjointed test finger.

18.11 Strength of electrical enclosures test; 250 N steady force test

18.11.1 General

This test verifies the resistance to deflection of electrical enclosure panels.

Electrical equipment within the scope of IEC 60950-1 may instead satisfy the test requirements of 4.2.4 of IEC 60950-1.

18.11.2 Test equipment

Force gauge.

18.11.3 Procedure

The panel is to be subjected to a steady force of 250 N ± 10 N for a period of 5 s, applied to the enclosure of the electrical equipment, by means of a suitable test tool providing contact over a circular plane surface 30 mm in diameter.

18.11.4 Acceptable results

If flexing of the enclosure panel occurs, it shall not cause shorting or reduction of a clearance distance to less than that stipulated between the enclosure and hazardous energized parts inside.

18.12 Finger probe test

18.12.1 General

This test need not be performed on electrical equipment that has satisfied the test requirements of 6.2.1 of IEC 61010-1.

18.12.2 Test equipment

IEC finger probes (see Annex D).

18.12.3 Procedure

The jointed test finger is applied without force in every possible position to all outer surfaces, including the bottom. Any enclosure panels that are not secured by a means that requires a tool to open are opened and the finger probe is applied.

18.12.4 Acceptable results

If the finger probe cannot touch any conductive part that is energized with a hazardous voltage under normal operating conditions, then this is an acceptable result.

18.13 Wire flexing test

This test applies to wiring supplied with hazardous voltage or power that runs from a fixed panel to a swing panel or door and is flexed during opening, that has no additional means of protection beyond basic insulation.

The swing panel or door is opened to its intended fully open position and then closed 500 times. After this procedure is completed a dielectric test is performed in accordance with 18.4. If inspection of the wire after testing indicates no physical damage and it passes the dielectric test as described, then it satisfies this test requirement.

18.14 Insulation resistance tests

When insulation resistance tests are performed, the insulation resistance measured at 500 V d.c. between the power circuit conductors and the protective bonding circuit shall be not less than 1 M . The test may be made on individual sections of the complete electrical installation.

EXCEPTION: for certain parts of electrical equipment, incorporating for example busbars, conductor wire or conductor bar systems or slip-ring assemblies, a lower minimum value is permitted, but that value shall not be less than 50 kΩ.

18.15 EMO functional test

18.15.1 General

A functional test of the EMO system shall be conducted. The following test shall be conducted separately for each EMO button.

18.15.2 Actuation

Actuate the EMO button. After this is done, verify that the device used to disconnect electrical energy during an EMO activation (e.g. contactor, relay) has opened and effectively disconnected electrical power to the system.

18.15.3 EMO button reset

After the verification of disconnection the EMO button shall be reset, and it shall be verified that the device used for disconnecting electrical energy during an EMO activation (e.g. contactor, relay), does not close and re-energize the equipment.

18.15.4 EMO circuit reset

The reset control device shall be activated in order to demonstrate that it closes the device used for disconnecting electrical energy during an EMO activation and makes electrical energy available to the equipment.

18.16 Input current test

18.16.1 Test equipment

True r.m.s. current measuring equipment, with accuracy of ± 3,0 %.

18.16.2 Procedure

Measure the input current to the electrical equipment under the maximum normal operating load.

18.16.3 Acceptable results

The measured current shall not exceed 110 % of the rated full load current value specified on the equipment nameplate.

18.17 Other safety circuit tests

Functional tests shall be performed on safety circuits that are not protective interlock circuits or EMO to ensure that they perform their intended function.

18.18 Motor temperature test

18.18.1 Application

This test is not intended to be applied to motors that are:

a) a motor/controller combination in accordance with 4.2, or
b) a motor provided with an overload protection device in accordance with 4.2 and 7.3.2, or
c) a motor having inherent protection (e.g. thermal protection or impedance protection) in accordance with 4.2.

18.18.2 Test equipment

A timer or clock with accuracy of ± 1 min.

18.18.3 Procedure

The motor shall either be stopped, or prevented from starting, while energized. The supply to the motor shall be maintained until either:

a) in the case of manually reset overload or overtemperature protection, the protection function operates, or
b) in the case of automatic reset overload or overtemperature protection, 8 h has elapsed, or
c) when no overload or overtemperature protection is provided, 8 h has elapsed.

A dielectric test in accordance with 18.4 shall then be performed.

18.18.4 Acceptable results

A dielectric test is performed. No voltage breakdown shall be detected, and there shall be no visible sign of damage or overheating.

Annex A
(normative)

Basic protection (protection against indirect contact) in TN-systems

(Derived from IEC 60364-4-41:2005, and IEC 60364-6-61:2001)

A.1 Disconnecting times

A.1.1 General

Basic protection (protection against indirect contact) shall be provided by an overcurrent protective device that automatically disconnects the supply to the circuit or electrical equipment in the event of a fault between a live part and an exposed conductive part or an extraneous conductive part or a protective conductor in the fabrication equipment, within a sufficiently short disconnecting time. A disconnecting time not exceeding 5 s is considered sufficiently short for fabrication equipment that is not hand-held equipment or portable equipment.

EXCEPTION: Where this disconnecting time cannot be assured, measures shall be implemented (for example supplementary protective bonding) to prevent a prospective touch voltage from exceeding 50 V a.c. or 120 V ripple-free d.c. between simultaneously accessible conductive parts. See Clause A.3.

A.1.2 Circuits which supply Class 1 hand-held equipment and portable equipment

For circuits which supply, through socket-outlets or directly without socket-outlets, Class 1 hand-held equipment or portable equipment (for example socket-outlets on fabrication equipment for accessory equipment, see 15.1), Table A.1 specifies the maximum disconnecting times that are considered sufficiently short.

Table A.1 – Maximum disconnecting times for TN systems

U_o [a] V	Disconnecting time s
120	0,8
230	0,4
277	0,4
400	0,2
>400	0,1

NOTE 1 For voltages which are within the tolerance band stated in IEC 60038, the disconnecting time appropriate to the nominal voltage applies.

NOTE 2 For intermediate values of voltage, the next higher value in the above table is to be used.

[a] U_o is the nominal a.c. r.m.s. voltage to earth.

A.2 Conditions for protection by automatic disconnection of the supply by overcurrent protective devices

The characteristics of overcurrent protective devices and the circuit impedances shall be such that, if a fault of negligible impedance occurs anywhere in the electrical equipment between a phase conductor and a protective conductor or exposed conductive part, automatic disconnection of the supply will occur within the specified time (i.e. 5 s or ≤ values in accordance with Table A.1). The following condition fulfils this requirement:

$$Z_{\mathbf{s}} \times I_{\mathbf{a}} \leq U_{\mathbf{0}}$$

where

Z_s is the impedance of the fault loop comprising the source, the live conductor up to the point of the fault and the protective conductor between the point of the fault and the source;

I_a is the current causing the automatic operation of the disconnecting protective device within the specified time;

U_o is the nominal a.c. voltage to earth.

The increase of the resistance of the conductors with the increase of temperature due to the fault current shall be taken into account (see A.4.3).

NOTE Information for calculating short circuit currents can be found in, for example, the IEC 60909 series or from suppliers of short-circuit protective devices.

A.3 Condition for protection by reducing the touch voltage below 50 V

Where the requirements of Clause A.2 cannot be ensured and supplementary bonding is selected as the means of ensuring protection against hazardous touch voltages, the condition for this protection is that the touch voltage has been reduced to below 50 V and it is achieved when the impedance of the protective circuit (Z_{PE}) does not exceed:

$$Z_{\mathbf{PE}} \leq \frac{50}{U_{\mathbf{0}}} \times Z_{\mathbf{S}}$$

where Z_{PE} is the impedance of the protective bonding circuit measured between anywhere in the fabrication equipment and the PE terminal at the supply of the fabrication equipment (see 5.2 and Figure 1) or between simultaneously accessible exposed conductive parts and/or extraneous conductive parts.

Confirmation of this condition can be achieved by using the method of procedure 1 of 18.2.2 to measure the resistance R_{PE}. The condition for protection is achieved when the measured value of R_{PE} does not exceed:

$$R_{\mathbf{PE}} \quad \frac{50}{I_{\mathbf{a(5s)}}}$$

where

$I_{a(5s)}$ is the 5 s operating current of the protective device;

R_{PE} is the resistance of the protective bonding circuit between the PE terminal (see 5.2 and Figure 1) and any point on the protective bonding circuit of the fabrication equipment, or between simultaneously accessible exposed conductive parts and/or extraneous conductive parts.

NOTE 1 Supplementary protective bonding is considered as an addition to protection against indirect contact.

NOTE 2 Supplementary protective bonding may involve the entire installation, a part of the installation, an item of apparatus, or a location.

A.4 Verification of conditions for protection by automatic disconnection of the supply

A.4.1 General

The effectiveness of the measures for fault protection (protection against indirect contact) by automatic disconnection of supply in accordance with Clause A.2 is verified as follows:

– verification of the characteristics of the associated protective device by visual inspection of the nominal current setting for circuit-breakers and the current rating for fuses, and
– measurement of the fault loop impedance (Z_s).

EXCEPTION: Where the calculations of the fault loop impedance or of the resistance of the protective conductors are available and when the arrangement of the installations permits the verification of the length and cross-sectional area of the conductors, verification of the continuity of the protective conductors may replace the measurement.

A.4.2 Measurement of the fault loop impedance

Measurement of the fault loop impedance shall be performed using measuring equipment that complies with IEC 61557-3. The information about the accuracy of the measuring results, and the procedures to be followed given in the documentation of the measuring equipment shall be considered.

Measurement shall be performed when the fabrication equipment is connected to a supply having the same frequency as the nominal frequency of the supply at the intended installation.

NOTE Figure A.1 illustrates a typical arrangement for measuring the fault loop impedance on a machine. If it is not practicable for the motor to be connected during the test, the two phase conductors not used in the test can be opened, for example, by removing fuses.

The measured value of the fault loop impedance shall comply with Clause A.2.

A.4.3 Consideration of the difference between the measured value of resistance of the conductors and the actual value under fault conditions

NOTE As the measurements are made at ambient temperature, with low currents, it is necessary to take into account the increase of resistance of the conductors with the increase of temperature under fault conditions, to verify the compliance of the measured value of the fault loop impedance with the requirements of Clause A.2.

The increase of resistance of the conductors with the increase of temperature due to the fault current is taken into account in the following equation:

$$Z_{s\,(m)} \quad \frac{2}{3} \times \frac{U_0}{I_a}$$

where Z_s(m) is the measured value of Z_s.

Where the measured value of the fault loop impedance exceeds $2U$n/$3I$a a more precise assessment can be made in accordance with the procedure described in E.612.6.3 of IEC 60364-6.

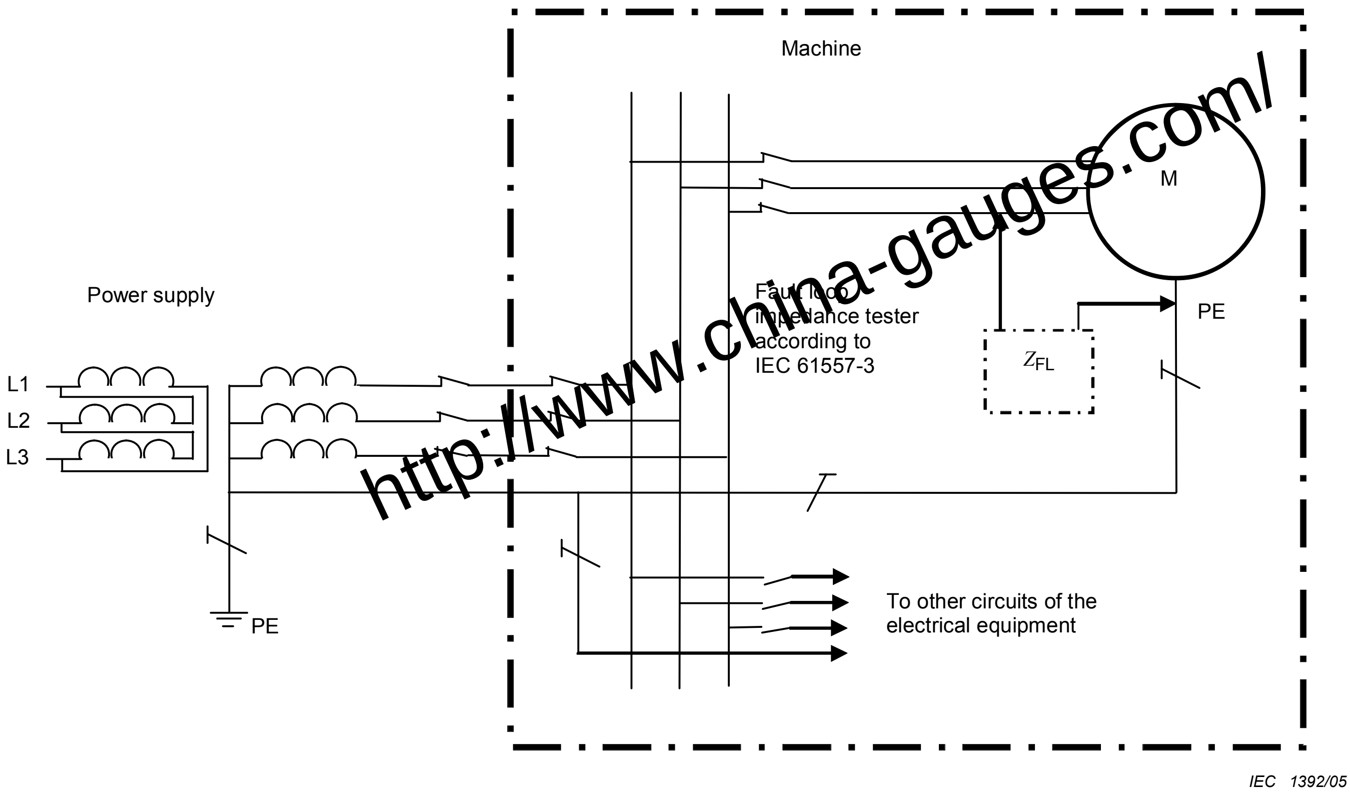


Figure A.1 – Typical arrangement for fault loop impedance measurement

Annex B
(normative)

Protection against indirect contact in TT-systems
(Derived from IEC 60364-4-41:2005 and IEC 60364-6:2006)

B.1 Requirements for TT systems

B.1.1 Connection to earth

All exposed-conductive-parts and all extraneous conductive parts likely to be touched shall be bonded to the protective conductor or directly to the PE terminal. The PE terminal shall be connected to one or more earthing electrodes as necessary to obtain a sufficiently low earth electrode resistance. Where a separate functional earthing circuit is provided for the common connection of sensitive equipment, the functional earth terminal shall be connected to the earth electrode(s). The neutral point or the mid-point of the power supply system shall be earthed. If a neutral point or mid-point is not available or not accessible, a line conductor shall be earthed.

