IEC 60204-1

Edition 6.0 2016-10

REDLINE VERSION

colour inside

Safety of machinery – Electrical equipment of machines –
Part 1: General requirements

IEC 60204-1:2016-10 RLV(en)

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ELECTROTECHNICAL
COMMISSION

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SAFETY OF MACHINERY – ELECTRICAL EQUIPMENT OF MACHINES –

Part 1: General requirements

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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This Redline version provides you with a quick and easy way to compare all the changes between this standard and its previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 60204-1 has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects.

This sixth edition cancels and replaces the fifth edition published in 2005. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) added requirements to address applications involving power drive systems (PDS);
b) revised electromagnetic compatibility (EMC) requirements;
c) clarified overcurrent protection requirements;
d) requirements for determination of the short circuit current rating of the electrical equipment;
e) revised protective bonding requirements and terminology;
f) reorganization and revision to Clause 9, including requirements pertaining to safe torque off of PDS, emergency stop, and control circuit protection;
g) revised symbols for actuators of control devices;
h) revised technical documentation requirements;
i) general updating to current special national conditions, normative standards, and bibliographical references.

The text of this standard is based on the following documents:

FDIS	Report on voting
44/765/FDIS	44/771/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60204 series, published under the general title *Safety of machinery – Electrical equipment of machines*, can be found on the IEC website.

The following differing practices of a less permanent nature exist in the countries indicated below.

4.3.1: The voltage characteristics of electricity supplied by public distribution systems in Europe are given in EN 50160:2010.

5.1: Exception is not allowed (USA).

5.1: TN-C systems are not permitted in low-voltage installations in buildings (Norway).

5.2: Terminals for the connection of the protective earthing conductors may be identified by the colour green, the letters “G” or “GR” or “GRD” or “GND”, or the word “ground” or “grounding”, or with the graphical symbol IEC 60417-5019:2006-08 or any combination (USA).

6.3.3 b), 13.4.5 b), 18.2.1: TT power systems are not allowed (USA).

6.3.3, 18.2, Annex A: TN systems are not used. TT systems are the national standard (Japan).

6.3.3 b): The use of residual current protective devices with a rated residual operating current not exceeding 1 A is mandatory in TT systems as a means for fault protection by automatic disconnection of supply (Italy).

7.2.3: Disconnection of the neutral conductor is mandatory in a TN-S system (France and Norway).

7.2.3: Third paragraph: distribution of a neutral conductor with an IT system is not allowed (USA and Norway).

7.10: For evaluation of short circuit ratings the requirements of UL 508A Supplement SB, may be used (USA).

8.2.2: See IEC 60364-5-54:2011, Annex E List of notes concerning certain countries.

9.1.2: Maximum nominal AC control circuit voltage is 120 V (USA).

12.2: Only stranded conductors are allowed on machines, except for 0,2 mm^2 solid conductors within enclosures (USA).

12.2: The smallest power circuit conductor allowed on machines is 0,82 mm^2 (AWG 18) in multiconductor cables or in enclosures (USA).

Table 5: Cross-sectional area is specified in NFPA 79 using American Wire Gauge (AWG) (USA). See Annex G.

13.2.2: For the protective conductor, the colour identification GREEN (with or without YELLOW stripes) is used as equivalent to the bicolour combination GREEN-AND-YELLOW (USA and Canada).

13.2.3: The colour identification WHITE or GREY is used for earthed neutral conductors instead of the colour identification BLUE (USA and Canada).

15.2.2: First paragraph: Maximum value between conductors 150 V (USA).

15.2.2: Second paragraph, 5th bullet: The full load current rating of lighting circuits does not exceed 15 A (USA).

16.4: Nameplate marking requirements (USA).

A.2.2.2: The permissible maximum value of R_A is regulated (e.g. when $U_o \geq 300$V, R_A shall be less than 10 Ω, when $U_o < 300$ V, R_A shall be less than 100 Ω, U_o is the nominal AC line to earth voltage in volts (V) (Japan).

A.2.2.2: The maximum permissible value of R_A is 83 Ω (Netherlands).

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This part of IEC 60204 provides requirements and recommendations relating to the electrical equipment of machines so as to promote:

– safety of persons and property;
– consistency of control response;
– ease of operation and maintenance.

More guidance on the use of this part of IEC 60204 is given in Annex F.

Figure 1 has been provided as an aid to the understanding of the inter-relationship of the various elements of a machine and its associated equipment. Figure 1 is a block diagram of a typical machine and associated equipment showing the various elements of the electrical equipment addressed in this part of IEC 60204. Numbers in parentheses ( ) refer to Clauses and Subclauses in this part of IEC 60204. It is understood in Figure 1 that all of the elements taken together including the safeguards, tooling/fixturing, software, and the documentation, constitute the machine, and that one or more machines working together with usually at least one level of supervisory control constitute a manufacturing cell or system.

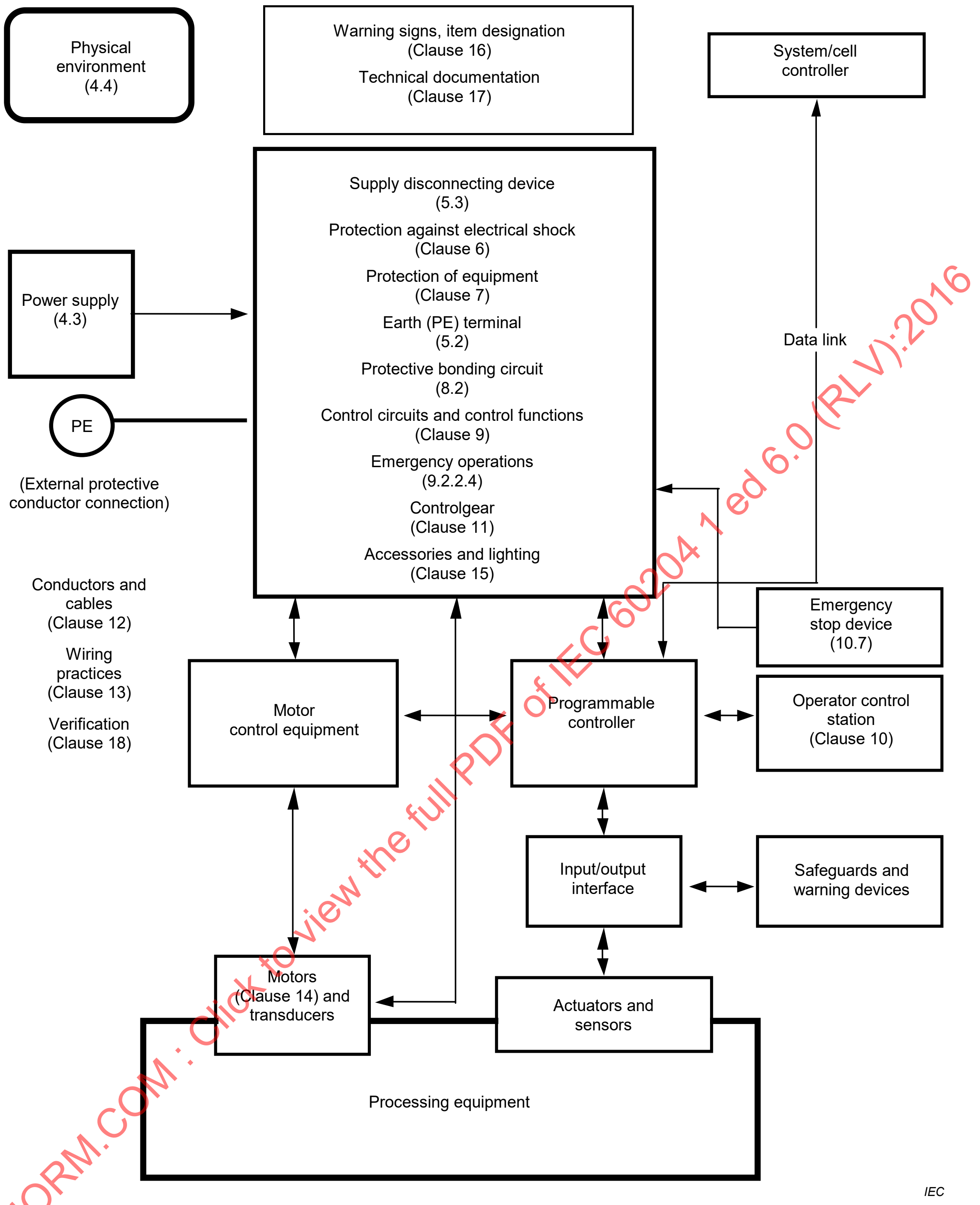


Figure 1 – Block diagram of a typical machine

SAFETY OF MACHINERY – ELECTRICAL EQUIPMENT OF MACHINES –

Part 1: General requirements

1 Scope

This part of IEC 60204 applies to ~~the application of~~ electrical, electronic and programmable electronic equipment and systems to machines not portable by hand while working, including a group of machines working together in a co-ordinated manner.

NOTE 1 This part of IEC 60204 is an application standard and is not intended to limit or inhibit technological advancement.

NOTE 2 In this part of IEC 60204, the term "electrical" includes electrical, electronic and programmable electronic matters (i.e. "electrical equipment" means electrical, electronic and programmable electronic equipment).

NOTE 3 In the context of this part of IEC 60204, 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 use and care of the machine in question.

The equipment covered by this part of IEC 60204 commences at the point of connection of the supply to the electrical equipment of the machine (see 5.1).

NOTE 4 The requirements for the electrical supply installation ~~in buildings~~ are given in the IEC 60364 series.

This part of IEC 60204 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 (AC) and not exceeding 1 500 V for direct current (DC), and with nominal supply frequencies not exceeding 200 Hz.

NOTE 5 ~~For higher voltages, see~~ Information on electrical equipment or parts of the electrical equipment that operate with higher nominal supply voltages can be found in IEC 60204-11.

This part of IEC 60204 does not cover all the requirements (for example guarding, interlocking, or control) that are needed or required by other standards or regulations in order to protect persons from hazards other than electrical hazards. Each type of machine has unique requirements to be accommodated to provide adequate safety.

This part of IEC 60204 specifically includes, but is not limited to, the electrical equipment of machines as defined in 3.1.40.

NOTE 6 Annex C lists examples of machines whose electrical equipment can be covered by this part of IEC 60204.

This part of IEC 60204 does not specify additional and special requirements that can apply to the electrical equipment of machines that, for example:

– are intended for use in open air (i.e. outside buildings or other protective structures);
– use, process, or produce potentially explosive material (for example paint or sawdust);
– are intended for use in potentially explosive and/or flammable atmospheres;
– have special risks when producing or using certain materials;
– are intended for use in mines;
– are sewing machines, units, and systems (which are covered by IEC 60204-31);
– are hoisting machines (which are covered by IEC 60204-32);
– are semiconductor fabrication equipment (which are covered by IEC 60204-33).

Power circuits where electrical energy is directly used as a working tool are excluded from this part of IEC 60204.

2 Normative references

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

IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

~~IEC 60034-5, *Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification*~~

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

IEC 60072 (all parts), *Dimensions and output series for rotating electrical machines*

~~IEC 60072-1, *Dimensions and output series for rotating electrical machines – Part 1: Frame numbers 56 to 400 and flange numbers 55 to 1 080*~~

~~IEC 60072-2, *Dimensions and output series for rotating electrical machines – Part 2: Frame numbers 355 to 1 000 and flange numbers 1 180 to 2 360*~~

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

IEC 60309-1~~:1999~~, *Plugs, socket-outlets and couplers for industrial purposes – Part 1: General requirements*

IEC 60364-1, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60364-4-41:~~2001~~ 2005, *Low-voltage electrical installations ~~of buildings~~ – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-4-43:~~2001~~ 2008, *Low-voltage electrical installations ~~of buildings~~ – Part 4-43: Protection for safety – Protection against overcurrent*

IEC 60364-5-52:~~2001~~ 2009, *Low-voltage Electrical installations ~~of buildings~~ – Part 5-52: Selection and erection of electrical equipment – Wiring systems*

IEC 60364-5-53:~~2002~~ 2001, *Electrical installations of buildings – Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control*
IEC 60364-5-53:2001/AMD1:2002

IEC 60364-5-54:~~2002~~ 2011, *Low-voltage Electrical installations ~~of buildings~~ – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors ~~and protective bonding conductors~~*

~~IEC 60364-6-61:2001, *Electrical installations of buildings – Part 6-61: Verification – Initial verification*~~

IEC 60417~~-DB:2002[1]~~, *Graphical symbols for use on equipment.* Available from: http://www.graphical-symbols.info/equipment

~~IEC 60439-1:1999, *Low-voltage switchgear and controlgear assemblies – Part 1: Type-tested and partially type-tested assemblies*~~

IEC 60445:~~1999~~ 2010, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals~~ and of terminations of certain designated conductors, including general rules for an alphanumeric system~~, conductor terminations and conductors*

~~IEC 60446:1999, *Basic and safety principles for man-machine interface, marking and identification – Identification of conductors by colours or numerals*~~

~~IEC 60447:2004, *Basic and safety principles for man-machine interface, marking and identification – Man-machine interface (MMI) – Actuating principles*~~

IEC 60529~~:1999~~, *Degrees of protection provided by enclosures (IP Code)*
~~Amendment 1 (2001)~~

~~IEC 60617-DB:2001[2], *Graphical symbols for diagrams*~~

~~IEC 60621-3:1979, *Electrical installations for outdoor sites under heavy conditions (including open-cast mines and quarries) – Part 3: General requirements for equipment and ancillaries*~~

IEC 60664-1~~:1992~~, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

~~IEC 60947-1:2004, *Low-voltage switchgear and controlgear – Part 1: General rules*~~

IEC 60947-2~~:2003~~, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

IEC 60947-3~~:1999~~, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors, and fuse-combination units*

IEC 60947-5-1:2003, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*
IEC 60947-5-1:2003/AMD1:2009

IEC 60947-5-5, *Low-voltage switchgear and controlgear – Part 5-5: Control circuit devices and switching elements – Electrical emergency stop device with mechanical latching function*

IEC 60947-6-2, *Low-voltage switchgear and controlgear – Part 6-2: Multiple function equipment – Control and protective switching devices(or equipment) (CPS)*

~~IEC 60947-7-1:2002, *Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*~~

~~IEC 61082-1:1991, *Preparation of documents used in electrotechnology – Part 1: General requirements*~~

~~[1] "DB" refers to the IEC on-line database.~~

~~[2] "DB" refers to the IEC on-line database.~~

~~IEC 61082-2:1993, *Preparation of documents used in electrotechnology – Part 2: Function-oriented diagrams*~~

~~IEC 61082-3:1993, *Preparation of documents used in electrotechnology – Part 3: Connection diagrams, tables and lists*~~

~~IEC 61082-4:1996, *Preparation of documents used in electrotechnology – Part 4: Location and installation documents*~~

IEC 61140~~:2001~~, *Protection against electric shock – Common aspects for installation and equipment*

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

~~IEC 61346 (all parts), *Industrial systems, installations and equipment and industrial products –Structuring principles and reference designations*~~

IEC 61439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

~~IEC 61557-3:1997, *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:~~1997~~ 2005, *Safety of power transformers, power ~~supply units~~ supplies, reactors and similar products – Part 1: General requirements and tests*
~~Amendment 1 (1998)~~
IEC 61558-1:2005/AMD1:2009

IEC 61558-2-6, *Safety of ~~power~~ 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 ~~for general use~~ and power supply units incorporating safety isolating transformers*

IEC 61984~~:2001~~, *Connectors ~~–~~ Safety requirements and tests*

IEC 62023~~:2000~~, *Structuring of technical information and documentation*

~~IEC 62027:2000, *Preparation of parts lists*~~

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

~~IEC 62079:2001, *Preparation of instructions – Structuring, content and presentation*~~

~~ISO 7000:2004, *Graphical symbols for use on equipment – Index and synopsis*~~

ISO 7010:2011, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

~~ISO 12100-1:2003, *Safety of machinery – Basic concepts, general principles for design – Part 1: Basic terminology, methodology*~~

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

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

ISO 13849-2~~:2003~~, *Safety of machinery – Safety-related parts of control systems – Part 2: Validation*

ISO 13850:~~1996~~ 2006, *Safety of machinery – Emergency stop function – Principles for design*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

3.1.1
actuator
part of a device to which an external ~~manual~~ action is to be applied

Note 1 to entry: The actuator may take the form of a handle, knob, push-button, roller, plunger, etc.

Note 2 to entry: There are some actuating means that do not require an external actuating force, but only an action, e.g. touchscreens.

Note 3 to entry: See also 3.1.39.

3.1.2
ambient temperature
temperature of the air or other medium where the equipment is to be used

3.1.3
barrier
part providing protection against ~~direct~~ contact with live parts from any usual direction of access

3.1.4
basic protection
protection against electric shock under fault-free conditions

Note 1 to entry: Previously referred to as “protection against direct contact”

[SOURCE: IEC 60050-195:1998, 195-06-01, modified – The note has been added.]

3.1.5
cable tray
cable support consisting of a continuous base and raised edges and no covering

Note 1 to entry: A cable tray may be perforated or non-perforated.

[SOURCE: IEC 60050-826:2004, 826-15-08]

3.1.6
cable trunking system
system of closed enclosures comprising a base with a removable cover intended for the complete surrounding of insulated conductors~~,~~ or cables~~, cords and for the accommodation of other electrical equipment~~

3.1.7
concurrent
~~acting in conjunction; used to describe a situation wherein two or more control devices exist in an actuated condition~~ occurring or operating at the same time (but not necessarily synchronously)

3.1.8
conductor wire
conductor bar
conductive wire or bar of a feeder system with a sliding current collector

3.1.9
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 1 to entry: Conduits should be sufficiently close-jointed so that the insulated conductors and/or cables can only be drawn in and not inserted laterally.

[SOURCE:~~ IEV 826-06-03~~ IEC 60050-442:1998, 442-02-03, modified – The definition has been amended and the note has been added.]

3.1.10
control circuit, <of a machine>
circuit used for the control, including monitoring, of a machine and the electrical equipment

3.1.11
control device
device connected into the control circuit and used for controlling the operation of the machine

EXAMPLE Position sensor, manual control switch, relay, contactor, magnetically operated valve.

3.1.12
control station
operator control station
assembly of one or more control actuators (see 3.1.1) fixed on the same panel or located in the same enclosure

Note 1 to entry: A control station may also contain related equipment, for example, potentiometers, signal lamps, instruments, display devices, etc.

[SOURCE: IEC 60050-441:1984, 441-12-08, modified – The second preferred term has been added, the word "switches" has been replaced by "actuators" in the definition and the note has been added.]

3.1.13
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 in principle for the control of electrical energy consuming equipment

[SOURCE: IEC 60050-441:1984, 441-11-03~~, modified~~]

3.1.14
controlled stop
stopping of machine motion with~~ electrical~~ power to the machine actuators maintained during the stopping process

3.1.15
direct contact
contact of persons or livestock with live parts

Note 1 to entry: See 3.1.4.

[SOURCE: IEC 60050-826:2004, 826-12-03, modified – The note has been added.]

3.1.16
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)

[SOURCE: IEC 60947-5-1:2003, K.2.2]

3.1.17
duct
enclosed channel designed expressly for holding and protecting electrical conductors, cables, and busbars

Note 1 to entry: Conduits (see 3.1.9), cable trunking systems (see 3.1.6) and underfloor channels are types of duct.