B.1.2 Fault protection (protection against indirect contact) for TT systems

B.1.2.1 General

Generally in TT systems, RCDs shall be used for fault protection. Alternatively, over-current protective devices may be used for fault protection provided a suitably low value of Zs is permanently and reliably assured.

B.1.2.2 Protection by residual current protective device (RCD)

Where a residual current protective device (RCD) is used for fault protection, the following conditions shall be fulfilled:

a) the disconnection time as required by Table B.1,

EXCEPTION: a disconnection time not exceeding 1s is permitted for distribution circuits and for circuits not covered by Table B.1, and

b) $R_A \times I_{\Delta n} \leq 50$ V

where:

R_A is the sum of the resistance in Ω of the earth electrode and the protective conductor for the exposed conductive-parts,

$I_{\Delta n}$ is the rated residual operating current of the RCD.

NOTE 1 Fault protection is provided in this case also if the fault impedance is not negligible.

NOTE 2 Where discrimination between RCDs is necessary see 535.3 of IEC 60364-5-53.

NOTE 3 Where R_A is not known, it may be replaced by Z_S.

NOTE 4 The disconnection times in accordance with Table B.1 relate to prospective residual fault currents significantly higher than the rated residual operating current of the RCD (typically 5 $I_{\Delta n}$).

NOTE 5 in Japan, the permissible maximum value of R_A is regulated (i.e. Uo > 300 V, R_A is less than 10).

B.1.2.3 Protection by an over-current protection device

Where an over-current protective device is used the following condition shall be fulfilled:

$$Z_s \times I_a \leq U_o$$

where:

Z_s is the impedance in Ω of the fault loop comprising:

- the source,
- the line conductor up to the point of the fault,
- the protective conductor of the exposed-conductive-parts,
- the earthing conductor,
- the earth electrode of the installation and the earth electrode of the source;

I_a is the current in amperes causing the automatic operation of the disconnecting device within the time specified in Table B.1.

EXCEPTION: a disconnection time is not exceeding 1s is permitted for distribution circuits and for circuits not covered by Table B.1;

U_o is the nominal a.c. or d.c. line to earth voltage.

Table B.1 – Maximum disconnecting times

System	50 V < U_o ≤ 120 V s		120 V < U_o ≤ 230 V s		230 V < U_o ≤ 400 V s		U_o > 400 V s	
	a.c.	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.	d.c.
TN	0,8	Note	0,4	5	0,2	0,4	0,1	0,1
TT	0,3	Note	0,2	0,4	0,07	0,2	0,04	0,1
Where in TT systems the disconnection is achieved by an overcurrent protective device and the protective equipotential bonding is connected to all extraneous-conductive-parts within the fabrication equipment, the maximum disconnection times applicable to TN systems may be used. U_o is the nominal a.c. or d.c. line to earth voltage.								
NOTE Disconnection can be required for reasons other than protection against electric shock.								

B.1.3 Verification of protection by automatic supply disconnection using a residual current protective device

Protection against indirect contact in a TT system by automatic supply disconnection using a residual current protective device shall be verified by the following test, inspection and measurement. Inspection of the rated residual current for tripping, and the disconnecting time of the residual current protective device, verification that the residual current protective device has been tested in accordance with a relevant IEC standard, and inspection of the connections to the residual current protective device and protective bonding circuit, and measurement of the fault loop impedance of the protective bonding circuit connected to the exposed conductive parts of the semiconductor fabrication equipment. The earth resistance shall be less than 100 .

NOTE For the verification of performance of a residual current protective device and measurement of earth fault loop impedance, see IEC 60364-6.

Annex C
(normative)

Conductor ampacity, and creepage and clearance distances

C.1 Information for the use of Tables C.1 through C.6

Conductor sizes shall be selected so that the ampacity ratings in Tables C.1 through C.6 are not exceeded. The ampacity ratings are given for copper conductors operating at 0 V to 2 000 V.

In application, a conductor's ampacity is limited to its ampacity at the conductor temperature marked on the device to be connected. See 13.1.6.

The 90 ˚C and 105 ˚C ampacity columns are provided to allow bundled conductors to operate hotter than those with 60 ˚C or 75 ˚C ratings, and, thereby, when derated, to have more usable ampacity. The derating Tables, C.4 through C.7 reflect the application limitations of the conductors.

Devices are normally rated for conductor temperatures of 60 ˚C or 75 ˚C.

Table C.1 – Conductor ampacity for AWG 30 to 4 conductors, ambient temperature 30 ˚C

Wire size		Cross-sectional area	0 % derated 1 – 3 current-carrying conductors				Single wire bending space		Protective conductor wire size		Protective conductor cross-sectional area
			Amperes per conductor insulation rating								
Metric	AWG	mm^2	60 ºC	75 ºC	90 ºC	105 ºC	mm	Inches	Metric	AWG	mm^2
	30	0,050	-	0,5	0,8	1	6,4	0,25		30	0,050
	28	0,079	-	0,8	1	2	6,4	0,25		28	0,079
	26	0,128	-	1	2	3	6,4	0,25		26	0,126
	24	0,201	2	2	3	4	6,4	0,25		24	0,201
	22	0,324	3	3	5	7	13	0,5		22	0,318
0,50		0,500	5	5	9	11	13	0,5	0,50		0,500
	20	0,519	5	5	9	11	13	0,5		20	0,509
0,75		0,75	6	6	12	16	13	0,5	0,75		0,75
	18	0,823	7	7	14	18	13	0,5		18	0,823
1,00		1,0	8	8	15	19	19	0,75	1,00		1,0
	16	1,31	10	10	18	22	20	0,75		16	1,31
1,50		1,5	11	11	20	24	19	0,75	1,50		1,5
	14	2,08	15	15	25	30	20	0,75		14	2,08
2,50		2,5	17	17	27	32	25	1,0	2,50		2,5
	12	3,31	20	20	30	35	26	1,0		12	3,31
4,00		4,0	24	24	34	39	25	1,0	4,00		4,0
	10	5,26	30	30	40	45	26	1,0		10	5,26
6,00		6,0	32	35	44	49	38	1,5	6,00		6,0
	8	8,37	40	50	55	60	39	1,5		10	5,26
10,00		10,0	45	55	62	68	51	2	6,00		6,0
	6	13,30	55	65	75	85	51	2		10	5,26
16,00		16,0	60	72	82	92	76	3	10,00		10,0
	4	21,15	70	85	95	105	76	3		8	8,37

Table C.2 – Conductor ampacity, for 25 mm² to 600 kcmil conductors, ambient temperature 30 ˚C

Wire size		Cross-sectional area	0 % derated 1 – 3 current carrying conductors Amps per conductor insulation rating				Single wire bending space		Protective conductor wire size		Protective conductor cross-sectional area
Metric	AWG	mm²	60 ºC	75 ºC	90 ºC	105 ºC	mm	Inches	Metric	AWG	mm²
25,00		25,0	80	95	105	115	76	3	10,00		10,00
	3	26,67	85	100	110	120	76	3		8	8,37
	2	33,62	95	115	130	145	89	3,5		6	13,30
35,00		35,0	97	117	133	149	115	4,5	16,00		16,00
	1	42,41	110	130	150	170	115	4,5		6	13,30
50,00		50,0	120	144	164	180	140	5,5	16,00		16,00
	1/0	53,49	125	150	170	185	140	5,5		6	13,30
	2/0	67,43	145	175	195	205	152,4	6		6	13,30
70,00		70,0	148	179	199	210	165	6,5	16,00		16,00
	3/0	85,01	165	200	225	240	166	6,5		6	13,30
95,0		95,0	179	214	241	260	178	7	16,00		16,00
	4/0	107,2	195	230	260	285	178	7		4	21,15
120,0		120,0	208	246	280	308	216	8,5	25,00		25,00
	(250)	126,7	215	255	290	320	216	8,5		4	21,15
150,0		150,0	238	282	317	347	254	10	25,00		25,00
	(300)	152,0	240	285	320	350	254	10		4	21,15
	(350)	177,4	260	310	350	385	305	12		3	26,67
185,0		185,0	266	317	359	395	305	12	35,00		35,00
	(400)	202,7	280	335	380	420	331	13		3	26,67
240,0		240,0	309	367	416	456	331	13	35,00		35,00
	(500)	253,4	320	380	430	470	356	14		3	26,67
300,0		300,0	352	416	471	516	381	15	35,00		35,00
	(600)	304,0	355	420	475	520	381	15		2	33,62

Table C.3 – Derated ampacity (based on Table C.1 and Table C.2) for conductors 0,050 mm^2 to 4,00 mm^2

Derating factor for number of current carrying conductors in a raceway, wiring harness, or cable.

Number of current carrying conductors	Percentage of values in Tables C.1 and C.2
1-3	100
4-6	80
7-9	70
10-20	50
21-30	45
31-40	40
41 and above	35

C.2 Ambient temperature correction factors

Ambient temperature correction factors for Tables C.1 through C.3 are given in Table C.4.

Table C.4 – Ambient temperature correction factors

Ambient temperature °C	60 °C Insulation	75 °C Insulation	90 °C /105 °C Insulation
21–25	1,08	1,05	1,04
26–30	1,00	1,00	1,00
31–35	0,91	0,94	0,96
36–40	0,82	0,88	0,91
41–45	0,71	0,82	0,87
46–50	0,58	0,75	0,82
51–55	0,41	0,67	0,76
56–60	-	0,58	0,71
61–70	-	0,33	0,58
71–80	-	-	0,41

C.3 Non-insulated bus bar sizes

Non-insulated bus bars shall be sized in accordance with Table C.5.

Table C.5 – Non-insulated bus bar sizes

NOTE Creepage and clearance distances between non-insulated bus-bars are specified in Clause C.4.

Thickness	Thickness	Width	Width	Area	Area	Ampacity
mm	**Inches**	**mm**	**Inches**	**mm²**	**Inches²**	**A**
1,59	0,063	12,7	0,50	20,0	0,031	31
		19,1	0,75	30,3	0,047	47
		25,4	1,00	40,6	0,063	63
		38,1	1,50	60,6	0,094	94
		50,8	2,00	80,6	0,125	125
		76,2	3,00	121,3	0,188	188
3,18	0,125	12,7	0,50	40,6	0,063	63
		19,1	0,75	60,6	0,094	94
		25,4	1,00	80,6	0,125	125
		38,1	1,50	121,3	0,188	188
		50,8	2,00	161,3	0,250	250
		63,5	2,50	201,9	0,313	313
		76,2	3,00	241,9	0,375	375
		101,6	4,00	322,6	0,500	500
6,35	0,250	12,7	0,50	80,6	0,125	125
		19,1	0,75	121,3	0,188	188
		25,4	1,00	161,3	0,250	250
		38,1	1,50	241,9	0,375	375
		50,8	2,00	322,6	0,500	500
		63,5	2,50	403,2	0,625	625
		76,2	3,00	483,9	0,750	750
		88,9	3,50	564,5	0,875	875
		101,6	4,00	645,2	1,00	1 000
		127,0	5,00	806,5	1,25	1 250
		152,4	6,00	967,7	1,50	1 500
9,53	0,375	12,7	0,50	121,3	0,188	188
		19,1	0,75	181,3	0,281	281
		25,4	1,00	241,9	0,375	375
		38,1	1,50	363,2	0,563	563
		50,8	2,00	483,9	0,750	750
		63,5	2,50	605,2	0,938	938
		76,2	3,00	725,8	1,125	1 125
		88,9	3,50	847,1	1,313	1 313
		101,6	4,00	967,7	1,500	1 500
12,7	0,500	19,1	0,75	241,9	0,375	375
		25,4	1,00	322,6	0,500	500
		38,1	1,50	483,9	0,750	750
		50,8	2,00	645,2	1,00	1 000
		76,2	3,00	967,7	1,50	1 500
		101,6	4,00	1 290,3	2,00	2 000

C.4 Creepage and clearance distances

Creepage and clearance distances shall be in accordance with Tables C.6 or C.7, as appropriate.

When it is necessary to test using d.c. voltage, increase specified test voltage by 1,42.

Table C.6 – Creepage and clearance in Class 1 000 or less cleanroom

		Basic/supplementary mm			Double/reinforced mm		
Installation category	**Working voltage**	**Clearance**	**Creepage**	**Test voltage, V r.m.s.**	**Clearance**	**Creepage**	**Test voltage, V r.m.s.**
Category 1	50	0,1	0,18	230	0,10	0,35	400
	100	0,1	0,25	350	0,12	0,50	510
	150	0,1	0,30	490	0,40	0,60	740
	300	0,5	0,70	820	1,60	1,60	1 400
	600	1,5	1,70	1 350	3,30	3,40	2 300
	1 000	3,0	3,20	2 200	6,50	6,50	3 700
Category 2	50	0,1	0,18	350	0,12	0,35	510
	100	0,1	0,25	490	0,40	0,50	740
	150	0,5	0,50	820	1,60	1,60	1 400
	300	1,5	1,50	1 350	3,30	3,30	2 300
	600	3,0	3,00	2 200	6,50	6,50	3 700
	1 000	5,5	5,50	3 250	11,50	11,50	5 550
Category 3	50	0,1	0,18	490	0,4	0,4	740
	100	0,5	0,50	820	1,6	1,6	1 400
	150	1,5	1,50	1 350	3,3	3,3	2 300
	300	3,0	3,00	2 200	6,5	6,5	3 700
	600	5,5	5,50	3 250	11,5	11,5	5 550
	1 000	8,0	8,00	4 350	16,0	16,0	7 400

NOTE 1 Specified creepage distances less than 0,70 mm may be reduced on uncoated printed wiring boards according to Table C.8.2.

NOTE 2 Cleanroom Class 1 000 or less is pollution degree 1, however the pollution degree in a particular area in a given piece of equipment can exceed pollution degree 1, even if the equipment is installed in a cleanroom class 1 000 or less.

Table C.7 – Printed wiring board (PWB) creepage distances

<table>
<tr><th rowspan="3">Equipment creepage distance
mm</th><th colspan="4">PWB creepage distance</th></tr>
<tr><th>Basic or supple-mentary insulation</th><th colspan="3">Double or reinforced insulation</th></tr>
<tr><th></th><th>Installation category 1</th><th>Installation category 2</th><th>Installation category 3</th></tr>
<tr><td>0,18</td><td>0,1</td><td colspan="2" rowspan="3">No reduction</td><td rowspan="6">No reduction</td></tr>
<tr><td>0,25</td><td>0,1</td></tr>
<tr><td>0,30</td><td>0,2</td></tr>
<tr><td>0,35</td><td></td><td>0,10</td><td>0,12</td></tr>
<tr><td>0,50</td><td>0,5</td><td>0,20</td><td>0,40</td></tr>
<tr><td>0,60</td><td></td><td>0,45</td><td></td></tr>
</table>

Table C.8 – Creepage and clearance in greater than Class 1 000 cleanroom

		Basic or supplementary insulation						Double or reinforced insulation					
			Creepage distance						Creepage distance				
Installation category	Working voltage	Clearance distance	CTI > 600	CTI > 400	CTI > 100	Printed Wiring Board CTI > 175	Test voltage, r.m.s.	Clearance distance	CTI > 600	CTI > 400	CTI > 100	Printed wiring board CTI > 175	Test voltage, r.m.s.
Category 1	50	0,2	0,6	0,85	1,2	0,20	230	0,2	1,2	1,7	2,4	0,4	400
	100	0,2	0,7	1,00	1,4	0,20	350	0,2	1,4	2,0	2,8	0,4	510
	150	0,2	0,8	1,10	1,6	0,35	490	0,4	1,6	2,2	3,2	0,7	740
	300	0,5	1,5	2,10	3,0	1,40	820	1,6	3,0	4,2	6,0	2,8	1 400
	600	1,5	3,0	4,30	6,0	3,00	1 350	3,3	6,0	8,5	12,0	6,0	2 300
	1 000	3,0	5,0	7,00	7,0	5,00	2 200	6,5	10,0	14,0	20,0	10,0	3 700
Category 2	50	0,2	0,6	0,85	1,2	0,2	350	0,2	1,2	1,7	2,4	0,4	510
	100	0,2	0,7	1,00	1,4	0,2	490	0,2	1,4	2,0	2,8	0,4	740
	150	0,5	0,8	1,10	1,6	0,5	820	1,6	1,6	2,2	3,2	1,6	1950
	300	1,5	1,5	2,10	3,0	1,5	1 350	3,3	3,3	4,2	6,0	3,3	3 250
	600	3,0	3,0	4,30	6,0	3,0	2 200	6,5	6,5	8,5	12,0	6,5	5 250
	1 000	5,5	5,5	7,00	10,0	5,5	3 250	11,5	11,5	14,0	24,0	11,5	7 850
Category 3	50	0,2	0,6	0,85	1,2	0,2	490	0,4	1,2	1,7	2,4	0,4	740
	100	0,5	0,7	1,00	1,4	0,5	820	1,6	1,6	2,0	2,8	1,6	1 950
	150	1,5	1,5	1,50	1,6	1,5	1 350	3,3	3,3	3,3	3,3	3,3	3 250
	300	3,0	3,0	3,00	3,0	3,0	2 200	6,5	6,5	6,5	6,5	6,5	5 250
	600	5,5	5,5	5,50	6,0	5,5	3 250	11,5	11,5	11,5	12,0	11,5	7 850
	1 000	8,0	8,0	8,00	10,0	8,0	4 350	16,0	16,0	16,0	20,0	16,0	10 450

NOTE Cleanroom Class greater than 1 000 is pollution degree 2, however the pollution degree in a particular area in a given piece of equipment can exceed pollution degree 2, even if the equipment is installed in a cleanroom greater than 1 000.

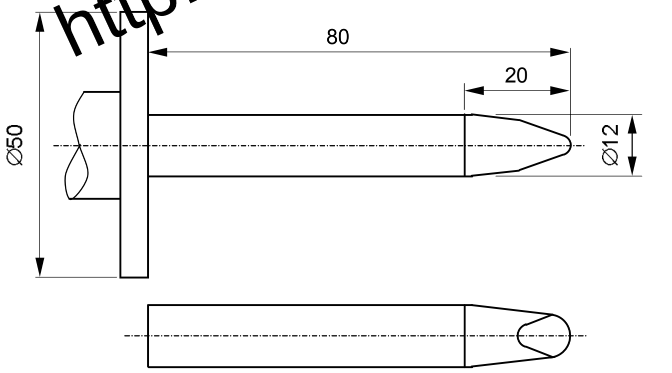
Annex D
(normative)

Standard test fingers

The standard test fingers to be used for the tests of 18.10 and 18.12 are detailed in Figure D.1 and D.2.

NOTE 1 Derived from IEC 61010-1.

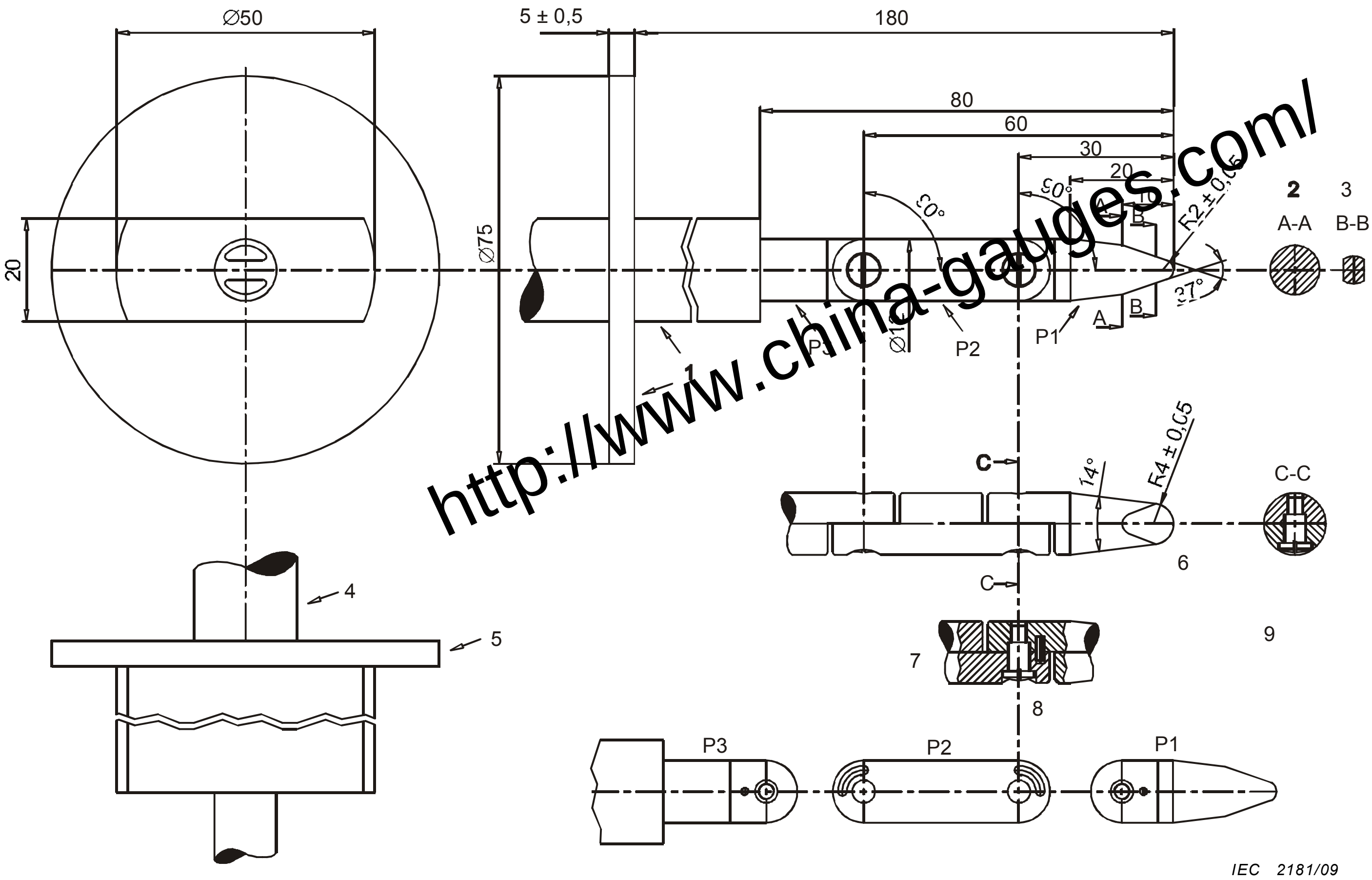
Dimensions in millimetres



For tolerances and dimensions of the fingertip, see Figure D.2.

NOTE 2 This test finger is identical to test probe 11 from IEC 61032.

Figure D.1 – Rigid test finger



Key

1 insulating material
2 section AA
3 section BB
4 handle
5 stop plate
6 spherical
7 detail x (example)
8 side view
9 chamfer all edges

Dimensions in millimetres

Tolerances on dimensions without specific tolerance:

a) on angles: $^{0}_{-10'}$

b) on linear dimensions: up to 25 mm $^{0}_{-0,05}$ mm

over 25 mm + 0,2 mm

Material of finger: heat-treated steel, etc.

Both joints of this finger can be bent through an angle of $(90\ ^{+10}_{0})°$ but in the same direction only.

Using the pin and groove solution is only one of the possible approaches in order to limit the bending angle to 90°. For this reason dimensions and tolerances of these details are not given in the drawing. The actual design shall ensure a $(90\ ^{+10}_{0})°$ bending angle.

NOTE This test finger is identical to test probe B from IEC 61032.

Figure D.2 – Jointed test finger

Annex E
(informative)

Types of system earthing

(Derived from IEC 60364-1: 2005)

E.1 Types of system earthing

E.1.1 General

The following types of system earthing are taken into account in this standard.

NOTE 1 Figures E.1 to E.13 show examples of commonly used three-phase systems. Figures E.14 to E.18 show examples of commonly used d.c. systems.

NOTE 2 The dotted lines indicate the parts of the system that are not covered by the scope of the standard, whereas the solid lines indicate the part that is covered by the standard.

NOTE 3 For private systems, the source and/or the distribution system may be considered as part of the installation within the meaning of this standard. For this case, the figures may be completely shown in solid lines.

NOTE 4 The codes used have the following meanings:

First letter – Relationship of the power system to earth:

T = direct connection of one point to earth;

I = all live parts isolated from earth, or one point connected to earth through a high impedance.

Second letter – Relationship of the exposed-conductive-parts of the installation to earth:

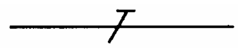
T = direct electrical connection of exposed-conductive-parts to earth, independently of the earthing of any point of the power system;

N = direct electrical connection of the exposed-conductive-parts to the earthed point of the power system (in a.c. systems, the earthed point of the power system is normally the neutral point or, if a neutral point is not available, a line conductor).