3.1.18
earth
local earth
ground (US)
local ground (US)
part of the Earth which is in electric contact with an earth electrode and the electrical potential of which is not necessarily equal to zero

[SOURCE: IEC 60050-195:1998,195-01-03]

3.1.19
electrical operating 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 without the use of a key or tool, and which is clearly marked by appropriate warning signs

3.1.20
electronic equipment
part of the electrical equipment containing circuitry dependent for its operation on electronic devices and components

3.1.21
emergency stop device
manually actuated control device used to initiate an emergency stop function

Note 1 to entry: See ~~Annex E~~ 9.2.3.4.2.

[SOURCE: ISO 13850:2006, 3.2, modified – The note has been added.]

3.1.22
emergency switching off device
manually actuated control device used to switch off or to initiate the switching off of the supply of electrical energy to all or a part of an installation where a risk of electric shock or another risk of electrical origin is involved

Note 1 to entry: See ~~Annex E~~ 9.2.3.4.3.

3.1.23
enclosed electrical operating area
room or location for electrical equipment to which access is intended to be restricted to skilled or instructed persons by the use of a key or tool to open a door, or remove a barrier, and which is clearly marked by appropriate warning signs

3.1.24
enclosure
part providing protection of equipment against certain external influences and, in any direction, basic protection as protection against direct contact

Note 1 to entry: The existing definition taken from the IEV needs the following explanations within the scope of this part of IEC 60204:

a) Enclosures provide protection of persons or livestock 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.

[SOURCE: IEC 60050-195:1998, 195-02-35, modified – The definition has been amended.]

3.1.25
electrical equipment
items used in connection with the utilisation of electricity by machines or parts of machines, for example material, fittings, devices, components, appliances, fixtures, apparatus, and ~~the like used as part of, or in connection with, the electrical equipment of machines~~ similar

3.1.26
equipotential bonding
provision of electric connections between conductive parts, intended to achieve equipotentiality

[SOURCE: IEC 60050-195:1998, 195-01-10]

3.1.27
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

[SOURCE: IEC 60050-826:2004, 826-12-10, modified – The definition has been amended.]

3.1.28
extraneous-conductive-part
conductive part not forming part of the electrical installation and liable to introduce an electric potential, generally the ~~earth~~ electric potential of a local earth

[SOURCE: IEC 60050-195:1998, 195-06-11~~, modified~~]

3.1.29
failure
termination of the ability of an item to perform a required function

Note 1 to entry: After failure, the item has a fault.

Note 2 to entry: "Failure" is an event, as distinguished from "fault", which is a state.

Note 3 to entry: This concept as defined does not apply to items consisting of software only.

Note 4 to entry: In practice, the terms fault and failure are often used synonymously.

[SOURCE: IEC 60050-191:1990, 191-04-01]

3.1.30
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 to entry: A fault is often the result of a failure of the item itself, but may exist without prior failure.

Note 2 to entry: In English, the term “fault” and its definition are identical with those given in IEC 60050-191:1990, 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.

3.1.31
fault protection
protection against electric shock under single-fault conditions

Note 1 to entry: Previously referred to as “protection against indirect contact”

[SOURCE: IEC 60050-195:1998, 195-06-02, modified – the Note has been added]

3.1.32
functional bonding
equipotential bonding necessary for proper functioning of electrical equipment

3.1.33
hazard
potential source of physical injury or damage to health

Note 1 to entry: 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 to entry: 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).

[SOURCE: ISO 12100:2010, 3.6, modified – The word “harm" has been replaced by " physical injury or damage to health" in the definition and Note 3 has been removed]

3.1.34
indirect contact
contact of persons or livestock with exposed conductive parts which have become live under fault conditions

Note 1 to entry: See 3.1.31.

[SOURCE: IEC 60050-826:2004, 826-12-04, modified – The definition has been amended.]

3.1.35
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 1 to entry: The track conductor and the pick-up are analogous to the primary and secondary of a transformer respectively.

3.1.36
instructed person, <in electricity>
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

[SOURCE: IEC 60050-826:2004, 826-18-02, modified – "an electrically skilled person" has been used to replace "electrically skilled persons"]

3.1.37
interlock ~~**(for safeguarding)**~~
arrangement ~~that interconnects guard(s) or device(s) with the control system and/or all or part of the electrical supply to the machine~~ of devices operating together to:

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

3.1.38
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.~~

3.1.39
machine actuator
power mechanism of the machine used to effect motion (for example, motor, solenoid, pneumatic or hydraulic cylinder)

3.1.40
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

Note 1 to entry: 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.

Note 2 to entry: The term "component" is used here in a general sense and it does not refer only to electrical components.

[SOURCE: ISO 12100:2010, 3.1, modified – The definition has been amended and Note 2 referring to an Annex has been removed and replaced by the present Note 2 to entry.]

3.1.41
marking
signs or inscriptions primarily for the purpose of identifying equipment, components and/or devices~~, which can include certain features thereof~~

3.1.42
neutral conductor
N
conductor electrically connected to the neutral point~~ of a system~~ and capable of contributing to the~~ transmission~~ distribution of electrical energy

[SOURCE:~~ IEV 826-14-07, modified~~ IEC 60050-195:1998, 195-02-06]

3.1.43
obstacle
part preventing unintentional direct contact with live parts, but not preventing direct contact by deliberate action

[SOURCE: IEC 60050-195:1998, 195-06-16, modified – The words "(electrically) protective" have been removed from the term.]

3.1.44
overcurrent
current exceeding the rated value

Note 1 to entry: For conductors, the rated value is considered as equal to the current-carrying capacity.

[SOURCE: IEC 60050-826:2004, 826-11-14, modified – The definition has been amended.]

3.1.45
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 1 to entry: Overload should not be used as a synonym for overcurrent.

3.1.46
plug/socket combination
component and a suitable mating component, appropriate to terminate conductors, intended for connection or disconnection of two or more conductors

Note 1 to entry: 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.

3.1.47
power circuit
circuit that supplies power~~ from the supply network~~ to units of equipment used for productive operation and to transformers supplying control circuits

3.1.48
prospective short-circuit current
***I*cp**
r.m.s. value of the current which would flow when the supply conductors to the electrical equipment are short-circuited by a conductor of negligible impedance located as near as practicable to the supply terminals of the electrical equipment

[SOURCE: IEC 61439-1: 2011, 3.8.7, modified – “assembly” has been replaced by “electrical equipment”]

3.1.49
protective bonding
equipotential bonding for protection against electric shock

Note 1 to entry: Measures for protection against electric shock can also reduce the risk of burns or fire.

Note 2 to entry: Protective bonding can be achieved with protective conductors and protective bonding conductors and by conductive joining of conductive parts of the machine and its electrical equipment.

3.1.50
protective bonding circuit
protective conductors and conductive parts connected together to provide protection against electric shock in the event of an insulation failure

3.1.51
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 826-13-22, modified]~~

conductor providing a primary fault current path from the exposed conductive parts of the electrical equipment to a protective earthing (PE) terminal

3.1.52
redundancy
application of more than one device or system, or part of a device or system, with the objective of ensuring that in the event of one failing to perform its function, another is available to perform that function

3.1.53
reference designation
distinctive code which serves to identify an object in the documentation and on the equipment

3.1.54
risk
combination of the probability of occurrence of harm (i.e. physical injury or damage to health) and the severity of that harm

[SOURCE: ISO 12100~~-1~~:2010, 3.12, modified – The text in parentheses has been added]

3.1.55
safeguard
guard or protective device provided as a means to protect persons from a hazard

[SOURCE: ISO 12100:2010, 3.26, modified – The words “provided as a means to protect persons from a hazard” have been added.]

3.1.56
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

[SOURCE: ISO 12100~~-1~~:2010, 3.21]

3.1.57
safety function
function of a machine whose failure can result in an immediate increase of the risk(s)

[SOURCE: ISO 12100:2010, 3.30; IEC 62061:2005, 3.2.15]

3.1.58
servicing level
level on which persons stand when operating or maintaining the electrical equipment

3.1.59
short-circuit current
overcurrent resulting from a short-circuit due to a fault or an incorrect connection in an electric circuit

[SOURCE: IEC 60050-441:1984, 441-11-07]

3.1.60
short-circuit current rating
value of prospective short-circuit current that can be withstood by the electrical equipment for the total operating time (clearing time) of the short-circuit protective device (SCPD) under specified conditions

[SOURCE: IEC 61439-1: 2011, 3.8.10.4, modified – The word “rated” is removed from the term, and the reference to “assembly” removed from the definition.]

3.1.61
skilled person
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

[SOURCE: IEC 60050-826:2004, 826-18-01, modified – The parentheses have been removed and “training” has been added.]

3.1.62
supplier
entity (for example manufacturer, contractor, installer, integrator) who provides equipment or services associated with the machine

Note 1 to entry: The user organization may also act in the capacity of a supplier to itself.

3.1.63
switching device
device designed to make and/or break the current in one or more electric circuits

Note 1 to entry: A switching device may perform one or both of these actions.

[SOURCE: IEC 60050-441:1984, 441-14-01]

3.1.64
uncontrolled stop
stopping of machine motion by removing electrical power to the machine actuators

Note 1 to entry: This definition does not imply any particular state of other stopping devices, for example mechanical or hydraulic brakes.

3.1.65
user
entity who utilizes the machine and its associated electrical equipment

3.2 Abbreviated terms

AWG	American Wire Gauge
AC	Alternating Current
BDM	Basic Drive Module
CCS	Cableless Control System
DC	Direct Current
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
IFLS	Insulation Fault Location System
MMI	Man-Machine interface
PDS	Power Drive System
PELV	Protective Extra-Low Voltage
RCD	Residual Current protective Device
SPD	Surge Protective Devices
SCPD	Short-Circuit Protective Device
SELV	Safe Extra-Low Voltage
SLP	Safely-Limited Position
STO	Safe Torque Off

4 General requirements

4.1 General

~~This part of IEC 60204 is intended to apply to electrical equipment used with a wide variety of machines and with a group of machines working together in a co-ordinated manner.~~

This standard specifies requirements for the electrical equipment of machines.

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 machine. This will:

– identify the need for risk reduction; and
– determine~~ the~~ adequate risk reductions; and

– determine the necessary protective measures

for persons who can be exposed to those hazards, while still maintaining an ~~acceptable level of~~ appropriate performance of the machine and its 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, arc, or ~~electrical~~ fire;
- failures or faults in control circuits (or components and devices associated with those circuits) resulting in the malfunctioning of the machine;
- disturbances or disruptions in power sources as well as failures or faults in the power circuits resulting in the malfunctioning of the machine;
- loss of continuity of circuits that can result in a failure of a safety function, for example those that depend ~~up~~ on sliding or rolling contacts;
- electrical disturbances for example, electromagnetic, electrostatic either from outside the electrical equipment or internally generated, resulting in the malfunctioning of the machine;
- release of stored energy (either electrical or mechanical) resulting in, for example, electric shock, unexpected movement that can cause injury;
- ~~audible~~ acoustic noise and mechanical vibration at levels that cause health problems to persons;
- 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.

The design and development process shall identify hazards and the risks arising from them. 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.

~~The use of the enquiry form as shown in Annex B of this part of IEC 60204 is recommended in order to facilitate an appropriate agreement~~ It is recommended that, where the user is known, Annex B be used to facilitate an exchange of information between the user and the supplier(s) on basic conditions and additional user specifications related to the electrical equipment.

NOTE Those additional specifications ~~are to~~ can:

- provide additional features that are dependent on the type of machine (or group of machines) and the application;
- facilitate maintenance and repair; and
- improve the reliability and ease of operation.

4.2 Selection of equipment

4.2.1 General

Electrical components and devices shall:

- be suitable for their intended use; and
- conform to relevant IEC standards where such exist; and
- be applied in accordance with the supplier’s instructions.

4.2.2 ~~Electrical equipment in compliance with the IEC 60439 series~~ Switchgear

~~The electrical equipment of the machine shall satisfy the safety requirements identified by the risk assessment of the machine.~~ In addition to the requirements of IEC 60204-1, depending upon the machine, its intended use and its electrical equipment, the designer may select parts of the electrical equipment of the machine that are in compliance with relevant parts of the IEC ~~60439~~ 61439 series (see also Annex F).

~~NOTE The IEC 60439 series specifies requirements for equipment covering a wide range of possible applications of low-voltage switchgear and controlgear assemblies.~~

4.3 Electrical supply

4.3.1 General

The electrical equipment shall be designed to operate correctly with the conditions of the supply:

– as specified in 4.3.2 or 4.3.3, or

– as otherwise specified by the user ~~(see Annex B)~~, or

– as specified by the supplier ~~in the case~~ of a special source of supply ~~such as an on-board generator~~ (see 4.3.4)

4.3.2 AC supplies

Voltage	Steady state voltage: 0,9 to 1,1 of nominal voltage.
Frequency	0,99 to 1,01 of nominal frequency continuously; 0,98 to 1,02 short time.
Harmonics	Harmonic distortion not exceeding ~~10~~ 12 % of the total r.m.s. voltage between live conductors for the sum of the 2nd through to the ~~5th~~ 30th harmonic. ~~An additional 2 % of the total r.m.s. voltage between live conductors for the sum of the 6th through to the 30th harmonic is permissible.~~
Voltage unbalance	Neither the voltage of the negative sequence component nor the voltage of the zero sequence component in three-phase supplies exceeding 2 % of the positive sequence component.
Voltage interruption	Supply interrupted or at zero voltage for not more than 3 ms at any random time in the supply cycle with more than 1 s between successive interruptions.
Voltage dips	Voltage dips not exceeding 20 % of the ~~peak~~ rms voltage of the supply for more than one cycle with more than 1 s between successive dips.

4.3.3 DC supplies

From batteries:

Voltage	0,85 to 1,15 of nominal voltage; 0,7 to 1,2 of nominal voltage in the case of battery-operated vehicles.
Voltage interruption	Not exceeding 5 ms.

From converting equipment:

Voltage	0,9 to 1,1 of nominal voltage.
Voltage interruption	Not exceeding 20 ms with more than 1 s between successive interruptions.

NOTE This is a variation to IEC Guide 106 to ensure proper operation of electronic equipment.

Ripple (peak-to-peak) Not exceeding 0,15 of nominal voltage.

4.3.4 Special supply systems

For special supply systems (e.g. on-board generators, DC bus, etc.) the limits given in 4.3.2 and 4.3.3 may be exceeded provided that the equipment is designed to operate correctly with those conditions.

4.4 Physical environment and operating conditions

4.4.1 General

The electrical equipment shall be suitable for the physical environment and operating conditions of its intended use. The requirements of 4.4.2 to 4.4.8 cover the physical environment and operating conditions of the majority of machines covered by this part of IEC 60204. When special conditions apply or the limits specified are exceeded, ~~an agreement~~ exchange of information between user and supplier (see 4.1) can be necessary.

4.4.2 Electromagnetic compatibility (EMC)

The electrical equipment shall not generate electromagnetic disturbances above levels that are appropriate for its intended operating environment. In addition, the electrical equipment shall have a sufficient level of immunity to electromagnetic disturbances so that it can function in its intended environment.

Immunity and/or emission tests are required on the electrical equipment unless the following conditions are fulfilled:

- the incorporated devices and components comply with the EMC requirements for the intended EMC environment specified in the relevant product standard (or generic standard where no product standard exists), and;
- the electrical installation and wiring are consistent with the instructions provided by the supplier of the devices and components with regard to mutual influences, (cabling, screening, earthing etc.) or with informative Annex H if such instructions are not available from the supplier.

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.

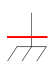
~~NOTE 2 IEC 61000-5-2 gives guidelines for earthing and cabling of electrical and electronic systems aimed at ensuring EMC. If specific product standards exist (for example, IEC 61496-1, IEC 61800-3, IEC 60947-5-2) they take precedence over generic standards.~~

~~Measures to limit the generation of electromagnetic disturbances, i.e. conducted and radiated emissions include:~~

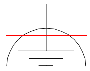
- ~~power supply filtering;~~
- ~~cable shielding;~~
- ~~enclosures designed to minimize RF radiation;~~
- ~~RF suppression techniques.~~

~~Measures to enhance the immunity of the equipment against conducted and radiated RF disturbance include:~~

- ~~design of functional bonding system taking into account the following;~~
  - ~~connection of sensitive electrical circuits to the chassis. Such terminations should be marked or labelled with the symbol IEC 60417-5020 (DB:2002-10):~~



  - ~~connection of the chassis to earth (PE) using a conductor with low RF impedance and as short as practicable;~~
- ~~connection of sensitive electrical equipment or circuits directly to the PE circuit or to a functional earthing conductor (FE) (see Figure 2), to minimize common mode disturbance. This latter terminal should be marked or labelled by the symbol IEC 60417-5018 (DB:2002-10):~~



- ~~separation of sensitive circuits from disturbance sources;~~
- ~~enclosures designed to minimize RF transmission;~~
- ~~EMC wiring practices:~~
  - ~~using twisted conductors to reduce the effect of differential mode disturbances,~~
  - ~~keeping sufficient distance between conductors emitting disturbances and conductors of sensitive circuits,~~
  - ~~using cable orientation as close to 90° as possible when cables cross,~~
  - ~~running the conductors as close as possible to the ground plane,~~
  - ~~using electrostatic screens and/or electromagnetic shields with a low RF impedance termination.~~

4.4.3 Ambient air temperature

Electrical equipment shall be capable of operating correctly in the intended ambient air temperature. The minimum requirement for all electrical equipment is correct operation in ambient air temperatures outside of enclosures (cabinet or box) between +5 °C and +40 °C. ~~For very hot environments (for example hot climates, steel mills, paper mills) and for cold environments, extra requirements can be necessary (see Annex B).~~

4.4.4 Humidity

The electrical equipment shall be capable of operating correctly when the relative humidity does not exceed 50 % at a maximum temperature of +40 °C. Higher relative humidities are permitted at lower temperatures (for example 90 % at 20 °C).

Harmful effects of occasional condensation shall be avoided by design of the equipment or, where necessary, by additional measures (for example built-in heaters, air conditioners, drain holes).

4.4.5 Altitude

Electrical equipment shall be capable of operating correctly at altitudes up to 1 000 m above mean sea level.

For equipment to be used at higher altitudes, it is necessary to take into account the reduction of:

- the dielectric strength, and;
- the switching capability of the devices, and;
- the cooling effect of the air.

It is recommended that the manufacturer is consulted regarding the correction factors to be used where the factors are not specified in product data.

4.4.6 Contaminants

Electrical equipment shall be adequately protected against the ingress of solids and liquids (see 11.3).

The electrical equipment shall be adequately protected against contaminants (for example dust, acids, corrosive gases, salts) that can be present in the physical environment in which the electrical equipment is to be installed~~ (see Annex B)~~.