Subsequent letter(s) (if any) – Arrangement of neutral and protective conductors:

S = protective function provided by a conductor separate from the neutral conductor or from the earthed line (or, in a.c. systems, earthed phase) conductor.

C = neutral and protective functions combined in a single conductor (PEN conductor).

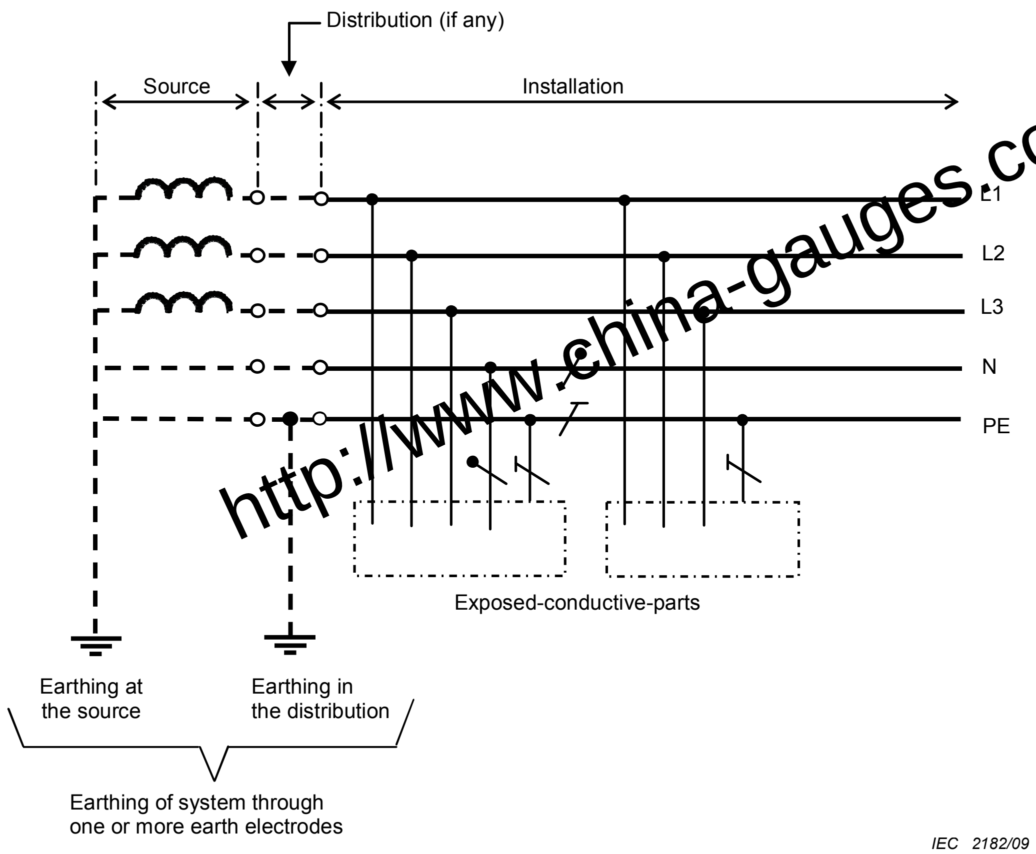
Explanation of symbols for Figures E.1 to E.18 according to IEC 60617	
	Neutral conductor (N); mid-point conductor (M)
	Protective conductor (PE)
	Combined protective and neutral conductor (PEN)

E.1.2 TN systems

E.1.2.1 Single-source systems

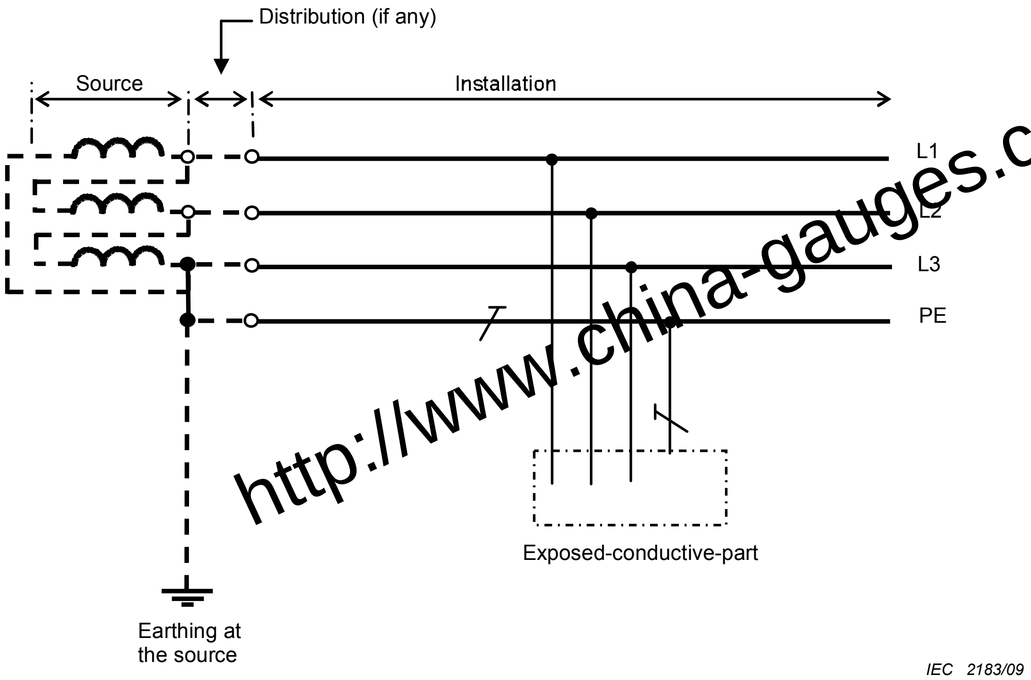
TN power systems have one point directly earthed at the source, the exposed-conductive-parts of the installation being connected to that point by protective conductors. Three types of TN system are considered according to the arrangement of neutral and protective conductors, as follows:

– TN-S system in which, throughout the system, a separate protective conductor is used (see Figures E.1, E.2 and E.3).



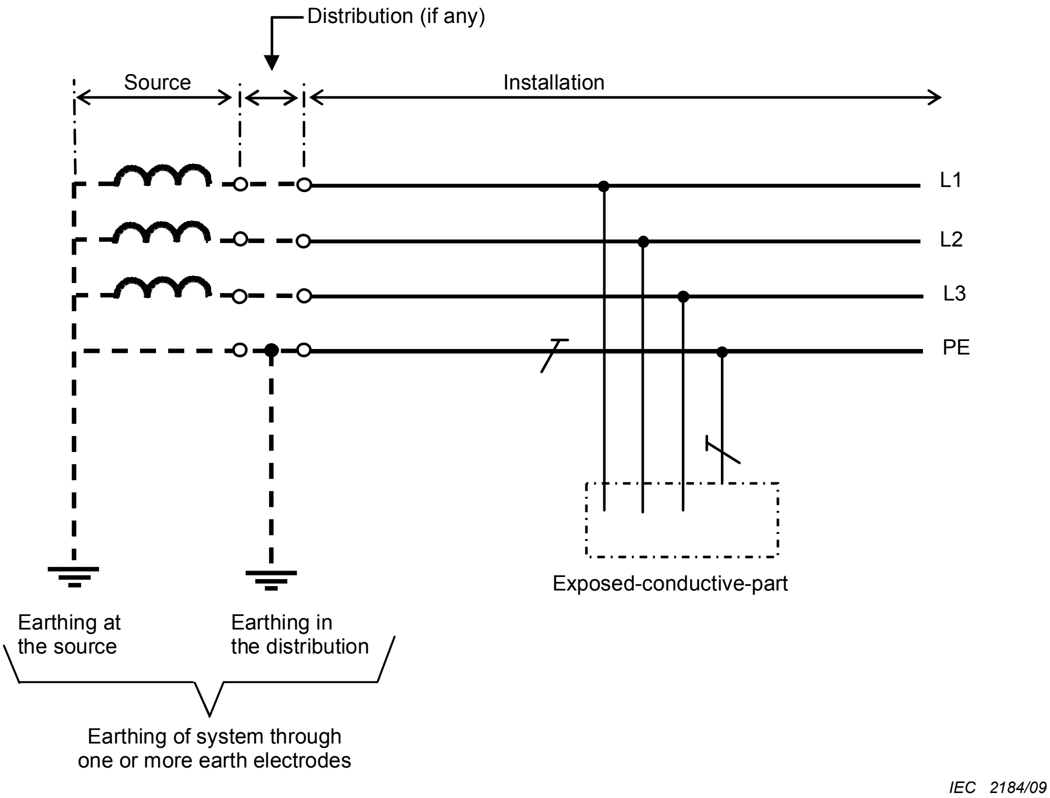
NOTE Additional earthing of the PE in the installation may be provided.

Figure E.1 – TN-S system with separate neutral conductor and protective conductor throughout the system



NOTE Additional earthing of the PE in the distribution and in the installation may be provided.

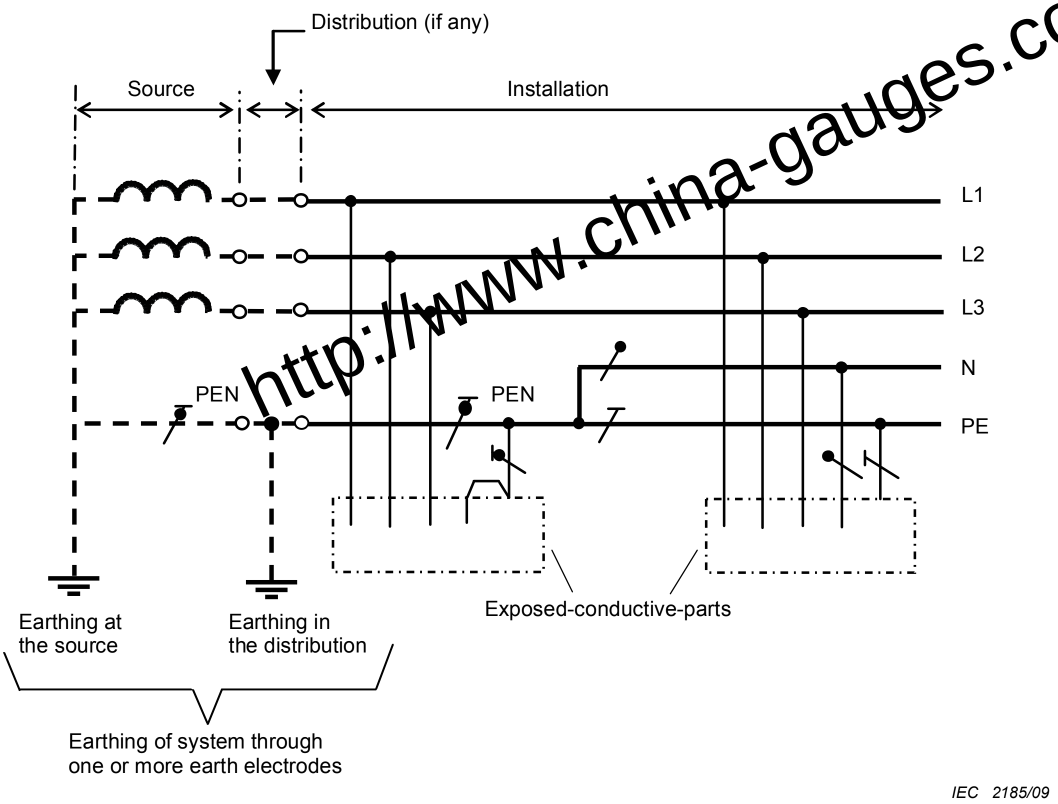
Figure E.2 – TN-S system with separate earthed line conductor and protective conductor throughout the system



NOTE Additional earthing of the PE in the installation may be provided.

Figure E.3 – TN-S system with earthed protective conductor and no distributed neutral conductor throughout the system

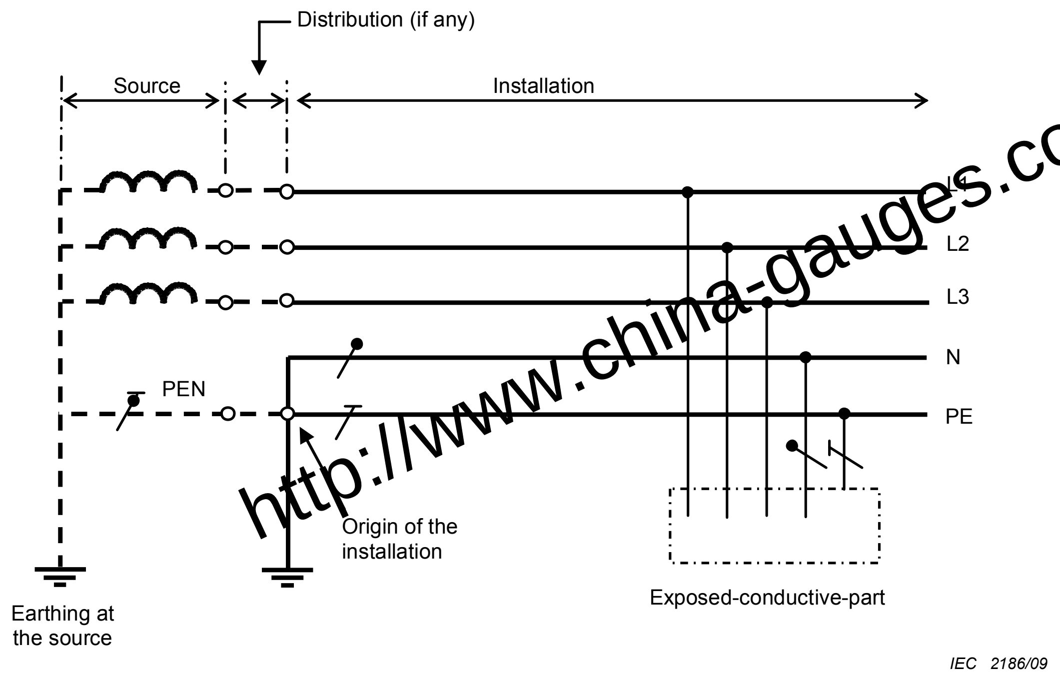
– TN-C-S system in which neutral and protective conductor functions are combined in a single conductor in a part of the system (see Figures E.4, E.5 and E.6).