4.4.7 Ionizing and non-ionizing radiation

When equipment is subject to radiation (for example microwave, ultraviolet, lasers, X-rays), additional measures shall be taken to avoid malfunctioning of the equipment and accelerated deterioration of the insulation.~~ A special agreement can be necessary between the supplier and the user (see Annex B).~~

4.4.8 Vibration, shock, and bump

Undesirable effects of vibration, shock and bump (including those generated by the machine and its associated equipment and those created by the physical environment) shall be avoided by the selection of suitable equipment, by mounting it away from the machine, or by provision of anti-vibration mountings.~~ A special agreement can be necessary between the supplier and the user (see Annex B).~~

4.5 Transportation and storage

Electrical equipment shall be designed to withstand, or suitable precautions shall be taken to protect against, the effects of transportation and storage temperatures within a range of –25 °C to +55 °C and for short periods not exceeding 24 h at up to +70 °C. Suitable means shall be provided to prevent damage from humidity, vibration, and shock.~~ A special agreement can be necessary between the supplier and the user (see Annex B).~~

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

4.6 Provisions for handling

Heavy and bulky electrical equipment that has to be removed from the machine for transport, or that is independent of the machine, shall be provided with suitable means for handling, including where necessary means for handling by cranes or similar 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

It is recommended that, where practicable, the electrical equipment of a machine is connected to a single incoming supply. Where another supply is necessary for certain parts of the 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 of the machine. For large complex machinery~~ comprising a number of widely-spaced machines 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).

Unless a plug is provided with the machine for the connection to the supply (see 5.3.2 e)), it is recommended that the supply conductors are terminated at the supply disconnecting device.

Where a neutral conductor is used it shall be clearly indicated in the technical documentation of the machine, such as in the installation diagram and in the circuit diagram, and a separate insulated terminal, labelled N in accordance with 16.1, shall be provided for the neutral conductor ~~(see also Annex B)~~. The neutral terminal may be provided as part of the supply disconnecting device.

There shall be no connection between the neutral conductor and the protective bonding circuit inside the electrical equipment ~~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 to the machine for~~ electrical equipment to a TN-C supply system~~s~~.

For machines supplied from parallel sources, the requirements of IEC 60364-1 for multiple source systems apply.

~~All~~ Terminals for the incoming supply connection shall be clearly identified in accordance with IEC 60445 ~~and 16.1~~. The terminal for the external protective conductor shall be identified in accordance with 5.2.

5.2 Terminal for connection ~~to~~ of the external protective ~~earthing system~~ conductor

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

The terminal shall be of such a size as to enable the connection of an external protective copper conductor with a cross-sectional area determined in relation to the size of the associated line conductors in accordance with Table 1.

Table 1 – Minimum cross-sectional area of ~~the external~~ copper protective conductors

Cross-sectional area of ~~copper phase conductors supplying the equipment~~ line conductors S mm²	Minimum cross-sectional area of the ~~external~~ corresponding protective ~~copper~~ conductor (PE) S_p mm²
$S \leq 16$	S
$16 < S \leq 35$	16
$S > 35$	$S/2$

Where an external protective conductor of a material other than copper is used, the terminal size and type shall be selected accordingly ~~(see also 8.2.2)~~.

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 (see IEC 60445).

5.3 Supply disconnecting (isolating) device

5.3.1 General

A supply disconnecting device shall be provided:

– for each incoming ~~source of~~ supply to (a) machine(s);

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

– for each on-board power supply.

The supply disconnecting device shall disconnect (isolate) the electrical equipment of the machine from the supply when required (for example for work on the machine, including the electrical equipment).

Where two or more supply disconnecting devices are provided, protective interlocks for their correct operation shall also be provided in order to prevent a hazardous situation, including damage to the machine or to the work in progress.

5.3.2 Type

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

a) switch-disconnector, with or without fuses, in accordance with IEC 60947-3, utilization category AC-23B or DC-23B;

~~b) disconnector, with or without fuses, in accordance with IEC 60947-3, 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;~~

b) control and protective switching device suitable for isolation, in accordance with IEC 60947-6-2;

c) a circuit-breaker suitable for isolation in accordance with IEC 60947-2;

d) any other switching device in accordance with an IEC product standard for that device and which meets the isolation requirements ~~of IEC 60947-1 as well as a~~ and the appropriate utilization category and/or specified endurance requirements defined in the product standard ~~as appropriate for on-load switching of motors or other inductive loads~~;

e) a plug/socket combination for a flexible cable supply.

5.3.3 Requirements

Where the supply disconnecting device is one of the types specified in 5.3.2 a) to d) it shall fulfil all of the following requirements:

– 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);

– 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;

– have an ~~external~~ operating means (see 5.3.4) ~~(for example handle), (exception: power-operated switchgear need not be operable from outside the enclosure where there are other means to open it). Where the external operating means is not intended for emergency operations, it is recommended that it be coloured BLACK or GREY (see 10.7.4 and 10.8.4)~~;

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

– 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 (when used) is compulsory;

– 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~~

other loads. The calculated breaking capacity may be reduced by the use of a proven diversity factor. Where motor(s) are supplied by converter(s) or similar devices, the calculation should take into account the possible effect on the required breaking capacity.

Where the supply disconnecting device is a plug/socket combination, it shall ~~fulfil~~ comply with the requirements of 13.4.5 and shall have the ~~switching capability~~ breaking capacity, or be interlocked with a switching device that has 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~~ other loads. The calculated breaking capacity may be reduced by the use of a proven diversity factor. Where the interlocked switching device is electrically operated (for example a contactor) it shall have an appropriate utilisation category. Where motor(s) are supplied by converter(s) or similar devices, the calculation should take into account the possible effect on the required breaking capacity.

~~– a) to f) of 13.4.5.~~

NOTE A suitably rated plug and socket-outlet, cable coupler, or appliance coupler, in accordance with IEC 60309-1 can fulfil these requirements.

Where the supply disconnecting device is a plug/socket combination, a switching device with an appropriate utilisation category shall be provided for switching the machine on and off. This can be achieved by the use of the interlocked switching device described above.

5.3.4 Operating means of the supply disconnecting device

The operating means (for example, a handle) of the supply disconnecting device shall be external to the enclosure of the electrical equipment.

Exception: power-operated switchgear need not be provided with a handle outside the enclosure where other means (e.g. pushbuttons) are provided to open the supply disconnecting device from outside the enclosure.

The operating means of the supply disconnecting device shall be easily accessible and located between 0,6 m and 1,9 m above the servicing level. An upper limit of 1,7 m is recommended.

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

Where the external operating means is intended for emergency operation, see 10.7.3 or 10.8.3.

Where the external operating means is not intended for emergency operations:

– it is recommended that it be coloured BLACK or GREY (see 10.2)
– a supplementary cover or door that can be readily opened without the use of a key or tool may be provided, for example for protection against environmental conditions or mechanical damage. Such a cover/door shall clearly show that it provides access to the operating means. This can be achieved, for example, by use of the relevant symbol IEC 60417-6169-1 (2012-08) (Figure 2) or IEC 60417-6169-2 (2012-08), (Figure 3).

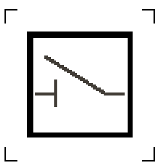


Figure 2 – Disconnector isolator

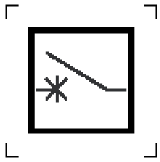


Figure 3 – Disconnecting circuit breaker

5.3.5 Excepted circuits

The following circuits need not be disconnected by the supply disconnecting device:

– lighting circuits for lighting needed during maintenance or repair;

– ~~plug and~~ socket outlets for the exclusive connection of repair or maintenance tools and equipment (for example hand drills, test equipment) (see 15.1);

– undervoltage protection circuits that are only provided for automatic tripping in the event of supply failure;

– circuits supplying equipment that should normally remain energized for correct operation (for example temperature controlled measuring devices, ~~product (work in progress)~~ heaters, program storage devices).

~~– control circuits for interlocking.~~

It is recommended, however, that such circuits be provided with their own disconnecting device.

Control circuits supplied via another supply disconnecting device, regardless of whether that disconnecting device is located in the electrical equipment or in another machine or other electrical equipment, need not be disconnected by the supply disconnecting device of the electrical equipment.

Where ~~such a~~ excepted circuits ~~is~~ are not disconnected by the supply disconnecting device:

– permanent warning label(s) ~~in accordance with 16.1~~ shall be appropriately placed in proximity to the operating means of the supply disconnecting device to draw attention to the hazard;

– a corresponding statement shall be included in the maintenance manual, and one or more of the following shall apply:

  - ~~a permanent warning label in accordance with 16.1 is affixed in proximity to each excepted circuit, or~~
  - the conductors are identified by colour taking into account the recommendation of 13.2.4;
  - ~~the~~ excepted circuits ~~is~~ are separated from other circuits;
  - excepted circuits are identified by permanent warning label(s).

5.4 Devices for ~~switching off~~ removal of power for prevention of unexpected start-up

Devices for ~~switching off~~ removal of power for the prevention of unexpected start-up shall be provided where a start-up of the machine or part of the machine can create a hazard (for example during maintenance). Such devices shall be appropriate and convenient for the intended use, be suitably placed, and readily identifiable as to their function and purpose ~~(for example by a durable marking in accordance with 16.1 where necessary)~~. Where their function and purpose is not otherwise obvious (e.g. by their location) these devices shall be marked to indicate the extent of removal of power.

NOTE 1 This part of IEC 60204 does not address all provisions for prevention of unexpected start up. Further information is provided in ISO 14118.

NOTE 2 Removal of power means removal of the connection to the source of electrical energy but does not imply isolation.

~~Means shall be provided to prevent inadvertent and/or mistaken closure of these devices either at the controller or from other locations (see also 5.6).~~

~~The following devices that fulfil the isolation function may be provided for this purpose:~~

- ~~devices described in 5.3.2,~~
- ~~disconnectors, withdrawable fuse links and withdrawable links only if located in an enclosed electrical operating area (see 3.19).~~

The supply disconnecting device or other devices in accordance with 5.3.2 may be used for prevention of unexpected start-up.

Disconnectors, withdrawable fuse links and withdrawable links may be used for protection of unexpected start-up only if they are located in an enclosed electrical operating area (see 3.1.23).

Devices that do not fulfil the isolation function (for example a contactor switched off by a control circuit, or Power Drive System (PDS) with a Safe Torque Off (STO) function in accordance with IEC 61800-5-2) may only be ~~provided where intended to be used for situations that include~~ used for prevention of unexpected start-up during tasks such as:

- inspections;
- adjustments;
- work on the electrical equipment where:
  - there is no hazard arising from electric shock (see Clause 6) and burn;
  - the switching off means remains effective throughout the work;
  - the work is of a minor nature (for example, replacement of plug-in devices without disturbing existing wiring).

NOTE ~~2~~ The selection of a device will be dependent on the risk assessment, taking into account the intended use of the device~~, for example, the use of disconnectors, withdrawable fuse links or withdrawable links located in enclosed electrical operating areas can be inappropriate for use by cleaners (see 17.2 b)12))~~ and the persons who are intended to operate them.

5.5 Devices for ~~disconnecting~~ isolating electrical equipment

Devices shall be provided for isolating (disconnecting) the electrical equipment or part(s) of the electrical equipment to enable work to be carried out when it is de-energised and isolated. Such devices shall be:

- appropriate and convenient for the intended use;
- suitably placed;
- readily identifiable as to which part(s) or circuit(s) of the equipment is served ~~(for example by durable marking in accordance with 16.1 where necessary)~~. Where their function and purpose is not otherwise obvious (e.g. by their location) these devices shall be marked to indicate the extent of the equipment that they isolate.

~~Means shall be provided to prevent inadvertent and/or mistaken closure of these devices either at the controller or from other locations (see also 5.6).~~

The supply disconnecting device (see 5.3) may, in some cases, fulfil that function. However, where it is necessary to work on individual parts of the electrical equipment of a machine, or on one of ~~a number of~~ the machines fed by a common conductor bar, conductor wire or inductive power supply system, a disconnecting device shall be provided for each part, or for each machine, requiring separate isolation.

In addition to the supply disconnecting device, the following devices that fulfil the isolation function may be provided for this purpose:

– devices described in 5.3.2;
– disconnectors, withdrawable fuse links and withdrawable links only if located in an enclosed electrical operating area (see 3.1.23) and relevant information is provided with the electrical equipment (see Clause 17).

~~NOTE Where protection against electric shock is provided in accordance with 6.2.2 c), withdrawable fuse links or withdrawable links for this purpose are intended for use by skilled or instructed persons.~~

5.6 Protection against unauthorized, inadvertent and/or mistaken connection

Where the devices described in 5.4 and 5.5 are located outside an enclosed electrical operating area they shall be equipped with means to secure them in the OFF position (disconnected state), (for example by provisions for padlocking, trapped key interlocking). When so secured, remote as well as local reconnection shall be prevented.

Where ~~a non-lockable disconnecting device (for example withdrawable fuse-links, withdrawable links)~~ the devices described in 5.4 and 5.5 are located inside an enclosed electrical operating area other means of protection against reconnection (for example warning labels) ~~may be provided~~ can be sufficient.

However, when a plug/socket combination according to 5.3.2 e) is so positioned that it can be kept under the immediate supervision of the person carrying out the work, means for securing in the disconnected state need not be provided.

6 Protection against electric shock

6.1 General

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

– ~~direct contact~~ basic protection (see 6.2 and 6.4), and;
– ~~indirect contact~~ fault protection (see 6.3 and 6.4).

The measures for protection given in 6.2, 6.3, and, for PELV, in 6.4, are a ~~recommended~~ selection from IEC 60364-4-41. Where those ~~recommended~~ measures are not practicable, for example due to the physical or operational conditions, other measures from IEC 60364-4-41 may be used (e.g. SELV).

6.2 Basic 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.

Exception: where those measures are not appropriate, other measures for basic protection ~~against direct contact~~ (for example by using barriers, by placing out of reach, using obstacles, using construction or installation techniques that prevent access) as defined in IEC 60364-4-41 may be applied (see also 6.2.5 and 6.2.6).

Where the equipment is located in places open to all persons, which can include children, measures of either 6.2.2 with a minimum degree of protection against ~~direct~~ contact with live parts corresponding to IP4X or IPXXD (see IEC 60529), or 6.2.3 shall be applied.

6.2.2 Protection by enclosures

Live parts shall be located inside enclosures that ~~conform to the relevant requirements of Clauses 4, 11, and 14 and that~~ provide protection against ~~direct~~ contact with live parts of at least IP2X or IPXXB (see IEC 60529).

Where the top surfaces of the enclosure are readily accessible, the minimum degree of protection against ~~direct~~ contact with live parts provided by the top surfaces shall be IP4X or IPXXD.

Opening an enclosure (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. ~~For enclosed electrical operating areas, see IEC 60364-4-41, or IEC 60439-1 as appropriate.~~

NOTE 1 The use of a key or tool is intended to restrict access to skilled or instructed persons (see 17.2 f)).

All live parts, (including those on the inside of doors) that are likely to be touched when resetting or adjusting devices intended for such operations while the equipment is still connected, shall be protected against ~~direct~~ contact to at least IP2X or IPXXB. Other live parts on the inside of doors shall be protected against unintentional direct contact to at least IP1X or IPXXA.

b) The disconnection of live parts inside the enclosure before the enclosure can be opened.

This may be accomplished by interlocking the door with a disconnecting device (for example, the supply disconnecting device) so that the door can only be opened when the disconnecting device is open and so that the disconnecting device can only be closed when the door is closed.

Exception: a ~~special device~~ key or tool as prescribed by the supplier can be used to defeat the interlock provided that the following conditions are met:

– it is possible at all times while the interlock is defeated to open the disconnecting device and lock the disconnecting device in the OFF (isolated) position or otherwise prevent unauthorised closure of the disconnecting device;

– upon closing the door, the interlock is automatically restored;

– all live parts, (including those on the inside of doors) that are likely to be touched when resetting or adjusting devices intended for such operations while the equipment is still connected, are protected against ~~direct~~ unintentional contact with live parts to at least IP2X or IPXXB and other live parts on the inside of doors are protected against ~~direct~~ unintentional contact to at least IP1X or IPXXA;

– relevant information about the procedures for the defeat of the interlock is provided with the instructions for use of the electrical equipment (see Clause 17).

~~NOTE 2 The special device or tool is intended for use only by skilled or instructed persons (see 17.2 b)12)).~~

– means ~~shall be~~ are provided to restrict access to live parts behind doors that are not directly interlocked with the disconnecting means to skilled or instructed persons. (See 17.2 b)).

All parts that are still live after switching off the disconnecting device(s) (see 5.3.5) shall be protected against direct contact to at least IP2X or IPXXB (see IEC 60529). Such parts shall be marked with a warning sign in accordance with 16.2.1 (see also 13.2.4 for identification of conductors by colour), except for:

~~Excepted from this requirement for marking are:~~

– parts that can be live only because of connection to interlocking circuits and that are distinguished by colour as potentially live in accordance with 13.2.4;

– the supply terminals of the supply disconnecting device when the latter is mounted alone in a separate enclosure.

c) Opening without the use of a key or a tool and without disconnection of live parts shall be possible only when all live parts are protected against ~~direct~~ contact to at least IP2X or IPXXB (see IEC 60529). Where barriers provide this protection, either they shall require a tool for their removal or all live parts protected by them shall be automatically disconnected when the barrier is removed.

   ~~NOTE 3~~ Where protection against ~~direct~~ contact is achieved in accordance with 6.2.2 c), and a hazard can be caused by manual actuation of devices (for example manual closing of contactors or relays), such actuation should be prevented by barriers or obstacles that require a tool for their removal.

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~~ when the supply ~~has been~~ is disconnected shall be discharged to 60 V or less within a time period of 5 s ~~after disconnection of the supply voltage~~ provided that this rate of discharge does not interfere with the proper functioning of the equipment. Exempted from this requirement are components having a stored charge of 60 µC or less. Where this specified rate of discharge would interfere with the proper functioning of the equipment, a durable warning notice drawing attention to the hazard and stating the delay required before the enclosure may be opened shall be displayed at an easily visible location on or immediately adjacent to the enclosure that contains the ~~capacitances~~ live parts.

In the case of plugs or similar devices, the withdrawal of which results in the exposure of conductors (for example pins), the discharge time to 60 V 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 (for example in the case of removable collectors on conductor wires, conductor bars, or slip-ring assemblies, see 12.7.4), additional switching devices or an appropriate warning ~~device (for example a warning notice in accordance with 16.1) shall be applied~~, for example a warning sign drawing attention to the hazard and stating the delay required shall be provided. When the equipment is located in places open to all persons, which can include children, warnings are not sufficient and therefore a minimum degree of protection against contact with live parts to IP4X or IPXXD is required.

NOTE Frequency converters and DC bus supplies could have typically a longer discharge time than 5 s.

6.2.5 Protection by barriers

For protection by barriers, the requirements of IEC 60364-4-41 shall apply.

6.2.6 Protection by placing out of reach or protection by obstacles

For protection by placing out of reach, the requirements of IEC 60364-4-41 shall apply. For protection by obstacles, the requirements of IEC 60364-4-41 shall apply.

For conductor wire systems or conductor bar systems with a degree of protection less than IP2X or IPXXB, see 12.7.1.

6.3 Fault protection ~~against indirect contact~~

6.3.1 General

Fault protection ~~against indirect contact~~ (3.31) 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 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 IEC 61140 provides information about classes of equipment and protective provisions.

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.

This protection is provided by one or more of the following:

– class II electrical devices or apparatus (double insulation, reinforced insulation or by equivalent insulation in accordance with IEC 61140);

– switchgear and controlgear assemblies having total insulation in accordance with IEC ~~60439-1~~ 61439-1;

– supplementary or reinforced insulation in accordance with IEC 60364-4-41.

6.3.2.3 Protection by electrical separation

Electrical separation of an individual circuit is intended to prevent a 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.

For this type of protection, the requirements of IEC 60364-4-41 apply.

6.3.3 Protection by automatic disconnection of supply

Automatic disconnection of the supply of any circuit affected by an insulation fault is intended to prevent a hazardous situation resulting from a touch voltage.