NOTE 1 Neutral and protective conductor functions combined in a single conductor in a part of the system.

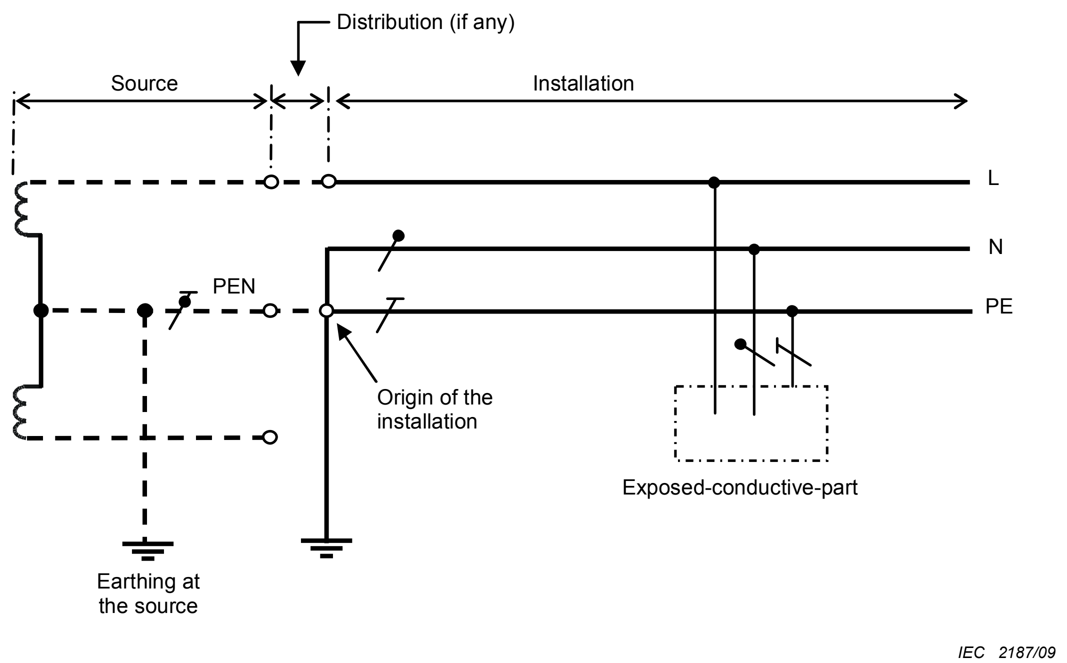
NOTE 2 Additional earthing of the PEN or PE in the installation may be provided.

Figure E.4 – TN-C-S system 3-phase, 4-wire, where the PEN is separated into PE and N elsewhere in the installation



NOTE Additional earthing of the PEN in the distribution and of the PE in the installation may be provided.

Figure E.5 – TN-C-S system 3-phase, 4-wire where the PEN is separated into PE and N at the origin of the installation



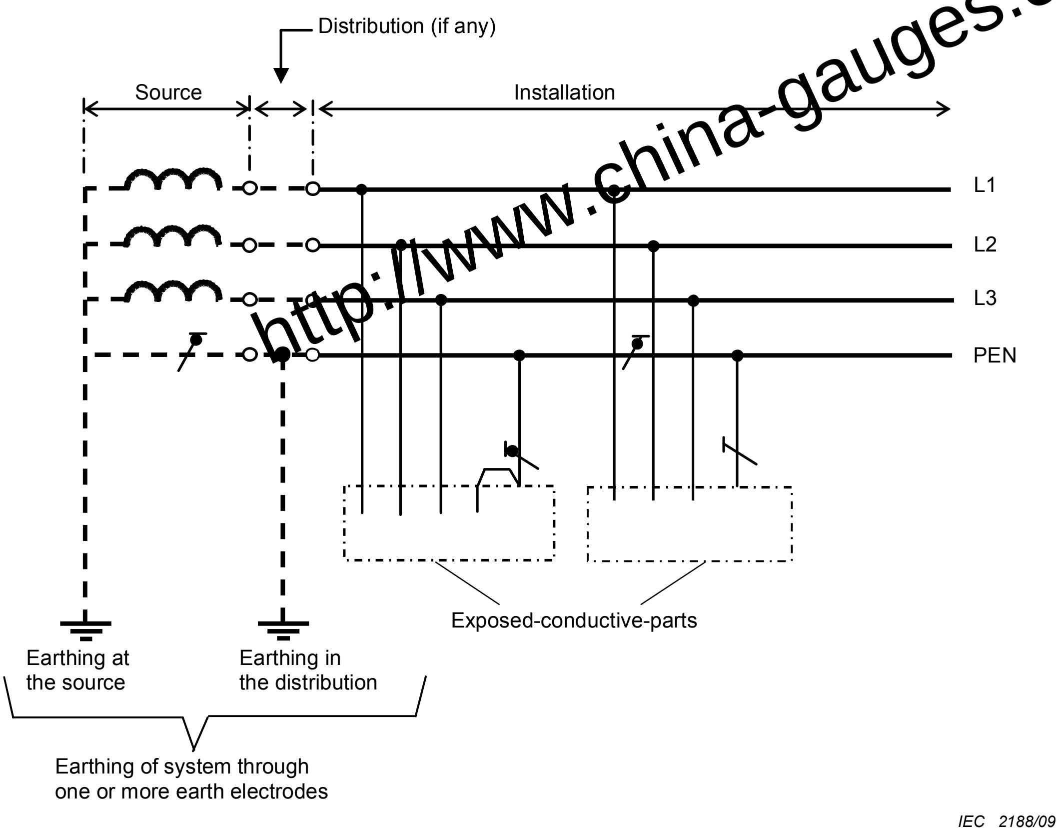
NOTE 1 Neutral and protective conductor functions combined in a single conductor in a part of the system.

NOTE 2 Additional earthing of the PEN in the distribution and of the PE in the installation may be provided.

Figure E.6 – TN-C-S system – single-phase, 2-wire where the PEN is separated into PE and N at the origin of the installation

– TN-C system in which neutral and protective conductor functions are combined in a single conductor throughout the system (see Figure E.7).

NOTE For symbols, see explanation given in E.1.1.



NOTE Additional earthing of the PEN in the installation may be provided.

Figure E.7 – TN-C system with neutral and protective conductor functions combined in a single conductor throughout the system

E.1.3 Multiple source systems

NOTE The multiple source system is shown for the TN system with the unique aim of providing EMC. The multiple source system is not shown for IT and TT systems because these systems are generally compatible with regard to EMC.

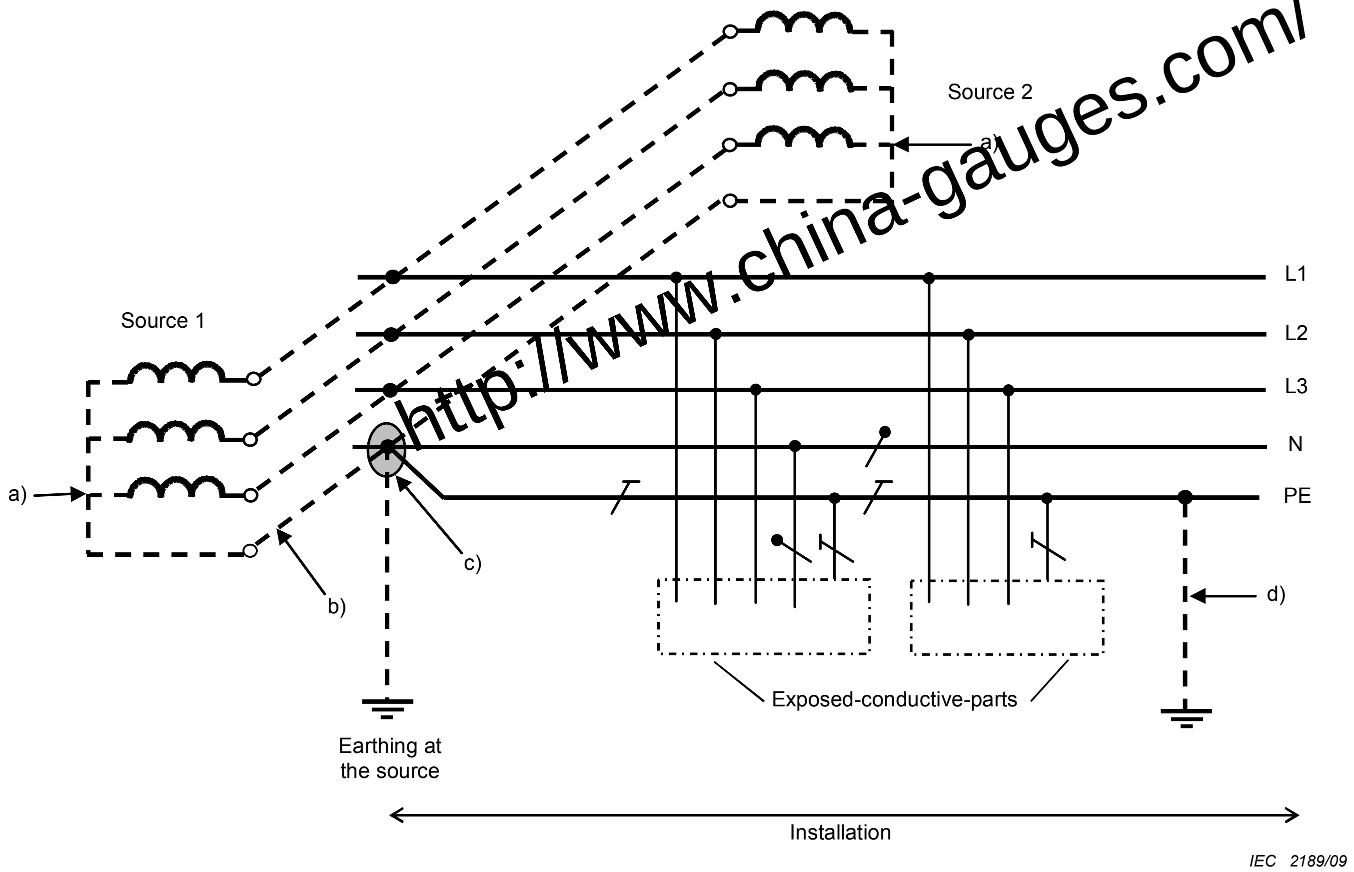
In the case of an inappropriate design of an installation forming part of a TN system with multiple sources some of the operating current may flow through unintended paths. These currents can cause

- fire;
- corrosion;
- electromagnetic interference.

The system shown in Figure E.8 is a system where minor partial operating currents flow as currents through unintended paths. The essential design rules shown in Figure E.8 from a) to d) are given in the key below Figure E.8.

The marking of the PE conductor shall be in accordance with IEC 60446.

Any extension of the system shall be taken into account with regard to the proper functioning of the protective measures.



Key

a) No direct connection from either the transformer neutral point or the generator star point to earth is permitted.