This measure consists of the interruption of one or more of the line conductors by the automatic operation of a protective device in case of a fault. This interruption shall occur within a sufficiently short time to limit the duration of a touch voltage to a time within ~~which the touch voltage is not hazardous~~ the limits specified in Annex A for TN and TT systems. ~~Interruption times are given in Annex A.~~

This measure necessitates co-ordination between:

– the type of supply system, the supply source impedance and the earthing system;
– the impedance values of the different elements of the line and of the associated fault current paths through the protective bonding ~~system~~ circuit;
– the characteristics of the protective devices that detect insulation fault(s).

NOTE 1 Details of verification of conditions for protection by automatic disconnection of supply are provided in 18.2.

This protective measure comprises both:

– protective bonding of exposed conductive parts (see 8.2.3),
– and one of the following:
  a) In TN systems, the following protective devices may be used:
     - overcurrent protective devices ~~for the automatic disconnection of the supply on detection of an insulation fault in TN systems, or~~;
     - residual current protective devices (RCDs) and associated overcurrent protective device(s).

     NOTE 2 The preventive maintenance can be enhanced by use of a residual current monitoring device, RCM, complying with IEC 62020.
  b) in TT systems, either:
     - RCDs and associated overcurrent protective device(s) 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
     - overcurrent protective devices may be used for fault protection provided a suitably low value of the fault loop impedance Z_s (see A.2.2.3) is permanently and reliably assured;

     NOTE 3 The preventive maintenance can be enhanced by use of a residual current monitoring device, RCM, complying with IEC 62020.
  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.~~

     In IT systems the relevant requirements of IEC 60364-4-41 shall be fulfilled. During an insulation fault, an acoustic and optical signal shall be sustained. After annunciation, the acoustic signal may then be manually muted. This can require an agreement between the supplier and user regarding the provision of insulation monitoring devices and/or insulation fault location system(s).

     NOTE 4 In large machines, the provision of an ~~earth~~ insulation fault location system (IFLS) in accordance with IEC 61557-9 can facilitate maintenance.

Where automatic disconnection is provided in accordance with a), and disconnection within the time specified in A.1.1 cannot be assured, supplementary protective bonding shall be provided as necessary to meet the requirements of A.1.3.

Where a power drive system (PDS) is provided, fault protection shall be provided for those circuits of the power drive system that are supplied by the converter. Where this protection is not provided within the converter, the necessary protection measures shall be in accordance with the converter manufacturer's instructions.

6.4 Protection by the use of PELV

6.4.1 General requirements

The use of PELV (Protective Extra-Low Voltage) is to protect persons against electric shock from indirect contact and limited area direct contact (see 8.2.1).

PELV circuits shall satisfy all of the following conditions:

a) the nominal voltage shall not exceed:
   - 25 V AC r.m.s. or 60 V ripple-free DC when the 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 AC r.m.s. or 15 V ripple-free DC 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.

7 Protection of equipment

7.1 General

This Clause 7 details the measures to be taken to protect equipment against the effects of:

– overcurrent arising from 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 where the current in ~~a machine~~ any circuit 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 selected are detailed in 7.2.10.

7.2.2 Supply conductors

Unless otherwise specified by the user, the supplier of the electrical equipment is not responsible for providing the supply conductors and the overcurrent protective device for the supply conductors to the electrical equipment ~~(see Annex B)~~.

The supplier of the electrical equipment shall state ~~on~~ in the installation ~~diagram~~ documents the data necessary for conductor dimensioning (including the maximum cross-sectional area of the supply conductor that can be connected to the terminals of the electrical equipment) and for selecting the overcurrent protective device (see 7.2.10 and 17).

7.2.3 Power circuits

Devices for detection and interruption of overcurrent, selected in accordance with 7.2.10, shall be applied to each live conductor including circuits supplying control circuit transformers.

The following conductors, as applicable, shall not be disconnected without disconnecting all associated live conductors:

– the neutral conductor of AC power circuits;
– the earthed conductor of DC power circuits;
– DC power conductors bonded to exposed conductive parts of mobile machines.

Where the cross-sectional area of the neutral conductor is at least equal to or equivalent to that of the ~~phase~~ line conductors, it is not necessary to provide overcurrent detection for the neutral conductor nor a disconnecting device for that conductor. For a neutral conductor with a cross-sectional area smaller than that of the associated ~~phase~~ line conductors, the measures detailed in 524 of IEC 60364-5-52:2009 shall apply.

In IT systems, it is recommended that the neutral conductor is not used. However, where a neutral conductor is used, the measures detailed in 431.2.2 of IEC 60364-4-43:2008 shall apply.

7.2.4 Control circuits

Conductors of control circuits directly connected to the supply voltage ~~and of circuits supplying control circuit transformers~~ shall be protected against overcurrent in accordance with 7.2.3.

Conductors of control circuits supplied by a ~~control circuit~~ transformer or DC supply shall be protected against overcurrent (see also 9.4.3.1.1):

– in control circuits connected to the protective bonding circuit, by inserting an overcurrent protective device into the switched conductor;
– in control circuits not connected to the protective bonding circuit;
  - where ~~the same cross sectional area conductors are used in all control circuits~~ all control circuits of the equipment have the same current carrying capacity, by inserting an overcurrent protective device into the switched conductor, ~~and~~ or;
  - where different ~~cross sectional areas conductors are used in different sub-circuits~~ control circuits of the equipment have different current carrying capacity, by inserting

an overcurrent protective device into both switched and common conductors of each ~~sub-~~control circuit.

Exception: Where the supply unit provides current limiting below the current carrying capacity of the conductors in a circuit and below the current rating of connected components, no separate overcurrent protective device is required.

7.2.5 Socket outlets and their associated conductors

Overcurrent protection shall be provided for the circuits feeding the general purpose socket outlets intended primarily for supplying power to maintenance equipment. Overcurrent protective devices shall be provided in the unearthed live conductors of each circuit feeding such socket outlets. See also 15.1.

7.2.6 Lighting circuits

All unearthed conductors of circuits supplying lighting shall be protected against the effects of short-circuits by the provision of overcurrent devices separate from those protecting other circuits.

7.2.7 Transformers

Transformers shall be protected ~~against~~ by an overcurrent protective device having a type and setting in accordance with the transformer manufacturer's instructions. Such protection shall (see also 7.2.10):

– avoid nuisance tripping due to transformer magnetizing inrush currents;

– avoid a winding temperature rise in excess of the permitted value for the insulation class of transformer when it is subjected to the effects of a short-circuit at its secondary terminals.

~~The type and setting of the overcurrent protective device should be in accordance with the recommendations of the transformer supplier.~~

7.2.8 Location of overcurrent protective devices

An overcurrent protective device shall be located at the point where a reduction in the cross-sectional area of the conductors or another change reduces the current-carrying capacity of the conductors, except where all the following conditions are satisfied:

– the current carrying capacity of the conductors is at least equal to that of the load;

– the part of the conductor(s) between the point of reduction of current-carrying capacity and the position of the overcurrent protective device is no longer than 3 m;

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

7.2.9 Overcurrent protective devices

The rated short-circuit breaking capacity shall be at least equal to the prospective fault current at the point of installation. 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.

~~A lower breaking capacity is permitted where another protective device (for example the overcurrent protective device for the supply conductors (see 7.2.2) having the necessary breaking capacity is installed on the supply side. In that case, the characteristics of the two devices shall be co-ordinated 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 (see Annex A of IEC 60947-2).~~

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

NOTE Information on co-ordination under short-circuit conditions between a circuit-breaker and another short-circuit protective device is provided in Annex A of IEC 60947-2:2006, IEC 60947-2:2006/AMD1:2009 and IEC 60947-2:2006/AMD2:2013.

Where fuses are provided as overcurrent protective devices, a type readily available in the country of use shall be selected, or arrangements shall be made for the supply of spare parts.

7.2.10 Rating and setting of overcurrent protective devices

The rated current of fuses or the setting current of other overcurrent protective devices shall be selected as low as possible 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)~~.

The rated current or setting of an overcurrent protective device for conductors is determined by the current carrying capacity of the conductors to be protected in accordance with 12.4, Clause D.3 and the maximum allowable interrupting time t in accordance with Clause D.4, taking into account the needs of co-ordination with other electrical devices in the protected circuit.

7.3 Protection of motors against overheating

7.3.1 General

Protection of motors against overheating shall be provided for each motor rated at more than 0,5 kW.

Exception: In applications where an automatic interruption of the motor operation is unacceptable (for example fire pumps), the means of detection shall give a warning signal to which the operator can respond.

Protection of motors against overheating can be achieved by:

– overload protection (7.3.2),

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), or

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

– current-limiting protection ~~(7.3.4)~~.

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 or to the work in progress.

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.

However, where the motor overload detection is not used for cable overload protection (see also Clause D.2), ~~the number of overload detection devices may be reduced at the request of the user (see also Annex B)~~ detection of overload may be omitted in one of the live conductors. For motors having single-phase or DC 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.

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 (for example dusty environments). Depending upon the type 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 are either protected by mechanical overload protection devices or are adequately dimensioned), where the possibility of over-temperature exists (for example due to reduced cooling).

~~7.3.4 Current limiting protection~~

~~Where Protection against the effects of overheating in three phase motors is achieved by current limitation, the number of current limitation devices may be reduced from 3 to 2 (see 7.3.2). For motors having single phase a.c or d.c. power supplies, current limitation in only one unearthed live conductor is permitted.~~

7.4 Protection against abnormal temperature ~~protection~~

~~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) and therefore can cause a hazardous situation shall be provided with suitable detection to initiate an appropriate control response.~~

Equipment shall be protected against abnormal temperatures that can result in a hazardous situation.

7.5 Protection against the effects of supply interruption or voltage reduction and subsequent restoration

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

Where the operation of the machine 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 machine.

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

Where only a part of the machine or of the group of machines working together in a co-ordinated manner is affected by the voltage reduction or supply interruption, the undervoltage protection shall initiate appropriate control ~~responses~~ commands to ensure co-ordination.

7.6 Motor overspeed protection

Overspeed protection shall be provided where overspeeding can occur and could possibly cause a hazardous situation taking into account measures in accordance with 9.3.2. Overspeed protection shall initiate appropriate control responses and shall prevent automatic restarting.

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

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

7.7 Additional 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 equipment due to earth fault currents less than the detection level of the overcurrent protection.

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

If fault currents with DC components are possible, an RCD of type B in accordance with IEC TR 60755 can be required.

7.8 Phase sequence protection

Where an incorrect phase sequence of the supply voltage can cause a hazardous situation or damage to the machine, protection shall be provided.

NOTE Conditions of use that can lead to an incorrect phase sequence include:

- a machine transferred from one supply to another;
- a mobile machine with a facility for connection to an external power supply.

7.9 Protection against overvoltages due to lightning and to switching surges

Surge protective devices (SPDs) can be provided to protect against the effects of overvoltages due to lightning or to switching surges.

Where provided:

– ~~devices~~ SPDs for the suppression of overvoltages due to lightning shall be connected to the incoming terminals of the supply disconnecting device.
– ~~devices~~ SPDs for the suppression of overvoltages due to switching surges shall be connected ~~across the terminals of all~~ as necessary for equipment requiring such protection.

NOTE 1 Information about the correct selection and installation of SPDs is given for example in IEC 60364-4-44, IEC 60364-5-53, IEC 61643-12, IEC 62305-1 and IEC 62305-4.

NOTE 2 Equipotential bonding of the machine, its electrical equipment and extraneous-conductive-parts to a common bonding network of the building/site can help mitigate electromagnetic interference, including the effects of lightning, on the equipment.

7.10 Short-circuit current rating

The short-circuit current rating of the electrical equipment shall be determined. This can be done by the application of design rules or by calculation or by test.

NOTE The short-circuit current rating may be determined, for example, in accordance with IEC 61439-1, IEC 60909-0, IEC/TR 60909-1, or IEC/TR 61912-1.

8 Equipotential bonding

8.1 General

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

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

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

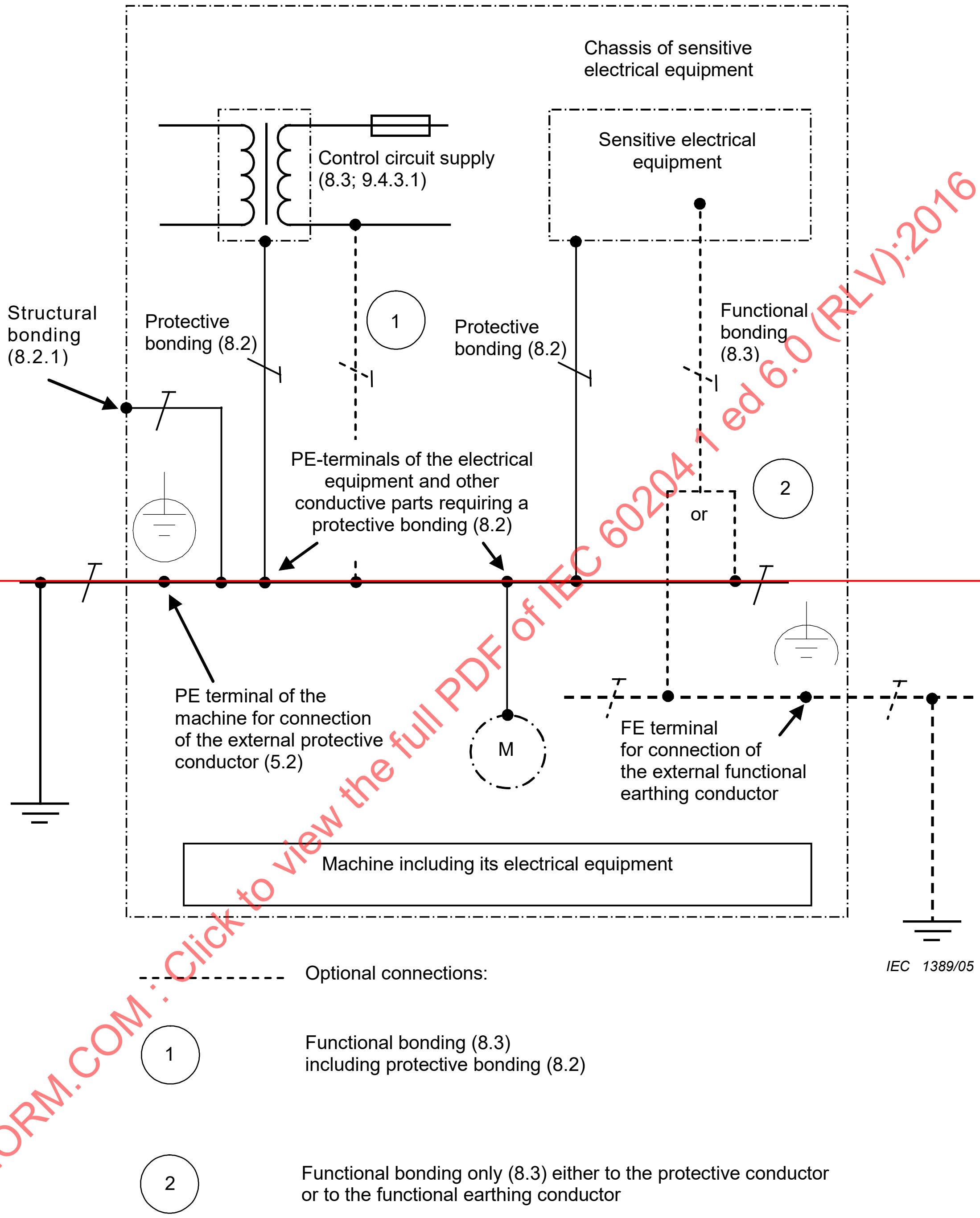
– the consequence of an insulation failure which could affect the operation of the machine;

~~– the consequences of electrical disturbances to sensitive electrical equipment which could affect the operation of the machine.~~

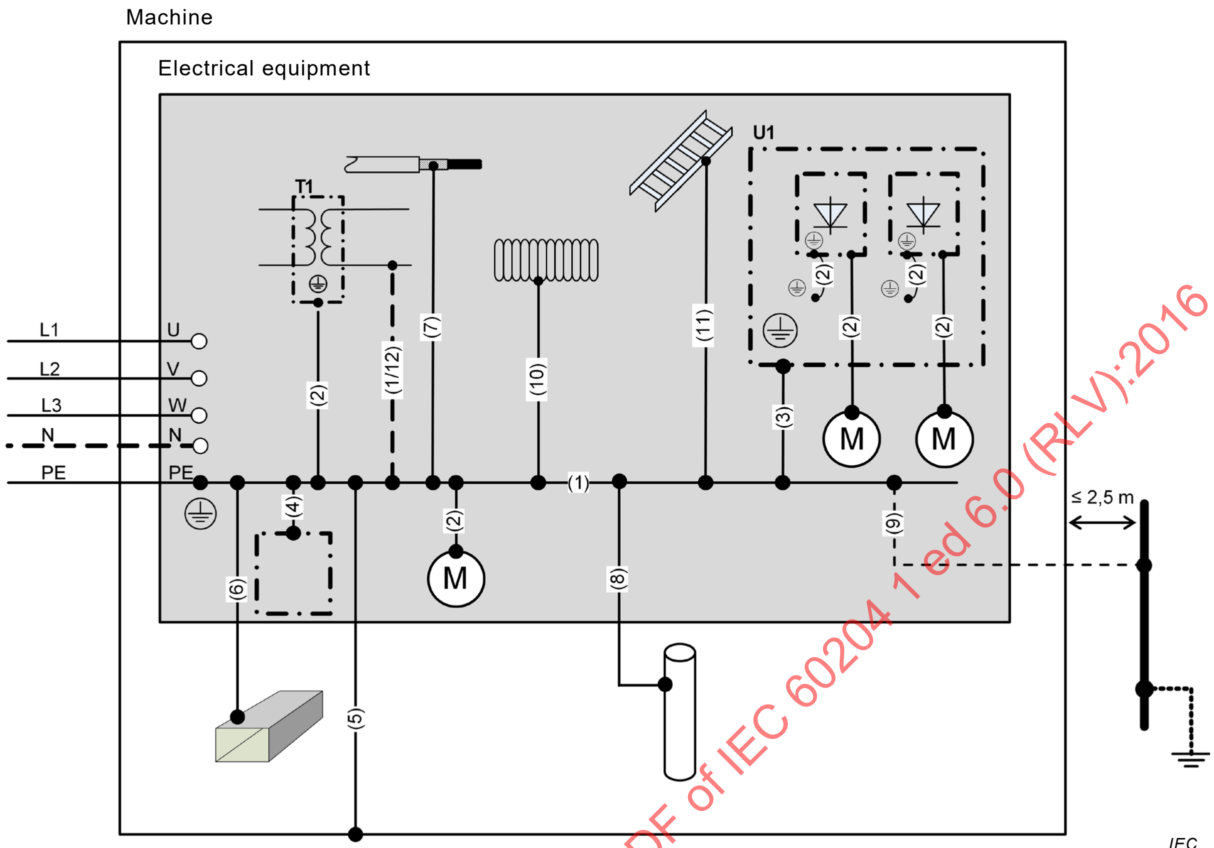
– electrical disturbances to sensitive electrical equipment which could affect the operation of the machine;

– induced currents from lightning which could damage the electric equipment.

~~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 ~~may~~ can be necessary to ~~connect the functional bonding circuit to a separate functional earthing conductor (see Figure 2)~~ use separate conductors for protective and functional bonding.



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



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

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

8.2 Protective bonding circuit

8.2.1 General

The protective bonding circuit consists of the interconnection of:

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

Exception: see 8.2.5.

- conductive structural parts of the machine.

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

~~Where the conductance of structural parts of the electrical equipment or of the machine is less than that of the smallest protective conductor connected to the exposed conductive parts, a supplementary bonding conductor shall be provided. This supplementary bonding conductor shall have a cross-sectional area not less than half that of the corresponding protective conductor.~~

~~If an IT distribution system is used, the machine structure shall be part of the protective bonding circuit and insulation monitoring shall be provided. See 6.3.3 c).~~

~~Conductive structural parts of 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 machine need not be connected to the protective bonding circuit where all the equipment provided is in accordance with 6.3.2.2.~~

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

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

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

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

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

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

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

This applies to small parts such as screws, rivets, and nameplates and to parts inside an enclosure, irrespective of their size (for example electromagnets of contactors or relays and mechanical parts of devices) ~~(see also 410.3.3.5 of IEC 60364-4-41)~~.

8.2.2 Protective conductors

Protective conductors shall be identified in accordance with 13.2.2.

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

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

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

The cross-sectional area of protective conductors shall either be ~~determined~~ calculatedin accordance with ~~the requirements of~~ 543.1.2 of IEC 60364-5-54:2011 ~~and 7.4.3.1.7 of IEC 60439-1, as appropriate~~, or selected in accordance with Table 1 (see 5.2). See also 8.2.6. and 17.2 (d) of this document.

~~This requirement is met in most cases where the relationship between the cross-sectional area of the phase conductors associated with that part of the equipment and the cross-sectional area of the associated protective conductor is in accordance with Table 1 (see 5.2).~~

~~See also 8.2.8.~~

Each protective conductor shall:

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

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

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

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

- conductive structural parts of the machine;
- metal ducts of flexible or rigid construction;
- metallic cable sheaths or armouring;
- metallic pipes containing flammable materials such as gases, liquids, powder.
- flexible or pliable metal conduits;

- constructional parts subject to mechanical stress in normal service;
- flexible metal parts; support wires; cable trays and cable ladders.

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

8.2.3 Continuity of the protective bonding circuit

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

~~Exception: see 8.2.5.~~

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

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

~~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.~~

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~~ Where a protective conductor is not provided, fastenings, hinges or sliding contacts designed to have a low resistance shall be used (see 18.2.2, Test 1).

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

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

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

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

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

~~8.2.4 Exclusion of switching devices from the protective bonding circuit~~

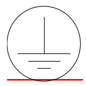
~~No means of interruption of the protective bonding conductor shall be provided.~~

~~**8.2.5 Parts that need not be connected to the protective bonding circuit**~~

8.2.4 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 60417-5019:2006-08 ~~(DB:2002-10)~~ as illustrated in Figure 5:



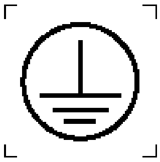


Figure 5 – Symbol IEC 60417-5019: Protective earth

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

8.2.5 Mobile machines

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

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

8.2.6 Additional ~~protective bonding~~ requirements for electrical equipment having earth leakage currents higher than 10 mA ~~a.c. or d.c.~~

~~NOTE 1 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.~~

~~NOTE 2 Most adjustable speed electrical power drive systems that comply with relevant parts of IEC 61800 will have an earth leakage current greater than 3,5 mA a.c. A touch current measurement method is specified as a type test in IEC 61800-5-1 to determine the earth leakage current of an adjustable speed electrical power drive system.~~

Where electrical equipment has an earth leakage current ~~(for example adjustable speed electrical power drive systems and information technology equipment)~~ that is greater than 10 mA AC or DC in any ~~incoming supply~~ protective conductor, one or more of the following conditions for the integrity of each section of the associated protective bonding circuit that carries the earth leakage current shall be satisfied:

a) the protective conductor is completely enclosed within electrical equipment enclosures or otherwise protected throughout its length against mechanical damage;

b) the protective conductor ~~shall have~~ has a cross-sectional area of at least 10 mm^2 Cu or 16 mm^2 Al~~, through its total run~~;

c) where the protective conductor has a cross-sectional area of less than 10 mm^2 Cu or 16 mm^2 Al, a second protective conductor of at least the same cross-sectional area ~~shall be~~ is provided up to a point where the protective conductor has a cross-sectional area not less than 10 mm^2 Cu or 16 mm^2 Al.

   ~~NOTE 3~~ This can require that the electrical equipment has a separate terminal for a second protective conductor;

d) the supply is automatically disconnected in case of loss of continuity of the protective conductor;

e) where a plug-socket combination is used, an industrial connector in accordance with IEC 60309 series, with adequate strain relief and a minimum protective earthing conductor cross-section of 2,5 mm^2 as part of a multi-conductor power cable is provided.

~~To prevent difficulties associated with electromagnetic disturbances, the requirements of 4.4.2 also apply to the installation of duplicate protective conductors.~~

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

NOTE A warning label ~~shall~~ may also be provided adjacent to the PE terminal to state that the protective conductor current exceeds 10mA~~, and where necessary on the nameplate of the electrical equipment~~.

~~The information provided under 17.2 b)1) shall include information about the leakage current and the minimum cross-sectional area of the external protective conductor.~~

8.3 Measures to ~~limit~~ restrict the effects of high leakage current

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

8.4 Functional bonding

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

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

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

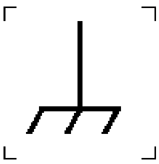


Figure 6 – Symbol IEC 60417-5020: Frame or chassis

9 Control circuits and control functions

9.1 Control circuits

9.1.1 Control circuit supply

Where control circuits are supplied from an AC source, ~~control transformers shall be used for supplying the control circuits. Such~~ transformers ~~shall have~~ having separate windings shall be used to separate the power supply from the control supply.

Examples include:

- control transformers having separate windings in accordance with IEC 61558-2-2,
- switch mode power supply units in accordance with IEC 61558-2-16 fitted with transformers having separate windings,
- low voltage power supplies in accordance with IEC 61204-7 fitted with transformers having separate windings.

Where several transformers are used, it is recommended that the windings of those transformers be connected in such a manner that the secondary voltages are in phase.

Exception: Transformers or switch mode power supply units fitted with transformers are not mandatory for machines with a single motor starter and/or a maximum of two control devices (for example, interlock device, start/stop control station).

Where DC control circuits derived from an AC supply are connected to the protective bonding circuit (see 8.2.1), they shall be supplied from a separate winding of the AC control circuit transformer or by another control circuit transformer.

~~NOTE Switch-mode units fitted with transformers having separate windings in accordance with IEC 61558-2-17 meet this requirement.~~

9.1.2 Control circuit voltages

The nominal value of the control voltage shall be consistent with the correct operation of the control circuit.

The nominal voltage of AC control circuits ~~shall~~ should preferably not exceed

– 230 V for circuits with 50 Hz nominal frequency,

– 277 V ~~when supplied from a transformer~~ for circuits with 60 Hz nominal frequency.

The nominal voltage of DC control circuits should preferably not exceed 220 V.

9.1.3 Protection

Control circuits shall be provided with overcurrent protection in accordance with 7.2.4 and 7.2.10.

9.2 Control functions

9.2.1 ~~Start functions~~ General

~~NOTE 1 Information on the safety-related aspects of control functions is given in ISO 13849-1 (1999), ISO 13849-2 (2003), and IEC 62061.~~

NOTE ~~2~~ Subclause 9.2 does not specify requirements for the ~~equipment~~ devices used to implement control functions. Examples of ~~such~~ requirements for devices are given in Clause 10.

~~Start functions shall operate by energizing the relevant circuit (see 9.2.5.2).~~

9.2.2 Categories of stop functions

There are three categories of stop functions as follows:

– stop category 0: stopping by immediate removal of power to the machine actuators (i.e. an uncontrolled stop – see 3.1.64);

– stop category 1: a controlled stop (see 3.1.14) 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 with power ~~left~~ remaining available to the machine actuators.

NOTE For removal of power it can be sufficient to remove the power needed to generate a torque or force. This can be achieved by declutching, disconnecting, switching off, or by electronic means (e.g. a PDS in accordance with IEC 61800 series), etc.

9.2.3 Operation

9.2.3.1 General

~~The necessary~~ Safety functions and/or protective measures (for example interlocks (see 9.3)) shall be provided ~~for safe operation~~ where required to reduce the possibility of hazardous situations.

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

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

9.2.3.2 Start

Start functions shall operate by energizing the relevant circuit.

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 9.3.6.

For those machines (for example mobile machines) where safety functions and/or protective measures cannot be applied for certain operations, ~~manual control~~ starting of such operations shall be by hold-to-run controls, together with enabling devices, as appropriate.

The provision of acoustic and/or visual warning signals before the starting of hazardous machine operation should be considered.

Suitable interlocks shall be provided ~~to secure~~ where necessary for correct sequential starting.

In the case of machines requiring the use of more than one control station to initiate a start, each of these control stations shall have a separate manually actuated start control device. The conditions to initiate a start shall be:

- all required conditions for machine operation shall be met, and
- all start control devices shall be in the released (off) position, then
- all start control devices shall be actuated concurrently (see 3.1.7).

9.2.3.3 Stop

Stop category 0 and/or stop category 1 and/or stop category 2 stop functions shall be provided as indicated by the risk assessment and the functional requirements of the machine (see 4.1).

NOTE 1 The supply disconnecting device (see 5.3) when operated achieves a stop category 0.

Stop functions shall override related start functions ~~(see 9.2.5.2)~~.

~~Where required, facilities to connect protective devices and interlocks shall be provided. If such a protective device or interlock causes a stop of the machine, it may be necessary for that condition to be signalled to the logic of the control system. The reset of the stop function shall not initiate any hazardous situation.~~

Where more than one control station is provided, stop commands from any control station shall be effective when required by the risk assessment of the machine.

NOTE 2 When stop functions are initiated, it can be necessary to discontinue machine functions other than motion.

9.2.3.4 Emergency operations (emergency stop, emergency switching off)

9.2.3.4.1 General

~~NOTE~~ Emergency stop and emergency switching off are complementary protective measures that are not primary means of risk reduction for hazards (for example trapping, entanglement, electric shock or burn) at a machine (see ISO 12100 ~~(all parts)~~).

This part of IEC 60204 specifies the requirements for the emergency stop and the emergency switching off functions of the emergency operations listed in Annex E, both of which are~~, in this part of IEC 60204,~~ intended to be initiated by a single human action.

Once active operation of an emergency stop (see 10.7) or emergency switching off (see 10.8) actuator has ceased following a stop or switching off command, the effect of this command shall be sustained until it is reset. This reset shall be possible only by a manual action at ~~that location~~ the device where the command has been initiated. The reset of the command shall not restart the machinery but only permit restarting.

It shall not be possible to restart the machinery until all emergency stop commands have been reset. It shall not be possible to reenergize the machinery until all emergency switching off commands have been reset.

9.2.3.4.2 Emergency stop

~~Principles~~ Requirements for functional aspects of emergency stop equipment are given in ISO 13850.

The emergency stop shall function either as a stop category 0 or as a stop category 1 ~~(see 9.2.2)~~. The choice of the stop category of the emergency stop depends on the results of a risk assessment of the machine.

Exception: In some cases, to avoid creating additional risks, it can be necessary to perform a controlled stop and maintain the power to machine actuators even after stopping is achieved. The stopped condition shall be monitored and upon detection of failure of the stopped condition, power shall be removed without creating a hazardous situation.

In addition to the requirements for stop given in 9.2.3.3, the emergency stop function has the following requirements:

- it shall override all other functions and operations in all modes;
- ~~power to the machine actuators that can cause a hazardous situation(s) shall be either removed immediately (stop category 0) or shall be controlled in such a way to stop the hazardous motion as quickly as possible (stop category 1) without creating other hazards;~~
- it shall stop the hazardous motion as quickly as practicable without creating other hazards;
- reset shall not initiate a restart.

9.2.3.4.3 Emergency switching off

The functional aspects of emergency switching off are given in 536.4 of IEC 60364-5-53:2001.

Emergency switching off should be provided where:

- basic protection ~~against direct contact~~ (for example ~~with~~ for conductor wires, conductor bars, slip-ring assemblies, controlgear in electrical operating areas) is achieved only by placing out of reach or by obstacles (see 6.2.6); or
- there is the possibility of other hazards or damage caused by electricity.

Emergency switching off is accomplished by switching off the relevant ~~incoming~~ supply by electromechanical switching devices, effecting a stop category 0 of machine actuators connected to this incoming supply. When a machine cannot tolerate this ~~stop~~ category 0 stop, it may be necessary to provide other measures, for example basic protection ~~against direct contact~~, so that emergency switching off is not necessary.

9.2.3.5 Operating modes

Each machine can have one or more operating modes (for example manual mode, automatic mode, setting mode, maintenance mode) determined by the type of machine and its application. ~~When a hazardous situation can result from a mode selection, unauthorised and/or inadvertent selection shall be prevented by suitable means (for example key operated switch, access code).~~

Where machinery has been designed and constructed to allow its use in several control or operating modes requiring different protective measures and having a different impact on safety, it shall be fitted with a mode selector which can be locked in each position (for example key operated switch). Each position of the selector shall be clearly identifiable and shall correspond to a single operating or control mode.

The selector may be replaced by another selection method which restricts the use of certain functions of the machinery to certain categories of operator (for example access code).

Mode selection by itself shall not initiate machine operation. A separate actuation of the 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).

9.2.3.6 Monitoring of command actions

Movement or action of a machine or part of a machine that can result in a hazardous situation shall be monitored by providing, for example, overtravel limiters, motor overspeed detection, mechanical overload detection or anti-collision devices.

NOTE On some manually controlled machines (for example, manual drilling machine), operators provide monitoring.

~~9.2.6 Other control functions~~

9.2.3.7 Hold-to-run controls

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

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

9.2.3.8 Two-hand control

Three types of two-hand control are defined in ISO 13851, the selection of which is determined by the risk assessment. These shall 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;
- machine operation 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 machine operation 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 machine operation can be initiated.

9.2.3.9 Enabling control

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

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

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 machine operation may be reinitiated. ~~It should not be possible to defeat the enabling function by simple means.~~

9.2.3.10 Combined start and stop controls

Push-buttons and similar control devices that, when operated, alternately initiate and stop motion shall only be provided for functions which cannot result in a hazardous situation.

9.2.4 Cableless control system (CCS)

9.2.4.1 General requirements

Subclause 9.2.4 deals with the functional requirements of control systems employing cableless (for example radio, infra-red) techniques for transmitting ~~commands and~~ control signals and data between ~~a machine control system and~~ operator control station(s) and other parts of the control system(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).~~

~~Means shall be provided to readily remove or disconnect the power supply of the operator control station (see also 9.2.7.3).~~

~~Means (for example key operated switch, access code) shall be provided, as necessary, to prevent unauthorized use of the operator control station.~~

~~Each operator control station shall carry an unambiguous indication of which machine(s) is (are) intended to be controlled by that operator control station.~~

NOTE 1 Reference to a machine in 9.2.4 is intended to be read as "machine or part(s) of a machine".

Transmission reliability requirements can be necessary for safety functions of a CCS that rely on data transmission (for example, safety-related active stop, motion commands).

The CCS shall have functionality and a response time suitable for the application based on the risk assessment.

NOTE 2 IEC 61784-3 describes communication failures of communication networks and requirements for safety-related data transmission.

NOTE 3 Further requirements for cableless control systems are under development by IEC TC 44 in draft IEC 62745[3].

9.2.4.2 Monitoring the ability of a cableless control system to control a machine

The ability of a cableless control system (CCS) to control a machine shall be automatically monitored, either continuously or at suitable intervals. The status of this ability shall be clearly indicated (for example, by an indicating light, a visual display indication, etc.)

If the communication signal is degraded in a manner that might lead to the loss of the ability of a CCS to control a machine (e.g., reduced signal level, low battery power) a warning to the operator shall be provided before the ability of the CCS to control a machine is lost.

When the ability of a CCS to control a machine has been lost for a time that is determined from a risk assessment of the application, an automatic stop of the machine shall be initiated.

NOTE In some cases, for example, in order to avoid this automatic stop generating an unexpected hazardous condition, it can be necessary for the machine to go to a predetermined state before stopping.

Restoration of the ability of a CCS to control a machine shall not restart the machine. Restart shall require a deliberate action, for example manual actuation of a start button.

9.2.4.3 Control limitation

~~Measures shall be taken to ensure that control commands:~~

~~– affect only the intended machine;~~

~~– affect only the intended functions.~~

Measures shall be taken (e.g. coded transmission) to prevent the machine from responding to signals other than those from the intended cableless operator control station(s).

3 Under consideration.

Cableless operator control station(s) shall only control the intended machine(s) and shall affect only the intended machine functions.

~~Where necessary, means shall be provided so that the machine can only be controlled from operator control stations in one or more predetermined zones or locations.~~

~~9.2.7.3 Stop~~

~~Operator control stations shall include a separate and clearly identifiable means to initiate the stop function of the machine or of all the operations that can cause a hazardous situation. The actuating means to initiate this stop function shall not be marked or labelled as an emergency stop device, even though the stop function initiated on the machine can fulfil an emergency stop function.~~

~~A machine which is equipped with cableless control shall have a means of automatically initiating the stopping of the machine and of preventing a potentially hazardous operation, in the following situations:~~

- ~~when a stop signal is received;~~
- ~~when a fault is detected in the cableless control system;~~
- ~~when a valid signal (which includes a signal that communication is established and maintained) has not been detected within a specified period of time (see Annex B), except when a machine is executing a pre-programmed task taking it outside the range of the cableless control where no hazardous situation can occur.~~

~~9.2.7.4 Use of more than one operator control station~~

~~Where a machine has more than one operator control station, including one or more cableless control stations, measures shall be provided 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 machine shall be provided at suitable locations as determined by the risk assessment of the machine.~~

~~**Exception:** a stop command from any one of the control stations shall be effective when required by the risk assessment of the machine.~~

~~9.2.7.5 Battery-powered operator control stations~~

~~A variation in the battery voltage shall not cause a hazardous situation. If one or more potentially hazardous motions are controlled using a battery-powered cableless operator control station, a clear warning shall be given to the operator when a variation in battery voltage exceeds specified limits. Under those circumstances, the cableless operator control station shall remain functional long enough for the operator to put the machine into a non-hazardous situation.~~

9.2.4.4 Use of multiple cableless operator control stations

When more than one cableless operator control station is used to control a machine, then:

- only one cableless operator control station shall be enabled at a time except as necessary for the operation of the machine;
- transfer of control from one cableless operator control station to another shall require a deliberate manual action at the control station that has control;
- during machine operation, transfer of control shall only be possible when both cableless operator control stations are set to the same mode of machine operation and/or function(s) of the machine;
- transfer of control shall not change the selected mode of machine operation and/or function(s) of the machine;

- each cableless operator control station that has control of the machine shall be provided with an indication that it has control (by for example, the provision of an indicating light, a visual display indication).

NOTE Indications at other locations can be necessary as determined by the risk assessment.

9.2.4.5 Portable cableless operator control stations

Portable cableless operator control stations shall be provided with means (for example key operated switch, access code) to prevent unauthorized use.

Each machine under cableless control should have an indication when it is under cableless control.