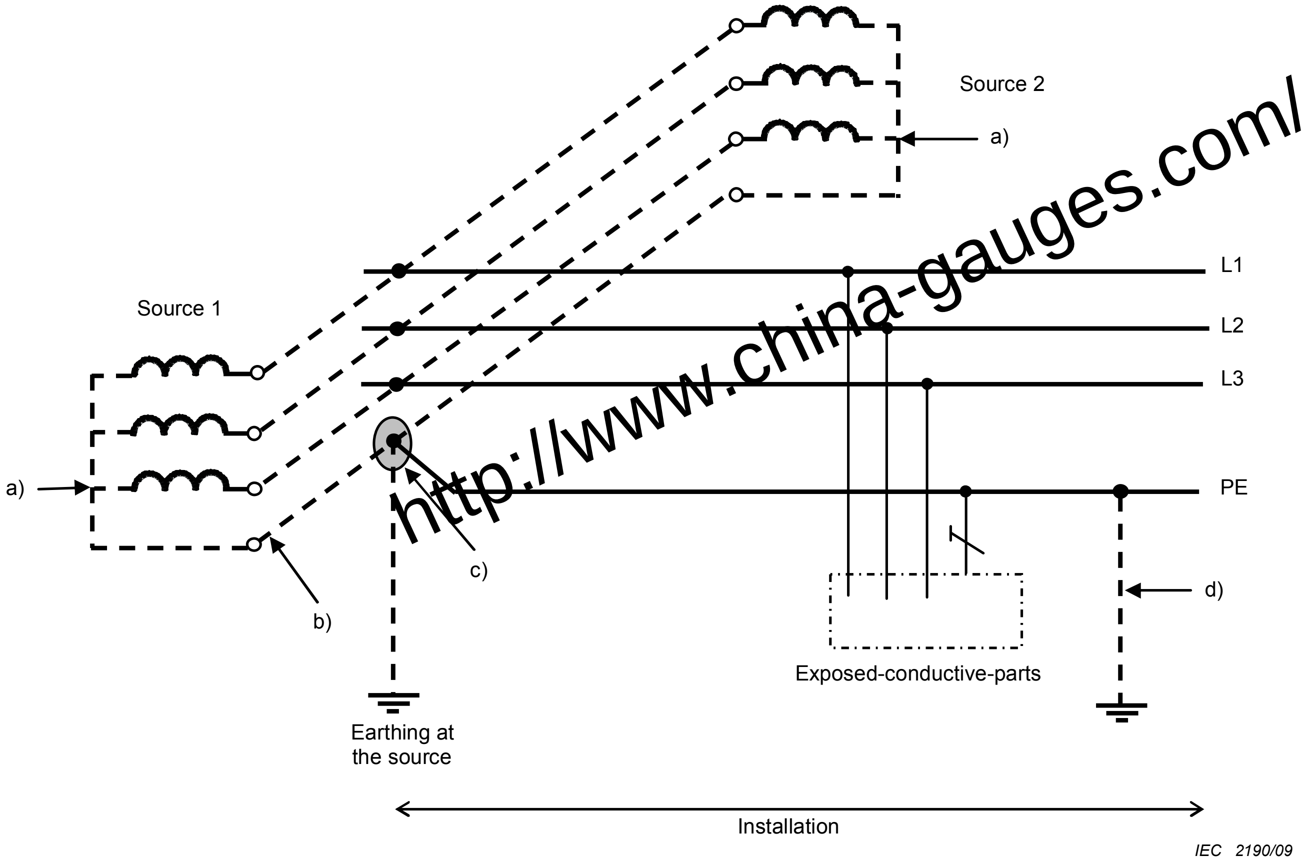
b) The interconnection conductor between either the neutral points of the transformers or the generator star points shall be insulated. The function of this conductor is like a PEN; however, it shall not be connected to current-using equipment.

c) Only one connection between the interconnected neutral points of the sources and the PE shall be provided. This connection shall be located inside the main switchgear assembly.

d) Additional earthing of the PE in the installation may be provided.

Figure E.8 – TN-C-S multiple source system with separate protective conductor and neutral conductor to current-using equipment

In industrial plants with only 2-phase loads and 3-phase loads between line conductors, it is not necessary to provide a neutral conductor (see Figure E.9). In this case, the protective conductor should have multiple connections to earth.



Key

a) No direct connection from either the transformer neutral point or the generator, star point to earth is permitted.

b) The interconnection conductor between either the neutral points of the transformers or the generator star points shall be insulated. The function of this conductor is like a PEN; however, it shall not be connected to current-using equipment.

c) Only one connection between the interconnected neutral points of the sources and the PE shall be provided. This connection shall be located inside the main switchgear assembly.

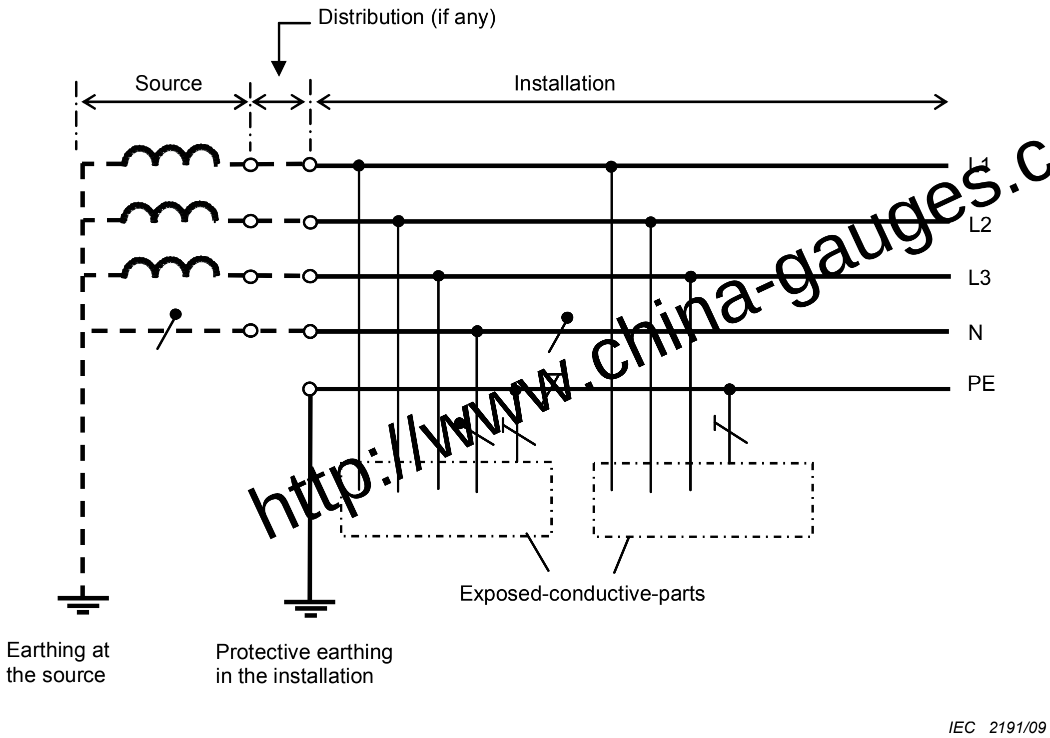
d) Additional earthing of the PE in the installation may be provided.

Figure E.9 – TN multiple source system with protective conductor and no neutral conductor throughout the system for 2- or 3-phase load

E.2 TT system

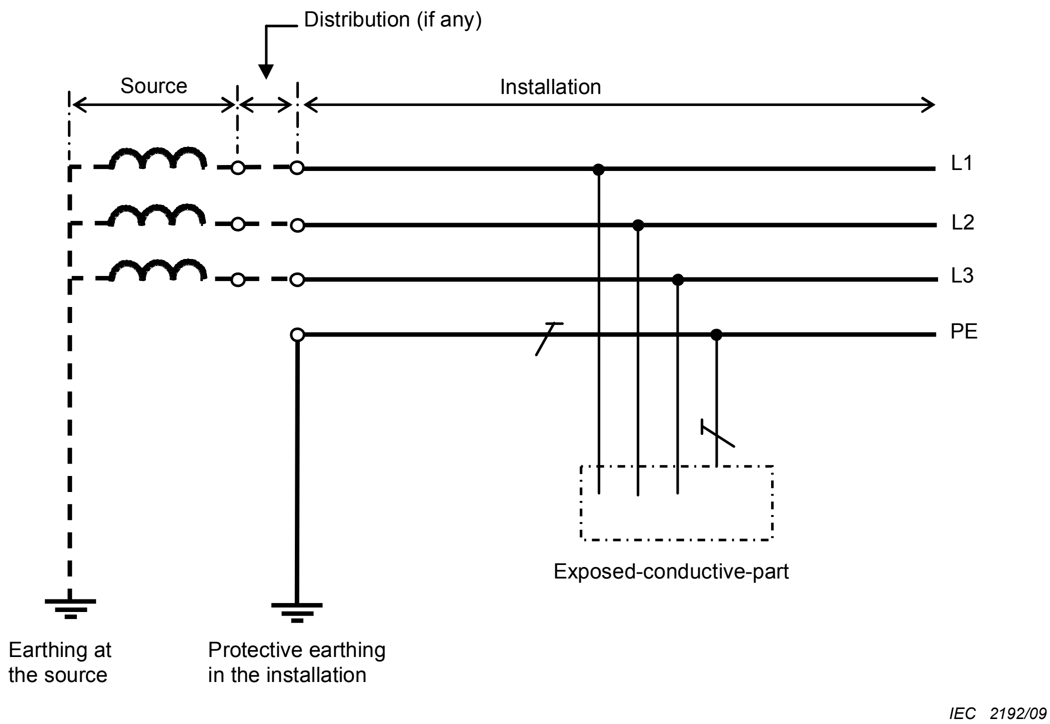
The TT system has only one point directly earthed and the exposed-conductive-parts of the installation are connected to earth electrodes electrically independent of the earth electrode of the supply system (see Figures E.10 and E.11):

NOTE 1 In Sweden TT systems are only allowed under special conditions.



NOTE 2 Additional earthing of the PE in the installation may be provided.

Figure E.10 – TT system with separate neutral conductor and protective conductor throughout the installation

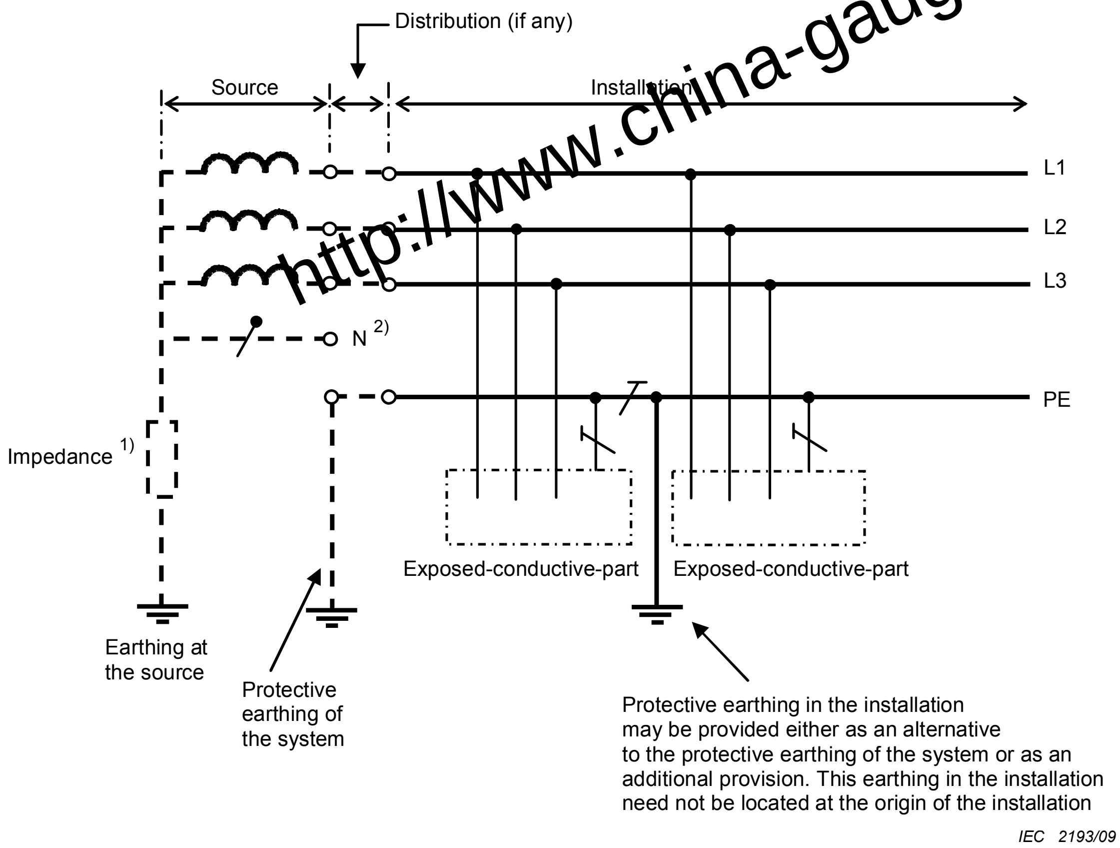


NOTE Additional earthing of the PE in the installation may be provided.