When a portable cableless operator control station can be connected to one or more of several machines, means shall be provided on the portable cableless operator control station to select which machine(s) is to be connected. Selecting a machine to be connected shall not initiate control commands.

9.2.4.6 Deliberate disabling of cableless operator control stations

Where a cableless operator control station is disabled when under control, the associated machine shall meet the requirements for loss of ability of a CCS to control a machine in 9.2.4.2.

Where it is necessary to disable a cableless operator control station without interrupting machine operation, means shall be provided (for example on the cableless operator control station) to transfer control to another fixed or portable control station.

9.2.4.7 Emergency stop devices on portable cableless operator control stations

Emergency stop devices on portable cableless operator control stations shall not be the sole means of initiating the emergency stop function of a machine.

Confusion between active and inactive emergency stop devices shall be avoided by appropriate design and information for use. See also ISO 13850.

9.2.4.8 Emergency stop reset

Restarting of cableless control after power loss, disabling and re-enabling, loss of communication, or failure of parts of the CCS shall not result in a reset of an emergency stop condition.

The instructions for use shall state that the reset of an emergency stop condition initiated by a portable cableless operator control station shall only be performed when it can be seen that the reason for initiation has been cleared.

Depending on the risk assessment, in addition to the resetting of the emergency stop actuator on the portable cableless operator control station, one or more supplementary fixed reset devices should be provided.

9.3 Protective interlocks

9.3.1 Reclosing or resetting of an interlocking safeguard

The reclosing or resetting of an interlocking safeguard shall not initiate hazardous machine operation.

NOTE Requirements for interlocking guards with a start function (control guards) are ~~given~~ specified in 6.3.3.2.5 of ISO 12100~~-2~~:2010.

9.3.2 Exceeding operating limits

Where an operating limit (for example speed, pressure, position) can be exceeded leading to a hazardous situation, means shall be provided to detect when a predetermined limit(s) is exceeded and initiate an appropriate control action.

9.3.3 Operation of auxiliary functions

The correct operation of auxiliary functions shall be checked by appropriate devices (for example pressure sensors).

Where the non-operation of a motor or device for an auxiliary function (for example lubrication, supply of coolant, swarf removal) can cause a hazardous situation, or cause damage to the machine or to the work in progress, appropriate interlocking shall be provided.

9.3.4 Interlocks between different operations and for contrary motions

All contactors, relays, and other control devices that control elements of the machine and that can cause a hazardous situation when actuated at the same time (for example those which initiate contrary motion), shall be interlocked against incorrect operation.

Reversing contactors (for example those controlling the direction of rotation of a motor) shall be interlocked in such a way that in normal service no short-circuit can occur when switching.

Where, for safety or for continuous operation, certain functions on the machine are required to be interrelated, proper co-ordination shall be ensured by suitable interlocks. For a group of machines working together in a co-ordinated manner and having more than one controller, provision shall be made to co-ordinate the operations of the controllers as necessary.

Where a failure of a mechanical brake actuator can result in the brake being applied when the associated machine actuator is energized and a hazardous situation can result, interlocks shall be provided to switch off the machine actuator.

9.3.5 Reverse current braking

Where braking of a motor is accomplished by current reversal, measures shall be provided to prevent the motor starting in the opposite direction at the end of braking where that reversal can cause a hazardous situation or damage to the machine or to the work in progress. For this purpose, a device operating exclusively as a function of time is not permitted.

Control circuits shall be so arranged that rotation of a motor shaft, for example ~~manually~~ by applying a manual force or any other force causing the shaft to rotate after it has stopped, shall not result in a hazardous situation.

9.3.6 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~~ the control or operating mode selector shall ~~be ensured by~~ simultaneously:

- disable all other operating (control) modes;
- ~~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;~~

- ~~a cableless control station with a device to initiate stop functions in accordance with 9.2.7.3 and, where appropriate, an enabling device. Where a cableless 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.~~

- permit operation only by the use of a hold-to-run device or by a similar control device positioned so as to permit sight of the hazardous elements;
- permit operation of the hazardous elements only in reduced risk conditions (e.g. reduced speed, reduced power / force, step-by-step operation, e.g. with a limited movement control device);
- prevent any operation of hazardous functions by voluntary or involuntary action on the machine's sensors.

If these four conditions cannot be fulfilled simultaneously, the control or operating mode selector shall activate other protective measures designed and constructed to ensure a safe intervention zone. In addition, the operator shall be able to control operation of the parts he is working on from the adjustment point.

9.4 Control functions in the event of failure

9.4.1 General requirements

Where failures or disturbances in the electrical equipment can cause a hazardous situation or damage to the machine or to the work in progress, appropriate measures shall be taken to minimize the probability of the occurrence of such failures or disturbances. The required measures and the extent to which they are implemented, either individually or in combination, depend on the level of risk associated with the respective application (see 4.1).

~~Measures to reduce those risks~~ Examples of such measures that can be appropriate include but are not limited to:

- ~~protective devices on the machine (for example interlocking guards, trip devices);~~
- protective interlocking of the electrical circuit;
- use of proven circuit techniques and components (see 9.4.2.2);
- provision of partial or complete redundancy (see 9.4.2.3) or diversity (see 9.4.2.4);
- provision for functional tests (see 9.4.2.5).

The electrical control ~~circuits~~ system(s) shall have an appropriate ~~level of safety~~ performance that has been determined from the risk assessment ~~at~~ of the machine.

The requirements for safety-related control functions of IEC 62061 and/or ISO 13849-1~~:1999~~, ISO 13849-2~~:2003~~ shall apply.

Where functions performed by the electrical control system(s) have safety implications but application of IEC 62061 leads to a required safety integrity less than that required by SIL 1, compliance with the requirements of this part of IEC 60204 can lead to an adequate performance of the electrical control system(s).

Where memory retention is achieved for example, by battery power, measures shall be taken to prevent hazardous situations arising from failure, undervoltage or removal of the battery.

Means shall be provided to prevent unauthorized or inadvertent memory alteration by, for example, requiring the use of a key, access code or tool.

9.4.2 Measures to minimize risk in the event of failure

9.4.2.1 General

Measures to minimize risk in the event of failure include but are not limited to:

- use of proven circuit techniques and components;
- provisions of partial or complete redundancy;
- provision of diversity;
- provision for functional tests.

9.4.2.2 Use of proven circuit techniques and components

These measures include but are not limited to:

- bonding of control circuits to the protective bonding circuit for functional purposes (see 9.4.3.1.1 and Figure 4);
- connection of control devices in accordance with 9.4.3.1.1;
- stopping by de-energizing ~~(see 9.2.2)~~;
- the switching of all control circuit conductors ~~to~~ (for example both sides of a coil) of the device being controlled ~~(see 9.4.3.1)~~;
- switching devices having direct opening action (see IEC 60947-5-1);
- monitoring by:
  – use of mechanically linked contacts (see IEC 60947-5-1);
  – use of mirror contacts (see IEC 60947-4-1);
- circuit design to reduce the possibility of failures causing undesirable operations.

9.4.2.3 Provisions of partial or complete redundancy

By providing partial or complete redundancy, it is possible to minimize the probability that one single failure in the electrical circuit can result in a hazardous situation. Redundancy can be effective in normal operation (on-line redundancy) or designed as special circuits that take over the protective function (off-line redundancy) only where the operating function fails.

Where off-line redundancy which is not active during normal operation is provided, suitable measures shall be taken to ensure that those control circuits are available when required.

9.4.2.4 Provision of diversity

The use of control circuits having different principles of operation, or using different types of components or devices can reduce the probability of hazards resulting from faults and/or failures. Examples include:

– the use of a combination of normally open and normally closed contacts ~~operated by interlocking guards~~;

– the use of different types of control ~~circuit components~~ devices in the circuit(s);

– the combination of electromechanical and electronic equipment in redundant configurations.

The combination of electrical and non-electrical systems (for example mechanical, hydraulic, pneumatic) may perform the redundant function and provide the diversity.

9.4.2.5 Provision for functional tests

Functional tests may be carried out automatically by the control system, or manually by inspection or tests at start-up and at predetermined intervals, or a combination as appropriate (see also 17.2 and 18.6).

9.4.3 Protection against ~~maloperation due to earth faults, voltage interruptions and loss of circuit continuity~~ malfunction of control circuits

~~9.4.3.1 Earth faults~~

~~Earth faults on any control circuit shall not cause unintentional starting, potentially hazardous motions, or prevent stopping of the machine.~~

~~Methods to meet these requirements include but are not limited to the following:~~

~~**Method a)** Control circuits, fed by control transformers:~~

~~1) In case of earthed control circuit supplies, the common conductor is connected to the protective bonding circuit at the point of supply. All contacts, solid state elements etc., which are intended to operate an electromagnetic or other device (for example, a relay, indicator light) are inserted between one side, the switched conductor of the control circuit supply and one terminal of the coil or device. The other terminal of the coil or device (preferably always having the same marking) is connected directly to the common conductor of the control circuit supply without any switching elements (see Figure 3).~~

~~**Exception**: Contacts of protective devices may be connected between the common conductor and the coils, provided that:~~

~~– the circuit is interrupted automatically in the event of an earth fault, or~~

~~– the connection is very short (for example in the same enclosure) so that an earth fault is unlikely (for example overload relays).~~

~~2) Control circuits fed from a control transformer and not connected to the protective bonding circuit, having the same arrangement as shown in Figure 3 and provided with a device that interrupts the circuit automatically in the event of an earth fault (see also 7.2.4).~~

~~**Method b)** Control circuits fed from a control transformer with a centre-tapped winding, this centre tap connected to the protective bonding circuit, arranged as shown in Figure 4 with the overcurrent protective device having switching elements in all control circuit supply conductors.~~

~~NOTE 1 On a centre-tapped earthed control circuit, the presence of one earth fault can leave 50 % voltage on a relay coil. In this condition, a relay can hold on, resulting in inability to stop a machine.~~

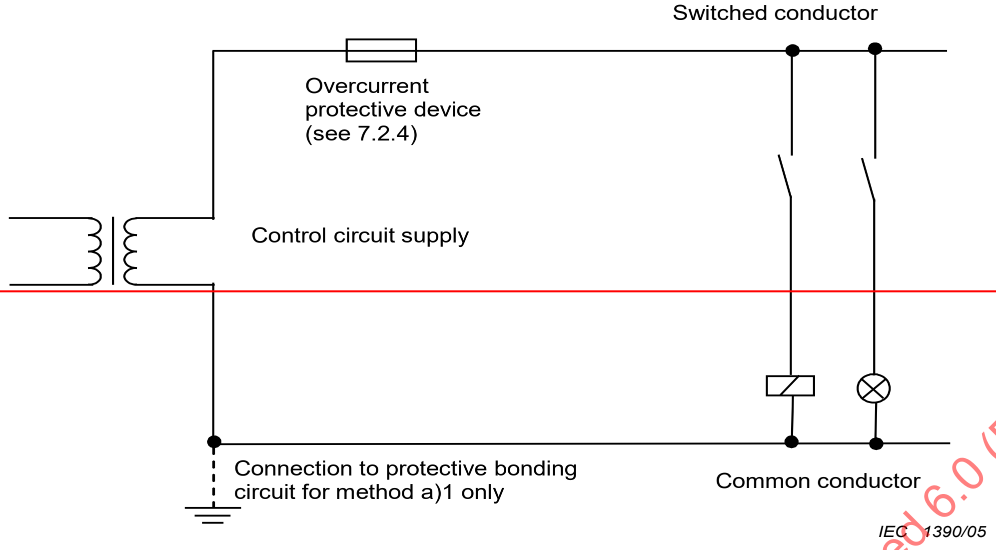
~~NOTE 2 Coils or devices may be switched on either or both sides.~~

~~**Method c)** Where the control circuit is not fed from a control transformer and is either:~~

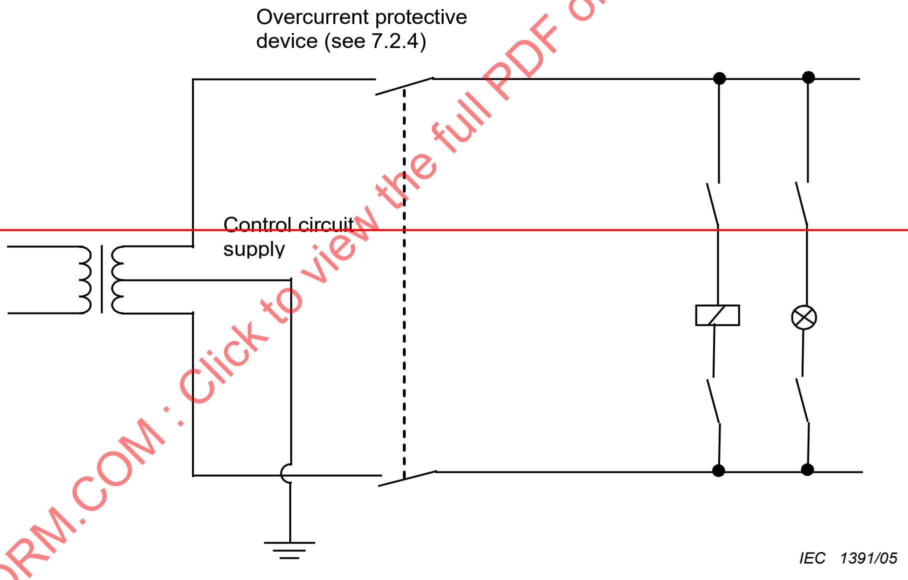
~~1) directly connected between the phase conductors of an earthed supply, or;~~

~~2) directly connected between the phase conductors or between a phase conductor and a neutral conductor of a supply that is not earthed or is earthed through a high impedance,~~

~~Multi-pole control switches that switch all live conductors are used for START or STOP of those machine functions that can cause a hazardous situation or damage to the machine in the event of unintentional starting or failure to stop, or in the case of c) 2), a device shall be provided that interrupts the circuit automatically in the event of an earth fault.~~



~~Figure 3 – Method a)~~



~~Figure 4 – Method b)~~

9.4.3.1 Insulation faults

9.4.3.1.1 General

Measures shall be provided to reduce the probability that insulation faults on any control circuit can cause malfunction such as unintentional starting, potentially hazardous motions, or prevent stopping of the machine.

The measures to meet the requirements include but are not limited to the following methods:

– method a) Earthed control circuits fed by transformers;

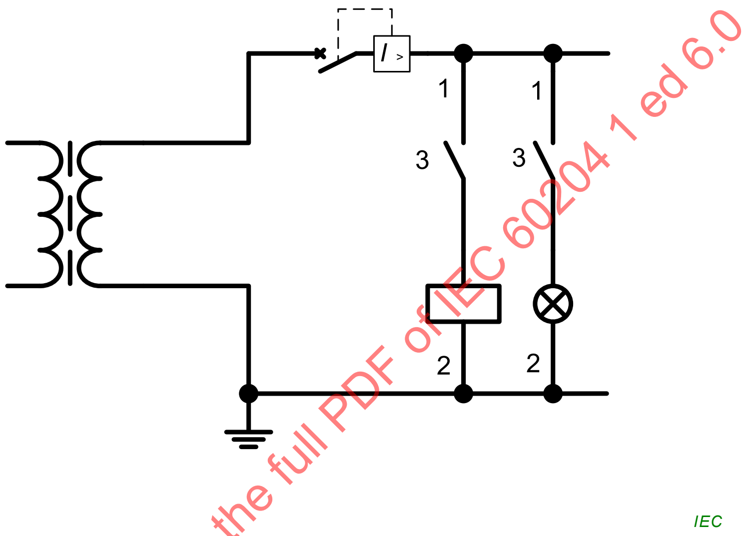
– method b) Non-earthed control circuits fed by transformers;

– method c) Control circuits fed by transformer with an earthed centre-tap winding;

– method d) Control circuits not fed by a transformer.

9.4.3.1.2 Method a) – Earthed control circuits fed by transformers

The common conductor shall be connected to the protective bonding circuit at the point of supply. All contacts, solid state elements, etc., which are intended to operate an electromagnetic or other device (for example, a relay, indicator light) are to be inserted between the switched conductor of the control circuit supply and one terminal of the coil or device. The other terminal of the coil or device is connected directly to the common conductor of the control circuit supply without any switching elements (see Figure 7).



1	Switched conductors
2	Common conductors
3	Control switches

Figure 7 – Method a) Earthed control circuit fed by a transformer

NOTE Method a) can be used also for DC control circuits. In this case the transformer shown in Figure 7 is substituted by a DC power supply unit.

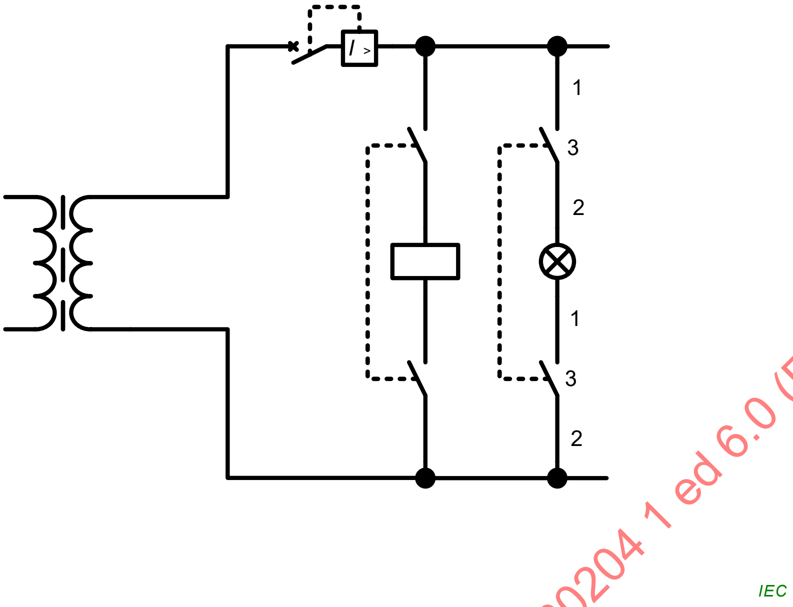
Exception: Contacts of protective devices may be connected between the common conductor and the coils, provided that the connection is very short (for example in the same enclosure) so that an earth fault is unlikely (for example overload relays directly fitted to contactors).

9.4.3.1.3 Method b) – Non-earthed control circuits fed by transformers

Control circuits fed from a control transformer that is not connected to the protective bonding circuit shall either:

1) have 2-pole control switches that operate on both conductors, see Figure 8; or
2) be provided with a device, for example an insulation monitoring device, that interrupts the circuit automatically in the event of an earth fault, see Figure 9; or
3) where an interruption as per item 2 above would increase the risk, for example when continued operation is required during the first fault to earth, it can be sufficient to provide an insulation monitoring device (e.g. in accordance with IEC 61557-8) that will initiate an acoustic and optical signal at the machine, see Figure 10. Requirements for the procedure

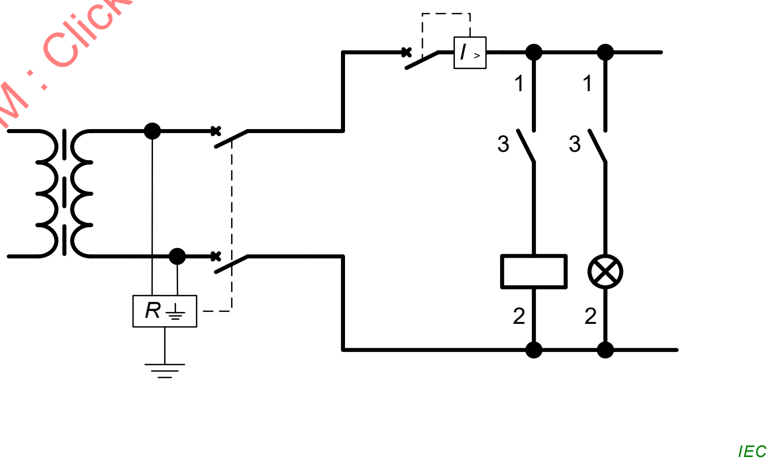
to be performed by the machine user in response to this alarm shall be described in the information for use.



1	Switched conductors
2	Common conductors
3	Control switches

Figure 8 – Method b1) Non-earthed control circuit fed by transformer

NOTE 1 Method b1) can be used also for DC control circuits. In this case the transformer shown in Figure 8 is substituted by a DC power supply.

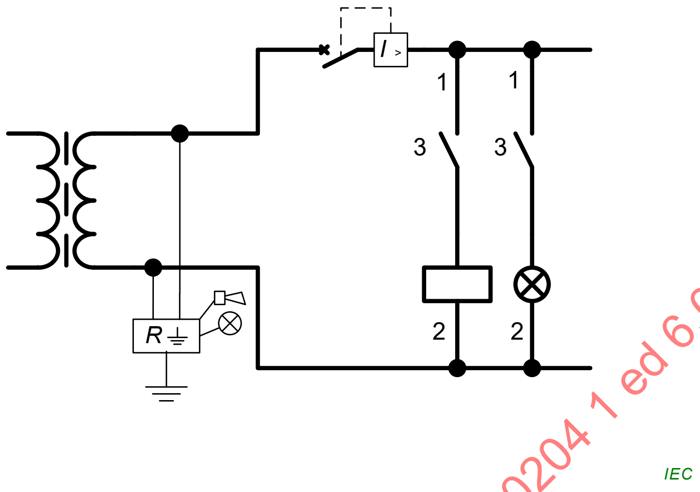


1	Switched conductors
2	Common conductors
3	Control switches

Figure 9 – Method b2) Non-earthed control circuit fed by transformer

NOTE 2 Method b2) can be used also for DC control circuits. In this case the transformer shown in Figure 9 is substituted by a DC power supply.

NOTE 3 Figure 9 does not show the overcurrent protective devices in the measurement circuits for protection of the insulation monitoring device.



1	Switched conductors
2	Common conductors
3	Control switches

Figure 10 – Method b3) Non-earthed control circuit fed by transformer

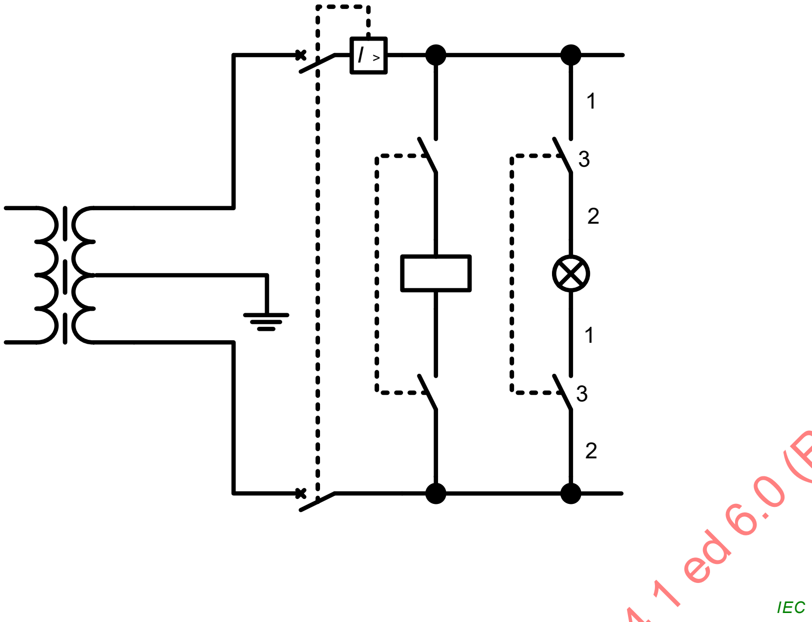
NOTE 4 Method b3) can be used also for DC control circuits. In this case the transformer shown in Figure 10 is substituted by a DC power supply. When a transformer and rectifier combination is used, the insulation monitoring device is connected to the protective bonding circuit in the DC part of the control circuit, so after the rectifier.

NOTE 5 Figure 10 does not show the overcurrent protective devices in the measurement circuits for protection of the insulation monitoring device.

9.4.3.1.4 Method c) – Control circuits fed by transformer with an earthed centre-tap winding

Control circuits fed from a control transformer with its centre-tap winding connected to the protective bonding circuit shall have overcurrent protective devices that break both the conductors.

The control switches shall be 2-pole types that operate on both conductors.



1	Switched conductors
2	Common conductors
3	Control switches

Figure 11 – Method c) Control circuits fed by transformer with an earthed centre-tap winding

9.4.3.1.5 Method d) – Control circuits not fed by a transformer

Control circuits that are not fed by a control transformer or switch mode power supply units fitted with transformers having separate windings in accordance with IEC 61558-2-16 are only allowed for machines with a maximum of one motor starter and/or maximum of two control devices, in accordance with 9.1.1.

Depending on the earthing of the supply system the possible cases are:

1) directly connected to an earthed supply system (TN- or TT-system) and:
   a) being powered between a line conductor and the neutral conductor, see Figure 12; or
   b) being powered between two line conductors, see Figure 13; or
2) directly connected to a supply system that is not earthed or is earthed through a high impedance (IT-system) and:
   a) being powered between a line conductor and the neutral conductor, see Figure 14; or
   b) being powered between two line conductors, see Figure 15.

Method d1b) requires multi-pole control switches that switch all live conductors in order to avoid an unintentional start in case of an earth fault in the control circuit.

Method d2) requires that a device shall be provided that interrupts the circuit automatically in the event of an earth fault.

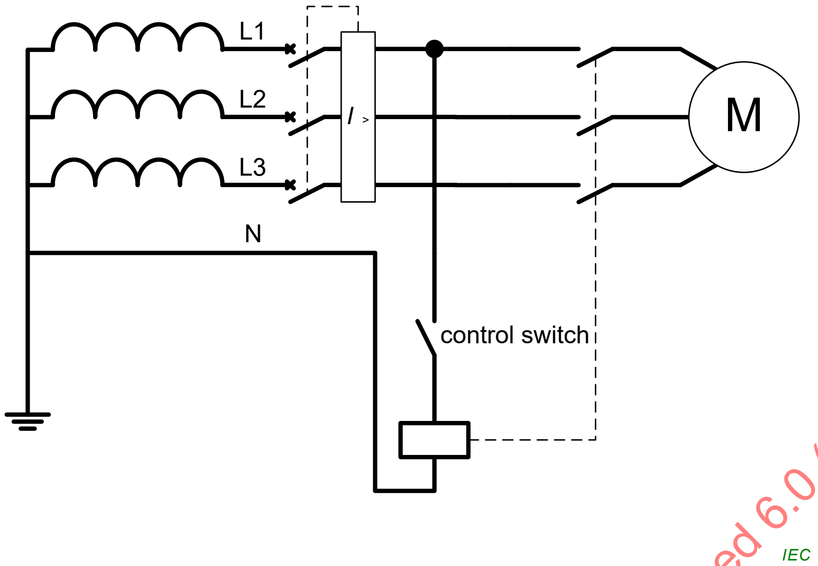


Figure 12 – Method d1a) Control circuit without transformer connected between a phase and the neutral of an earthed supply system

NOTE 1 Figure 12 shows the case where the supply system is a TN system. The control circuit is the same in the case of a TT system.

NOTE 2 Figure 12 does not show any protective devices for the power circuit and control circuit, provisions for which are stated in 6.3 and 7.2.

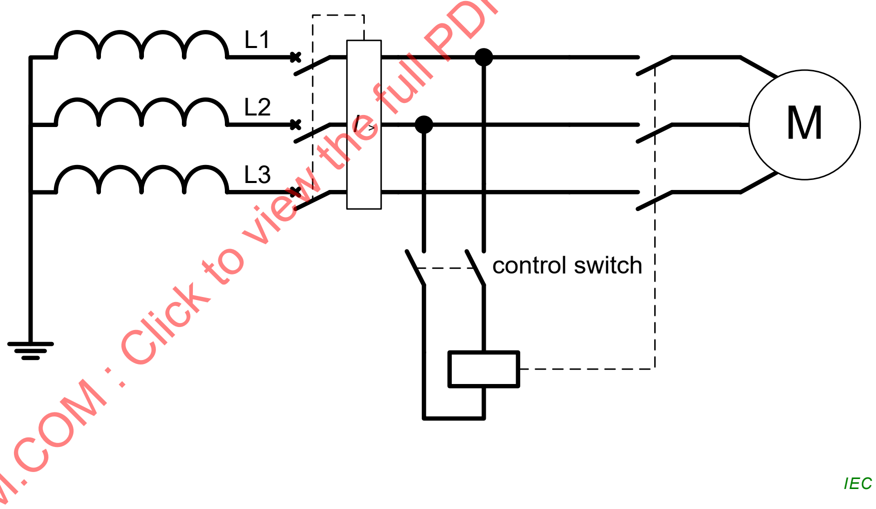


Figure 13 – Method d1b) Control circuit without transformer connected between two phases of an earthed supply system

NOTE 3 Figure 13 shows the case where the supply system is a TN system. The control circuit is the same in case of a TT system.

NOTE 4 Figure 13 does not show any necessary protective devices for power circuit and control circuit, provisions for which are stated in 6.3 and 7.2.

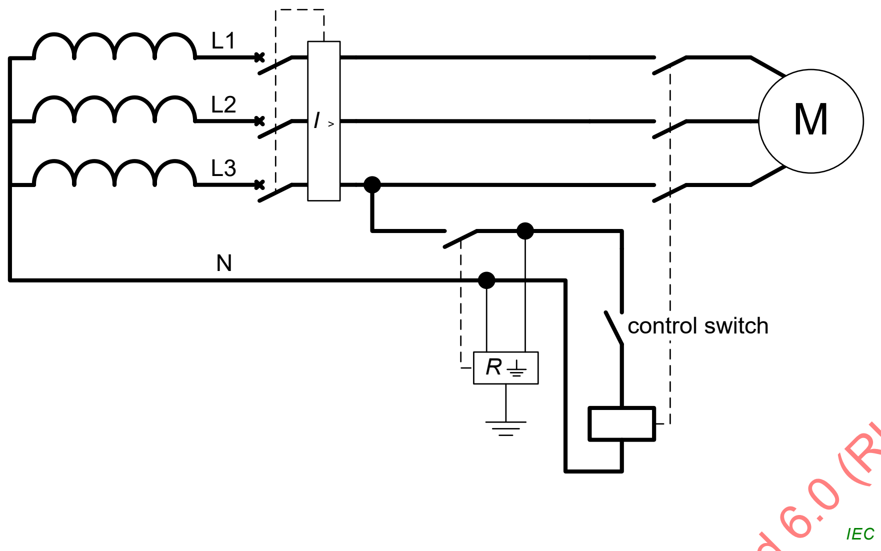


Figure 14 – Method d2a) Control circuit without transformer connected between phase and neutral of a non-earthed supply system

NOTE 5 Figure 14 does not show any necessary protective devices for the power circuit and control circuit, provisions for which are stated in 6.3 and 7.2.

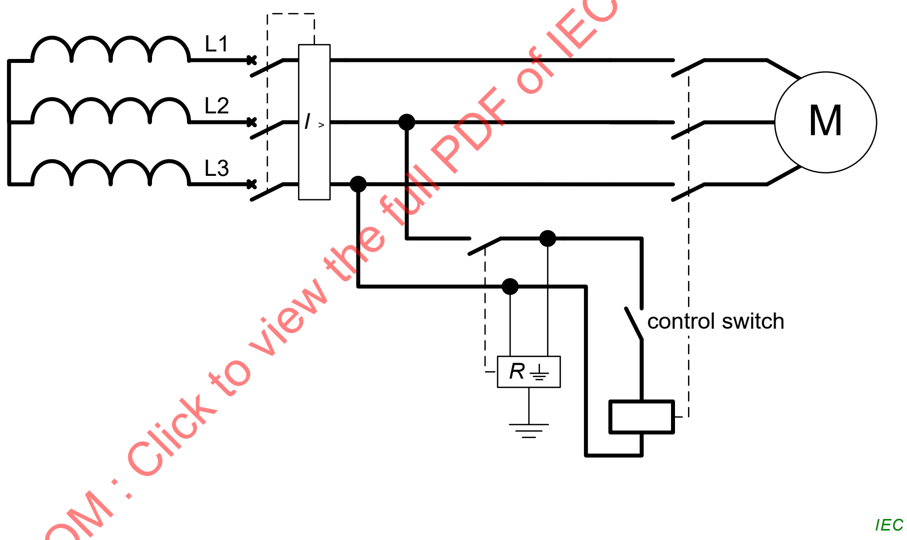


Figure 15 – Method d2b) control circuit without transformer connected between two phases of a non-earthed supply system

NOTE 6 Figure 15 does not show any necessary protective devices for power circuit and control circuit, provisions for which are stated in 6.3 and 7.2.

9.4.3.2 Voltage interruptions

See also 7.5.

Where the control system uses a memory device(s), proper functioning in the event of power failure shall be ensured (for example by using a non-volatile memory) to prevent any loss of memory that can result in a hazardous situation.

9.4.3.3 Loss of circuit continuity

Where the loss of continuity of ~~safety-related~~ control circuits depending upon sliding contacts can result in a hazardous situation, appropriate measures shall be taken (for example by duplication of the sliding contacts).

10 Operator interface and machine-mounted control devices

10.1 General

10.1.1 General ~~device~~ requirements

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

~~Those~~ Control devices for operator interface shall, as far as is practicable, be selected, mounted, and identified or coded in accordance with ~~relevant parts of~~ IEC 61310 series.

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 machine operations, and of sensors (for example position sensors) that can initiate machine operation. Further information can be found in IEC 60447.

Ergonomic principles shall be taken into account in the location of operator interface devices.

10.1.2 Location and mounting

As far as is practicable, machine-mounted control devices shall be:

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

The actuators of hand-operated control devices shall be selected and 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;
- the operator is not placed in a hazardous situation when operating them.

The actuators of foot-operated control devices shall be selected and installed so that:

- they are within easy reach of the normal working position of the operator;
- the operator is not placed in a hazardous situation when operating them.

10.1.3 Protection

The degree of protection (IP rating in accordance with IEC 60529) together with other appropriate measures shall ~~afford~~ provide protection against:

- the effects of ~~aggressive~~ liquids, vapours, or gases found in the physical environment or used on the machine;
- the ingress of contaminants (for example swarf, dust, particulate matter).

In addition, the operator interface control devices shall have a minimum degree of protection against ~~direct~~ contact with live parts of IPXXD in accordance with IEC 60529.

10.1.4 Position sensors

Position sensors (for example position switches, proximity switches) shall be so arranged that they will not be damaged in the event of overtravel.

Position sensors in circuits with safety-related control functions (for example, to maintain the safe condition of the machine or prevent hazardous situations arising at the machine) shall have direct opening action (see IEC 60947-5-1) or shall provide similar reliability (see 9.4.2).

~~NOTE A safety-related control function is intended to maintain the safe condition of the machine or prevent hazardous situations arising at the machine.~~

10.1.5 Portable and pendant control stations

Portable and pendant operator control stations and their control devices shall be so selected and arranged as to minimize the possibility of ~~inadvertent~~ machine operations caused by inadvertent actuation, shocks and vibrations (for example if the operator control station is dropped or strikes an obstruction) (see also 4.4.8).

10.2 ~~Push-buttons~~ Actuators

10.2.1 Colours

~~Push-button~~ Actuators (see 3.1.1) shall be colour-coded ~~in accordance with Table 2 (see also 9.2 and Annex B)~~ as follows.

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 switching off actuators (including supply disconnecting devices where it is foreseen that they are for use in an emergency). If a background exists immediately around the actuator, then this background shall be coloured YELLOW. The combination of a RED actuator with a YELLOW background shall only be used for emergency operation devices.

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~~ actuators. The colours RED, YELLOW, or GREEN shall not be used ~~(see also 9.2.6)~~.

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

The colour YELLOW is reserved for use in abnormal conditions, for example, in the event of an abnormal condition of the process, or to interrupt an automatic cycle.

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 2 – 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~~
~~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 (see note)~~	~~START/ON~~ ~~STOP/OFF~~
~~BLACK~~			~~START/ON~~ ~~STOP/OFF (preferred)~~
~~NOTE Where a supplementary means of coding (for example shape, position, texture) is used for the identification of push-button actuators, then the same colour WHITE, GREY, or BLACK may be used for various functions (for example WHITE for START/ON and for STOP/OFF actuators).~~			

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~~ recommended symbols to be placed near to or preferably directly on certain actuators are given in Table 2 or 3.

Table 2 – Symbols for ~~push-buttons~~ actuators (Power)

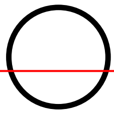
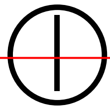
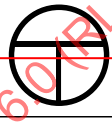
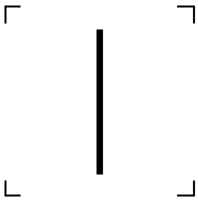
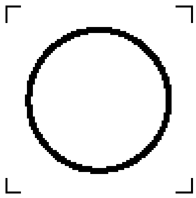
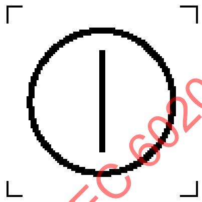
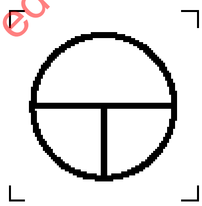
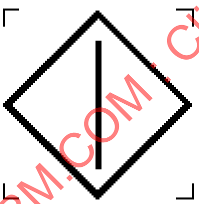
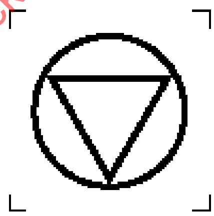
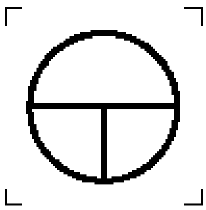
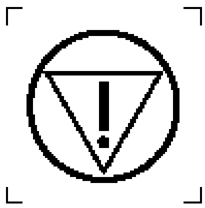
Power			
~~START or~~ ON	~~STOP or~~ OFF	~~Push-buttons acting alternately as START or STOP buttons and as ON or OFF buttons~~ ON/OFF (push on-push off)	~~Push-buttons acting as START or ON buttons when pressed and as STOP or OFF buttons when released (i.e. hold-to-run)~~ ON (hold-to-run)
IEC 60417-5007 (~~DB:~~2002-10)	IEC 60417-5008 (~~DB:~~2002-10)	IEC 60417-5010 (~~DB:~~2002-10)	IEC 60417-5011 (~~DB:~~2002-10)
			
			

Table 3 – Symbols for actuators (Machine operation)

Machine operation			
START	STOP	HOLD-TO-RUN	EMERGENCY STOP
IEC 60417-5104 (2006-08)	IEC 60417-5110A (2004-06)	IEC 60417-5011 (2002-10)	IEC 60417-5638 (2002-10)
			

10.3 Indicator lights and displays

10.3.1 General

Indicator lights and displays serve to give the following types of information:

– indication: to attract the operator's 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 and displays shall be selected and installed in such a manner as to be visible from the normal position of the operator (see also IEC 61310-1).