Figure E.11 – TT system with earthed protective conductor and no distributed neutral conductor throughout the installation

E.3 IT system

The IT power system has all live parts isolated from earth or one point connected to earth through an impedance. The exposed-conductive-parts of the electrical installation are earthed independently or collectively or to the earthing of the system according to 411.6 of IEC 60364-4-41 (see Figures E.12 and E.13):

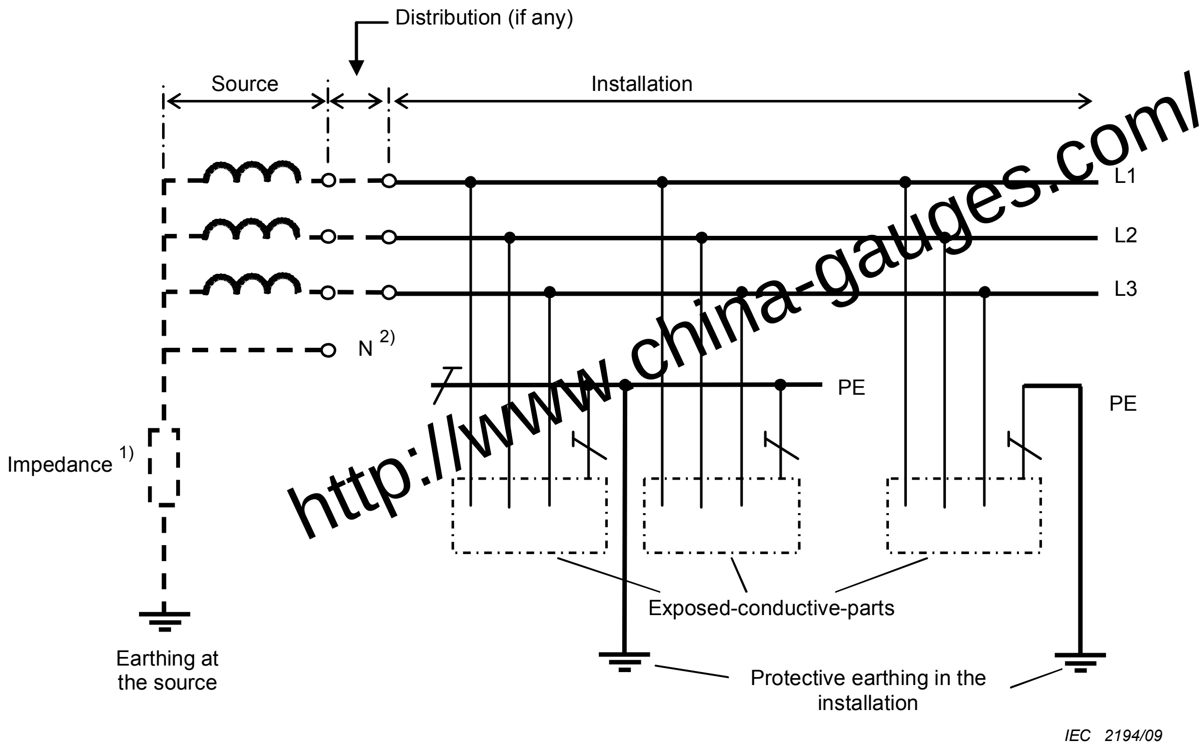


1) The system may be connected to earth via a sufficiently high impedance. This connection may be made, for example, at the neutral point, artificial neutral point, or a line conductor.

2) The neutral conductor may or may not be distributed.

NOTE Additional earthing of the PE in the installation may be provided.

Figure E.12 – IT system with all exposed-conductive-parts interconnected by a protective conductor which is collectively earthed



1) The system may be connected to earth via a sufficiently high impedance.

2) The neutral conductor may or may not be distributed.

NOTE Additional earthing of the PE in the installation may be provided.

Figure E.13 – IT system with exposed-conductive-parts earthed in groups or individually

E.4 DC systems

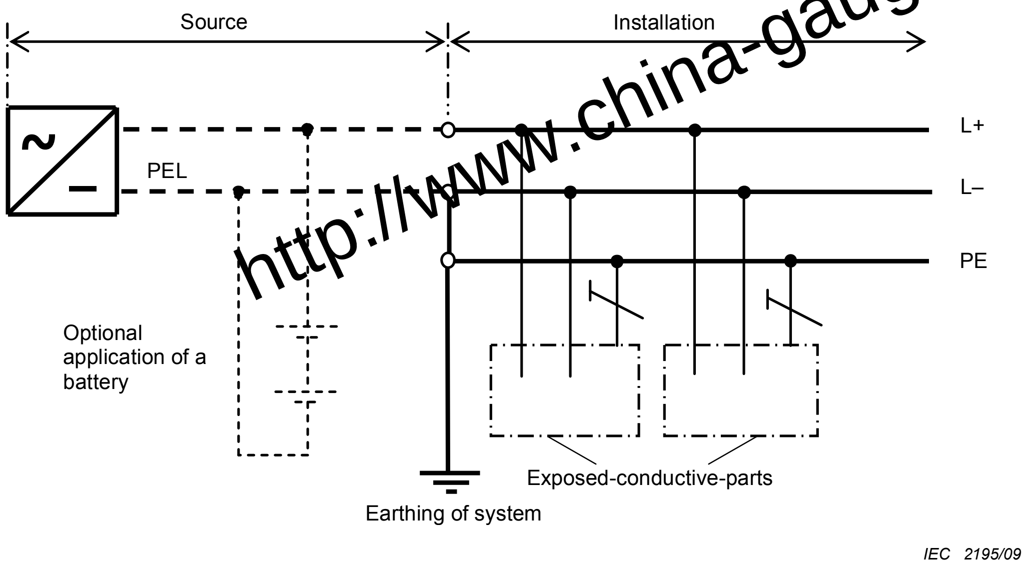
E.4.1 Type of system earthing for direct current (d.c.) systems

Where the following Figures E.14 to E.18 show earthing of a specific pole of a two-wire d.c. system, the decision whether to earth the positive or the negative pole shall be based upon operational circumstances or other considerations, for example, avoidance of corrosion effects on line conductors and earthing arrangements.

E.4.1.1 TN-S-system

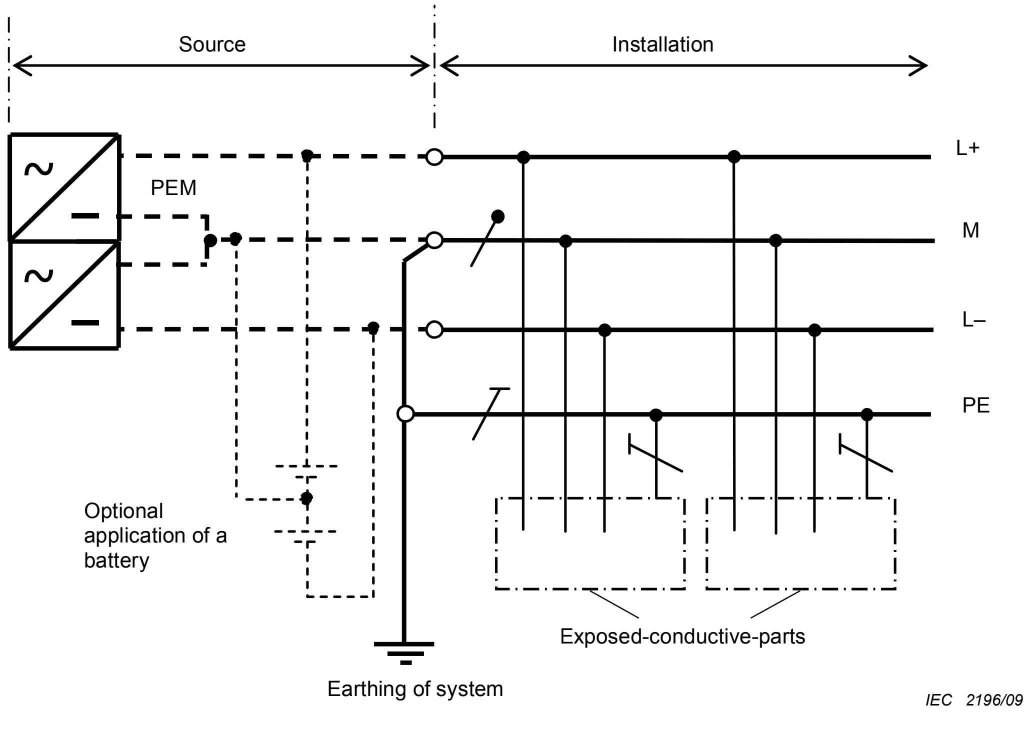
The earthed line conductor for example L– in type a) or the earthed mid-point conductor M in type b) is separated from the protective conductor throughout the installation.

Type a)



NOTE 1 Additional earthing of the PE in the installation may be provided.

Type b)



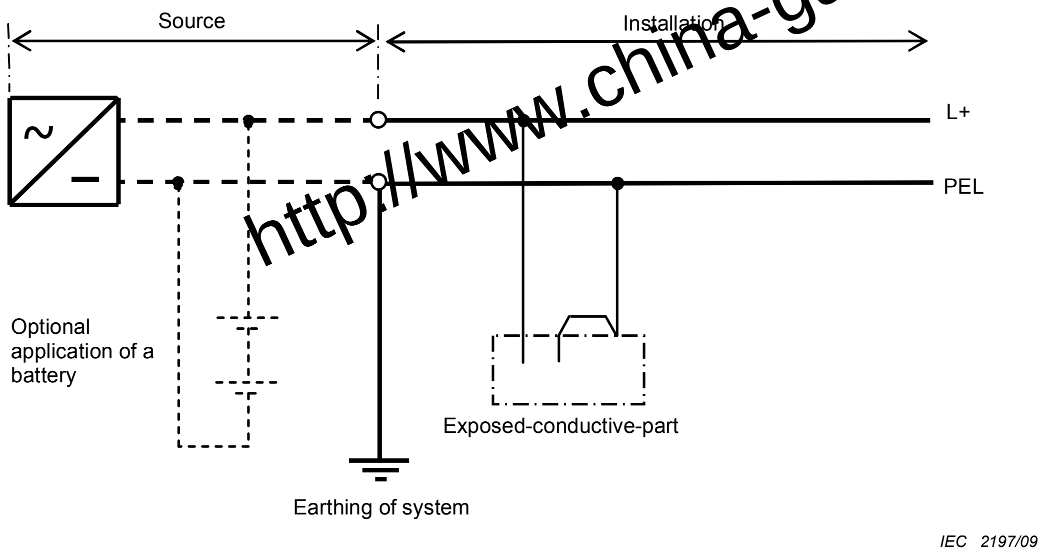
NOTE 2 Additional earthing of the PE in the installation may be provided.

Figure E.14 – TN-S d.c. system

E.4.1.2 TN-C-system

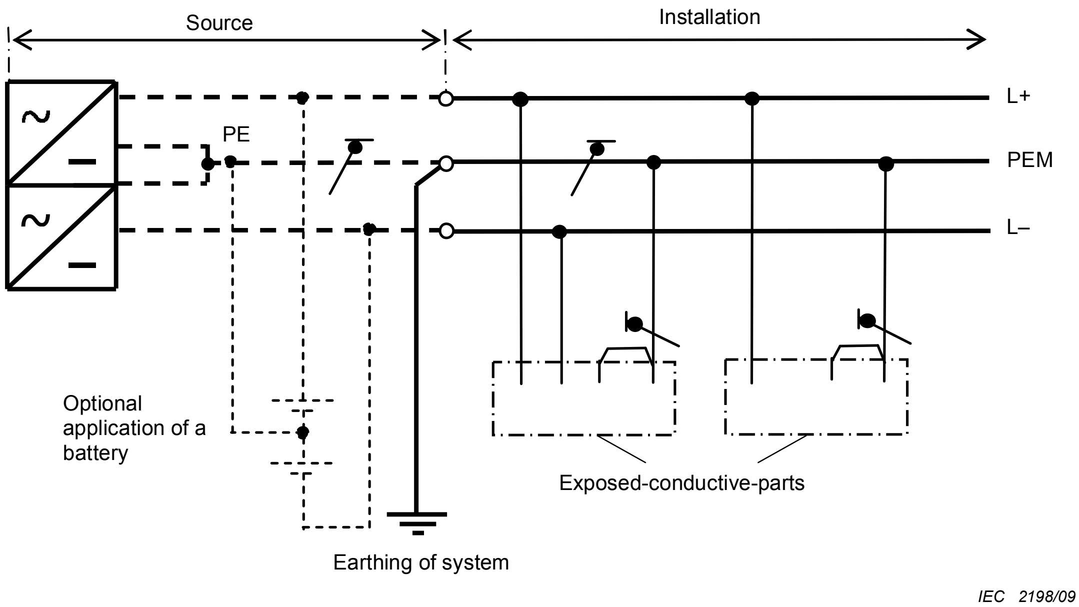
The functions of the earthed line conductor for example L– and of the protective conductor are in type a) combined in one single conductor PEL throughout the installation, or the earthed mid-point conductor M and the protective conductor are combined in type b) in one single conductor PEM throughout the installation.

Type a)



NOTE 1 Additional earthing of the PEL in the installation may be provided.

Type b)



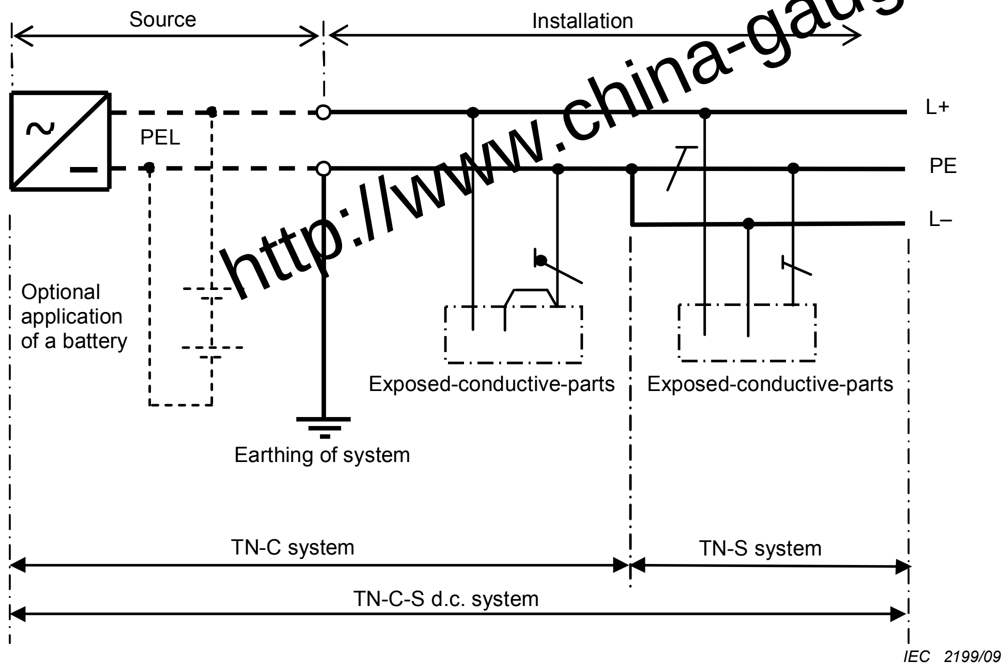
NOTE 2 Additional earthing of the PEM in the installation may be provided.

Figure E.15 – TN-C d.c. system

E.4.1.3 TN-C-S-system

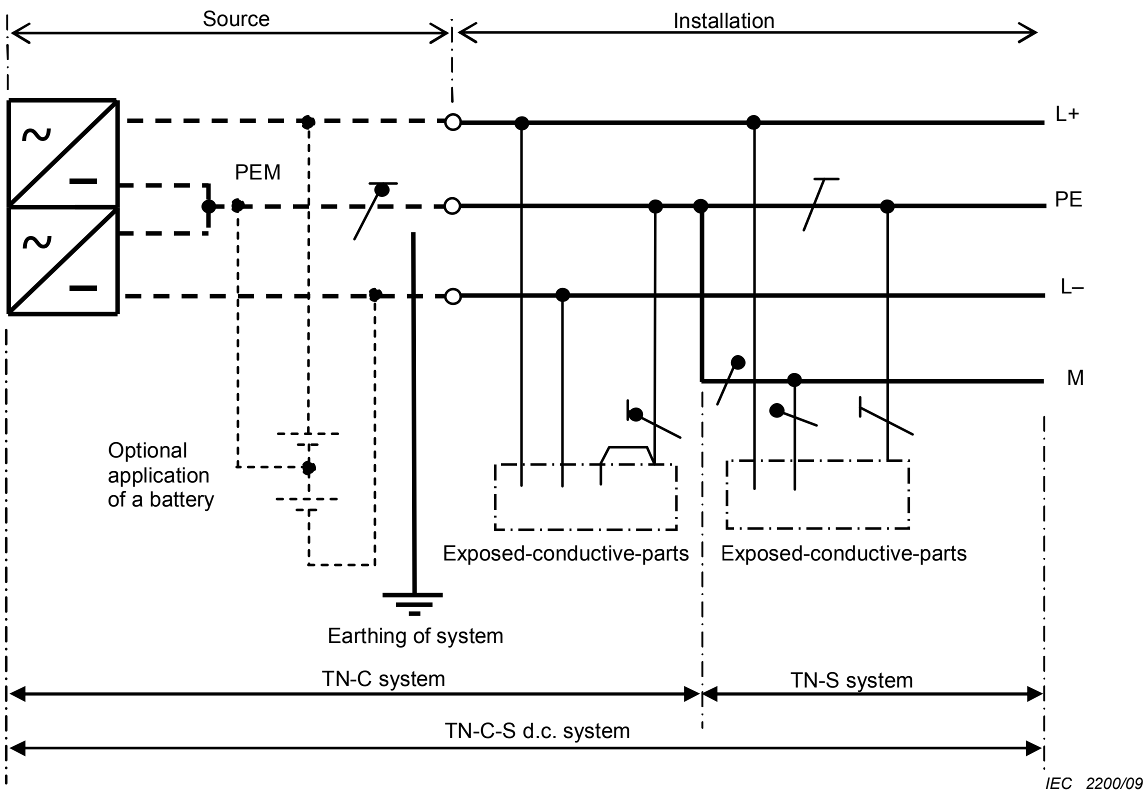
The functions of the earthed line conductor for example L– in type a) and of the protective conductor are combined in one single conductor PEL in a part of the installation, or the earthed mid-wire conductor M in type b) and the protective conductor are combined in one single conductor PEM in a part of the installation.

Type a)



NOTE 1 Additional earthing of the PE in the installation may be provided.

Type b)

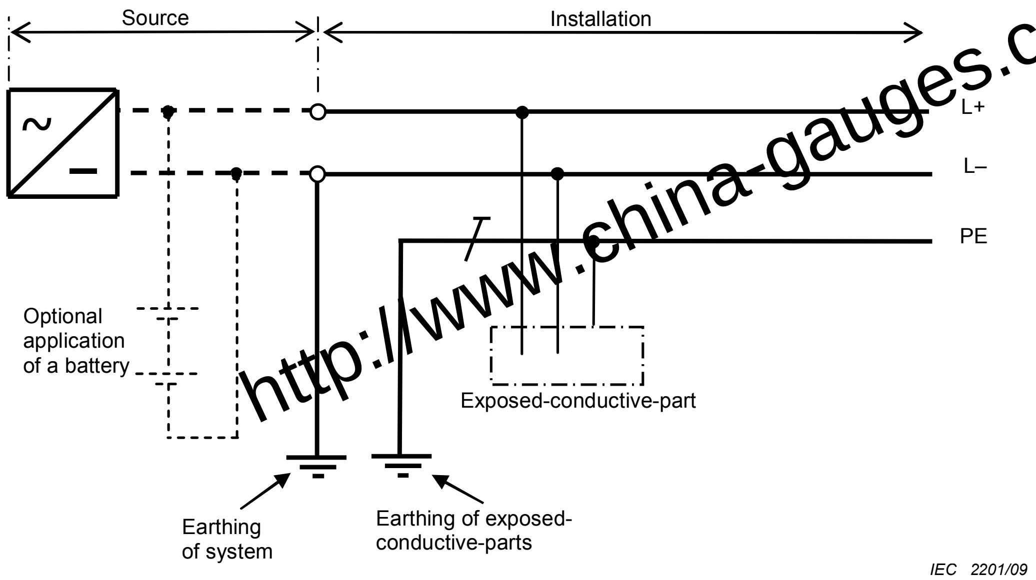


NOTE 2 Additional earthing of the PE in the installation may be provided.

Figure E.16 – TN-C-S d.c. system

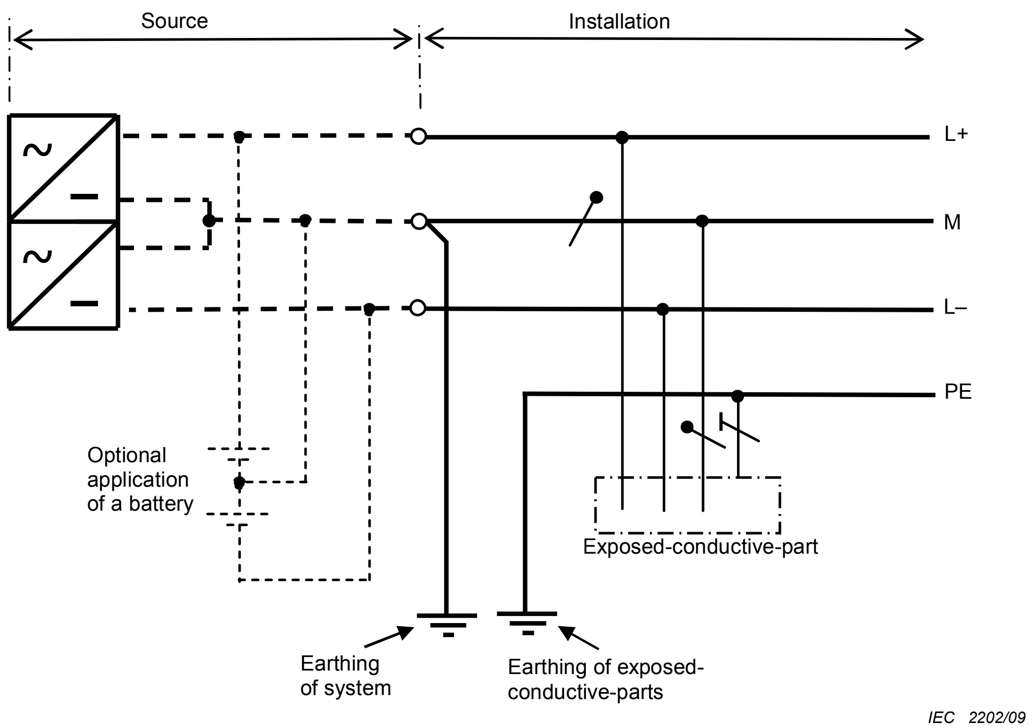
E.4.1.4 TT-system

Type a)



NOTE 1 Additional earthing of the PE in the installation may be provided.

Type b)

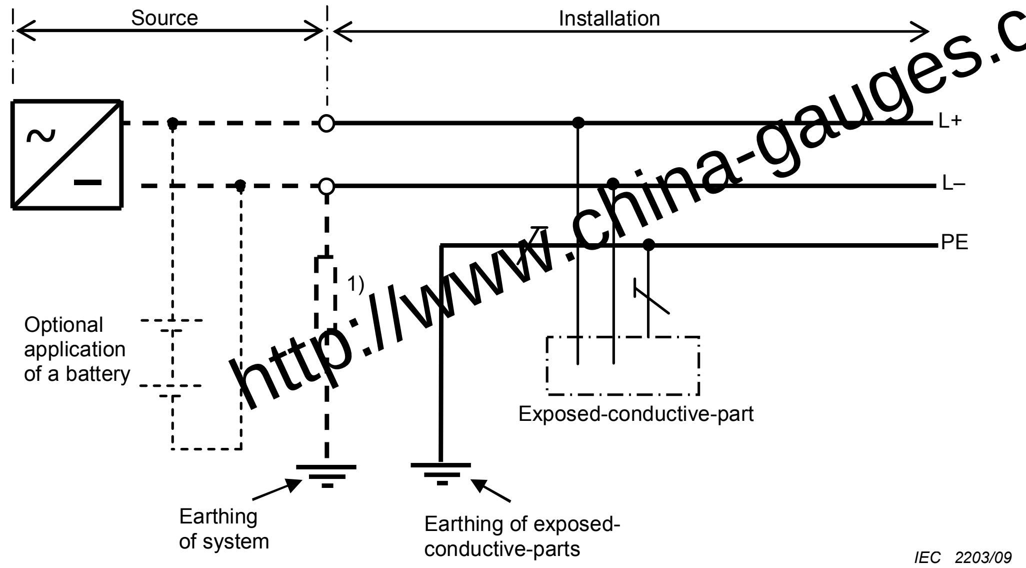


NOTE 2 Additional earthing of the PE in the installation may be provided.

Figure E.17 – TT d.c. system

E.4.1.5 IT-system

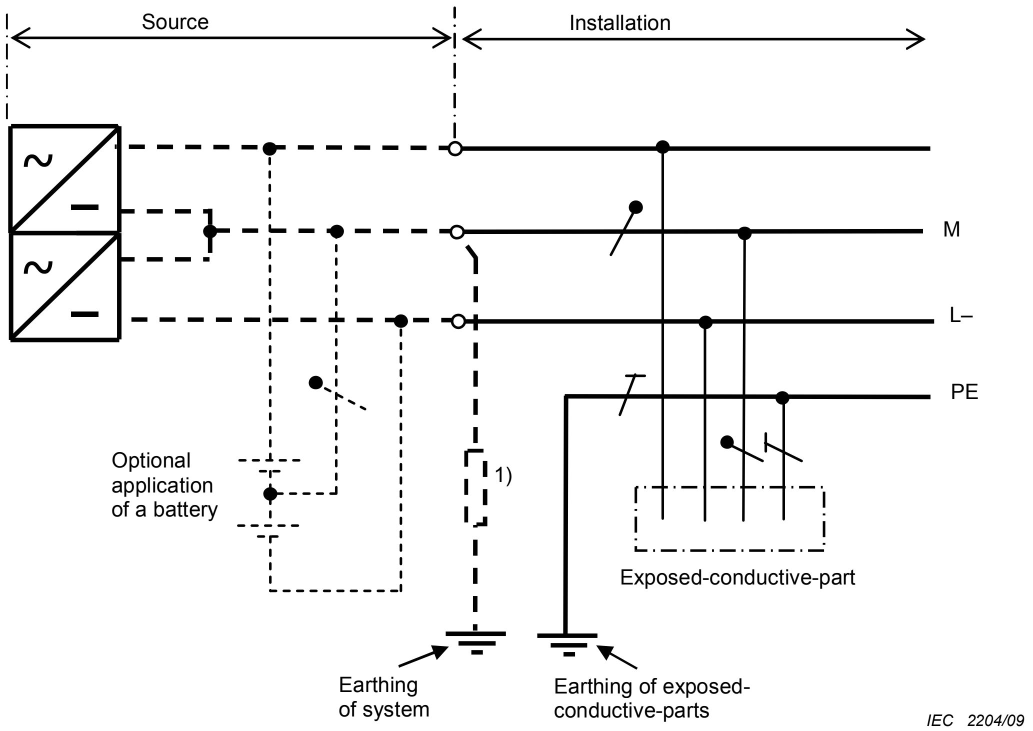
Type a)



[1] The system may be connected to earth via a sufficiently high impedance.

NOTE 1 Additional earthing of the PE in the installation may be provided.

Type b)



[1] The system may be connected to earth via a sufficiently high impedance.

NOTE 2 Additional earthing of the PE in the installation may be provided.

Figure E.18 – IT d.c. system

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