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

Circuits used for visual or audible devices used to warn persons of an impending hazardous event shall be fitted with facilities to check the operability of these devices.

10.3.2 Colours

~~Unless otherwise agreed between the supplier and the user (see Annex B),~~ Indicator lights ~~shall~~ should be colour-coded with respect to the condition (status) of the machine in accordance with Table 4.

Table 4 – Colours for indicator lights and their meanings with respect to the condition of the machine

Colour	Meaning	Explanation	Action by operator
RED	Emergency	Hazardous condition	Immediate action to deal with hazardous condition (for example switching off the machine supply, being alert to the hazardous condition and staying clear of the machine)
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

Indicating towers on machines should have the applicable colours in the following order from the top down; RED, YELLOW, BLUE, GREEN and WHITE.

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~~ flashing frequencies are 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~~ additional acoustic warnings should ~~also~~ be ~~provided~~ considered.

10.4 Illuminated push-buttons

Illuminated push-button actuators shall be colour-coded in accordance with 10.2.1. Where there is difficulty in assigning an appropriate colour, WHITE shall be used.

The colour of active emergency stop actuators shall remain RED regardless of the state of the illumination.

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 machine elements (for example slides, spindles, carriers) shall be constructed 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 stop devices

10.7.1 Location of emergency stop devices

Devices for emergency stop shall be readily accessible.

Emergency stop devices shall be ~~located~~ provided at each ~~operator control station and at other~~ location~~s~~ where the initiation of an emergency stop can be required ~~(exception: see 9.2.7.3)~~.

There can be circumstances where confusion can occur between active and inactive emergency stop devices caused by, for example, unplugging or otherwise disabling an operator control station. In such cases, means (for example, design and information for use) shall be provided to minimise confusion.

10.7.2 Types of emergency stop device

The types of device for emergency stop include, but are not limited to:

- a push-button ~~operated switch~~ device for actuation by the palm or the fist (e.g. mushroom head type);
- a pull-cord operated switch;
- a pedal-operated switch without a mechanical guard.

The devices shall ~~have direct opening operation (see IEC 60947-5-1, Annex K)~~ be in accordance with IEC 60947-5-5.

~~10.7.3 Colour of actuators~~

~~Actuators of emergency stop devices shall be coloured RED. If a background exists immediately around the actuator, then this background shall be coloured YELLOW. See also ISO 13850.~~

10.7.3 ~~Local~~ Operation of the supply disconnecting device to effect emergency stop

Where a stop category 0 is suitable, the supply disconnecting device may ~~be locally operated to~~ serve the function of emergency stop where:

- it is readily accessible to the operator; and
- it is of the type described in 5.3.2 a), b), c), or d).

Where intended for emergency use, the supply disconnecting device shall meet the colour requirements of 10.2.1.

10.8 Emergency switching off devices

10.8.1 Location of emergency switching off devices

Emergency switching off devices shall be located as necessary for the given application. Normally, those devices will be located separate from operator control stations. ~~Where it is necessary to provide a control station with an emergency stop device and an emergency switching off device, means shall be provided to avoid confusion between these devices.~~ Where confusion can occur between emergency stop and emergency switching off devices, means shall be provided to minimise confusion.

NOTE This can be achieved by, for example, the provision of a break-glass enclosure for the emergency switching off device.

10.8.2 Types of emergency switching off device

The types of device for initiation of emergency switching off include:

- a push-button operated switch with a palm or mushroom head type of actuator;
- a pull-cord operated switch.

The devices shall have direct opening action (see Annex K of IEC 60947-5-1:2003 and IEC 60947-5-1:2003/AMD1:2009).

~~The push-button operated switch may be in a break-glass enclosure.~~

~~10.8.3 Colour of actuators~~

~~Actuators of emergency switching off devices shall be coloured RED. If a background exists immediately around the actuator, then this background shall be coloured YELLOW.~~

10.8.3 Local operation of the supply disconnecting device to effect emergency switching off

Where the supply disconnecting device is to be locally operated for emergency switching off, it shall be readily accessible and ~~should~~ shall meet the colour requirements of 10.2.1.

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.~~

~~NOTE~~ The enabling control function is described in 9.2.3.9.

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:

– designed in accordance with ergonomic principles;
– 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 IEC 60947-5-8 specifies requirements for three-position enabling switches.

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 machine and its associated equipment.

11.2 Location and mounting

11.2.1 Accessibility and maintenance

All items of controlgear shall be placed and oriented so that they can be identified without moving them or the wiring. For items that require checking for correct operation or that are liable to need replacement, those actions should be possible without dismantling other equipment or parts of the machine (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 ~~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.

No devices except devices for operating, indicating, measuring, and cooling shall be mounted on doors or on access covers of enclosures that are expected to be removed.

Where control devices are connected through plug-in arrangements, their association shall be made clear by type (shape), marking or reference designation, singly or in combination (see 13.4.5).

Plug-in devices that are handled during normal operation shall be provided with non-interchangeable features where the lack of such a facility can result in malfunctioning.

Plug/socket combinations that are handled during normal operation shall be located and mounted so as to provide unobstructed access.

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

Non-electrical parts and devices, not directly associated with the electrical equipment, shall not be located within enclosures containing controlgear. Devices such as solenoid valves should be separated from the other electrical equipment (for example in a separate compartment).

Control devices mounted in the same location and connected to the ~~supply voltage~~ power circuits, or to both ~~supply~~ power and control ~~voltages shall~~ circuits should be grouped separately from those connected only to the control ~~voltages~~ circuits.

Terminals shall be separated into groups for:

– power circuits;
– ~~associated~~ control circuits of the machine;
– other control circuits, fed from external sources (for example for interlocking).

The groups may be mounted adjacently, provided that each group can be readily identified (for example by markings, by use of different sizes, by use of barriers or by colours).

When arranging the location of devices (including interconnections), the clearances and creepage distances specified for them by the supplier shall be maintained, taking into account the external influences or conditions of the physical environment.

11.2.3 Heating effects

The temperature rise inside electrical equipment enclosures shall not exceed the ambient temperature specified by the component manufacturers.

NOTE 1 IEC TR 60890 can be used for the calculation of temperature rise inside enclosures.

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

NOTE 2 Information on the selection of insulating materials to resist thermal stresses is given in IEC 60216 and IEC 60085.

11.3 Degrees of protection

The protection of controlgear against ingress of solid foreign objects and of liquids shall be adequate taking into account the external influences under which the machine is intended to operate (i.e. the location and the physical environmental conditions) and shall be sufficient against dust, coolants, lubricants and swarf.

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

NOTE 1 The degrees of protection against ingress of water are covered by IEC 60529. Additional protective measures can be necessary against other liquids.

Enclosures of controlgear shall provide a degree of protection of at least IP22 (see IEC 60529).

Exception: an enclosure providing a minimum degree of protection IP22 is not required where:

a) an electrical operating area ~~is used as a protective enclosure for~~ provides an appropriate degree of protection against ~~the~~ ingress of solids ~~bodies~~ and liquids, or.
b) removable collectors on conductor wire or conductor bar systems are used and ~~IP22 is not achieved, but~~ the measures of 12.7.1 are applied.

NOTE 2 Some examples of applications, along with the degree of protection typically provided by their enclosures, are listed below:

–	ventilated enclosure, containing only motor starter resistor and other large size equipment	IP10
–	ventilated enclosure, containing other equipment	IP32

– enclosure used in general industry IP32, IP43 and IP54

– enclosure used in locations that are cleaned with low-pressure water jets (hosing) IP55

– enclosure providing protection against fine dust IP65

– enclosure containing slip-ring assemblies IP2X

Depending upon the conditions where installed, another degree of protection can be appropriate.

11.4 Enclosures, doors and openings

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

Fasteners used to secure doors and covers should be of the captive type. Windows ~~provided for viewing internally mounted indicating devices~~ of enclosures shall be of a material suitable to withstand expected mechanical stress and chemical attack ~~(for example toughened glass or polycarbonate sheet of not less than 3 mm thickness)~~.

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

The joints or gaskets of doors, lids, covers and enclosures shall withstand the chemical effects of the aggressive liquids, vapours, or gases used on the machine. The means provided to maintain the degree of protection of an enclosure on doors, lids and covers that require opening or removal for operation or maintenance shall:

- be securely attached to either the door/cover or the enclosure;
- not deteriorate due to removal or replacement of the door or the cover, and so impair the degree of protection.

Where openings in enclosures are provided (for example, for cable access), including those towards the floor or foundation or to other parts of the machine, means shall be provided to ensure the degree of protection specified for the equipment. Openings for cable entries shall be easy to re-open on site. A suitable opening may be provided in the base of enclosures within the machine so that moisture due to condensation can drain away.

There shall be no opening between enclosures containing electrical equipment and compartments containing coolant, lubricating or hydraulic fluids, or those into which oil, other liquids, or dust can penetrate. This requirement does not apply to electrical devices specifically designed to operate in oil (for example electromagnetic clutches) nor to electrical equipment in which coolants are used.

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

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

– 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

– 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 16.2.2 ~~may~~ can be necessary.

11.5 Access to ~~controlgear~~ electrical equipment

Doors in gangways and for access to electrical operating areas shall:

- be at least 0,7 m wide and ~~2,1~~ 2,0 m high;
- open outwards;
- have a means (for example panic bolts) to allow opening from the inside without the use of a key or tool.

NOTE Further information is given in IEC 60364-7-729.

~~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 a clear width of at least 0,7 m and a clear height of at least 2,1 m.~~

~~In cases where:~~

- ~~equipment is likely to be live during access; and~~
- ~~conducting parts are exposed,~~

~~the clear width shall be at least 1,0 m. In cases where such parts are present on both sides of the access way, the clear width shall be at least 1,5 m.~~

~~NOTE These dimensions are derived from ISO 14122 series.~~

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.~~

These requirements do not apply to the integral wiring of assemblies, subassemblies, and devices that are manufactured and tested in accordance with their relevant IEC standard (for example IEC ~~60439-1~~ 61800 series).

12.2 Conductors

~~In general,~~ Conductors ~~shall~~ should be of copper. Where aluminium conductors are used, the cross-sectional area shall be at least 16 mm^2.

To ensure adequate mechanical strength, the cross-sectional area of conductors should not be less than as shown in Table 5. However, conductors with smaller cross-sectional areas or other constructions than shown in Table 5 may be used in equipment provided adequate mechanical strength is achieved by other means and proper functioning is not impaired.

NOTE Classification of conductors is given in Table D.4.

Table 5 – Minimum cross-sectional areas of copper conductors

Location	Application	Type of conductor, cable				
		Single core		Multicore		
		Flexible Class 5 or 6	Solid (class 1) or stranded (class 2)	Two core, shielded	Two core not shielded	Three or more cores, shielded or not
Wiring outside (protecting) enclosures	Power circuits, fixed	1,0	1,5	0,75	0,75	0,75
	Power circuits, subjected to frequent movements	1,0	–	0,75	0,75	0,75
	Control circuits	1,0	1,0	0,2	0,5	0,2
	Data communication	–	–	–	–	0,08
Wiring inside enclosures a)	Power circuits (connections not moved)	0,75	0,75	0,75	0,75	0,75
	Control circuits	0,2	0,2	0,2	0,2	0,2
	Data communication	–	–	–	–	0,08

NOTE All cross-sections in mm^2.

a) Except special requirements of individual standards, see also 12.1.

Class 1 and class 2 conductors are primarily intended for use between rigid, non-moving parts where vibration is not considered to be likely to cause damage.

All conductors that are subject to frequent movement (for example one movement per hour of machine operation) ~~shall~~ should have flexible stranding of class 5 or class 6.

12.3 Insulation

~~The types of insulation include (but are not limited to):~~

- ~~polyvinyl chloride (PVC);~~
- ~~rubber, natural and synthetic;~~
- ~~silicone rubber (SiR);~~
- ~~mineral;~~
- ~~cross-linked polyethylene (XLPE);~~
- ~~ethylene propylene compound (EPR).~~

Where the insulation of conductors and cables ~~(for example PVC)~~ can constitute hazards due for example to the propagation of a fire or the emission of toxic or corrosive fumes, guidance from the cable supplier should be sought. It is important to give special attention to the integrity of a circuit having a safety-related function.

The insulation of cables and conductors used, shall be suitable for a test voltage:

– not less than 2 000 V AC for a duration of 5 min for operation at voltages higher than 50 V AC or 120 V DC, or

– not less than 500 V AC for a duration of 5 min for PELV circuits (see IEC 60364-4-41, class III equipment).

The mechanical strength and thickness of the insulation shall be such that the insulation cannot be damaged in operation or during laying, especially for cables pulled into ducts.

12.4 Current-carrying capacity in normal service

The current-carrying capacity depends on several factors, for example insulation material, number of conductors in a cable, design (sheath), methods of installation, grouping and ambient temperature.

NOTE 1 Detailed information and further guidance can be found in IEC 60364-5-52, in some national standards or given by the manufacturer.

One typical example of the current-carrying capacities for PVC insulated wiring between enclosures and individual items of equipment under steady-state conditions is given in Table 6.

NOTE 2 For specific applications where the correct cable dimensioning can depend on the relationship between the period of the duty cycle and the thermal time constant of the cable (for example starting against high-inertia load, intermittent duty), the cable manufacturer ~~should be consulted~~ can provide information.

Table 6 – Examples of current-carrying capacity (I_Z) of PVC insulated copper conductors or cables under steady-state conditions in an ambient air temperature of +40 °C for different methods of installation

	Installation method (see D.2.2)			
	B1	B2	C	E
Cross-sectional area mm²	Current-carrying capacity I_z for three phase circuits A			
0,75	8,6	8,5	9,8	10,4
1,0	10,3	10,1	11,7	12,4
1,5	13,5	13,1	15,2	16,1
2,5	18,3	17,4	21	22
4	24	23	28	30
6	31	30	36	37
10	44	40	50	52
16	59	54	66	70
25	77	70	84	88
35	96	86	104	110
50	117	103	125	133
70	149	130	160	171
95	180	156	194	207
120	208	179	225	240
	Control circuit pairs			
~~Electronic (pairs)~~				
0,20	~~Not applicable~~ 4,5	4,3	4,4	4,4
0,5	~~Not applicable~~ 7,9	7,5	7,5	7,8
0,75	~~Not applicable~~ 9,5	9,0	9,5	10

NOTE 1 The values of the current-carrying capacity of Table 6 are based on:

– one symmetrical three-phase circuit for cross-sectional areas 0,75 mm² and greater;

– one control circuit pair for cross-sectional areas between 0,2 mm² and 0,75 mm².

Where more loaded cables/pairs are installed, ~~derate~~ derating factors for the values of Table 6 ~~in accordance with~~ can be found in Tables D.2 or D.3.

NOTE 2 For ambient temperatures other than 40 °C, ~~correct the~~ correction factors for current-carrying capacities ~~by using values given~~ are provided in Table D.1.

NOTE 3 These values are not applicable to flexible cables wound on drums (see 12.6.3).

NOTE 4 Current-carrying capacities of other cables are provided in IEC 60364-5-52.

12.5 Conductor and cable voltage drop

The voltage drop from the point of supply to the load in any power circuit cable shall not exceed 5 % of the nominal voltage under normal operating conditions. In order to conform to this requirement, it can be necessary to use conductors having a larger cross-sectional area than that derived from Table 6.

In control circuits, the voltage drop shall not reduce the voltage at any device below the manufacturer's specification for that device, taking into account inrush currents.

See also 4.3.

The voltage drop in components, for example overcurrent protective devices and switching devices, should be considered.

12.6 Flexible cables

12.6.1 General

Flexible cables shall have Class 5 or Class 6 conductors.

NOTE 1 Class 6 conductors have smaller diameter strands and are more flexible than Class 5 conductors (see Table D.4).

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

- 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 2 Cables for such conditions are specified in ~~relevant~~ some national standards.

NOTE 3 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.

12.6.2 Mechanical rating

The cable handling system of the machine shall be so designed to keep the tensile stress of the conductors as low as is practicable during machine operations. 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.

12.6.3 Current-carrying capacity of cables wound on drums

Cables to be wound on drums shall be selected with conductors having a cross-sectional area such that, when fully wound on the drum and carrying the normal service load, the maximum allowable conductor temperature is not exceeded.

For cables of circular cross-sectional area installed on drums, the maximum current-carrying capacity in free air should be derated in accordance with Table 7 ~~(see also Clause 44 of IEC 60621-3)~~.

NOTE The current-carrying capacity of cables in free air can be found in manufacturers' specifications or in relevant national standards.

Table 7 – Derating factors for cables wound on drums

Drum type	Number of layers of cable				
	Any number	1	2	3	4
Cylindrical ventilated	–	0,85	0,65	0,45	0,35
Radial ventilated	0,85	–	–	–	–
Radial non-ventilated	0,75	–	–	–	–

~~NOTE 3~~ It is recommended that the use of derating factors be discussed with the cable and the cable drum manufacturers. This may result in other factors being used.

NOTE 1 A radial type drum is one where spiral layers of cable are accommodated between closely spaced flanges; if fitted with solid flanges, the drum is described as non-ventilated and if the flanges have suitable apertures, as ventilated.

NOTE 2 A ventilated cylinder drum is one where the layers of cable are accommodated between widely spaced flanges and the drum and end flanges have ventilating apertures.

12.7 Conductor wires, conductor bars and slip-ring assemblies

12.7.1 Basic protection ~~against direct contact~~

Conductor wires, conductor bars and slip-ring assemblies shall be installed or enclosed in such a way that, during normal access to the machine, basic protection ~~against direct contact~~ is achieved by the application of one of the following protective measures:

- protection by partial insulation of live parts, or where this is not practicable;
- protection by enclosures or barriers of at least IP2X ~~(see 412.2 of IEC 60364-4-41)~~ or IPXXB.

Horizontal top surfaces of barriers or enclosures that are readily accessible shall provide a degree of protection of at least IP4X ~~(see 412.2.2 of IEC 60364-4-41)~~ or IPXXD.

Where the required degree of protection is not achieved, protection by placing live parts out of reach in combination with emergency switching off in accordance with 9.2.3.4.3 shall be applied.

Conductor wires and conductor bars shall be so placed and/or protected as to:

- prevent contact, especially for unprotected conductor wires and conductor bars, with conductive items such as the cords of pull-cord switches, strain-relief devices and drive chains;
- prevent damage from a swinging load.

See also 6.2.6.

12.7.2 Protective conductors ~~circuit~~

Where conductor wires, conductor bars and slip-ring assemblies are installed as part of the protective bonding circuit, they shall not carry current in normal operation. Therefore, the protective conductor (PE) and the neutral conductor (N) shall each use a separate conductor wire, conductor bar or slip-ring.

The continuity of ~~the~~ protective conductors ~~circuit~~ using sliding contacts shall be ensured by taking appropriate measures (for example, duplication of the current collector, continuity monitoring).

12.7.3 Protective conductor current collectors

Protective conductor current collectors shall have a shape or construction so that they are not interchangeable with the other current collectors. Such current collectors shall be of the sliding contact type.

12.7.4 Removable current collectors with a disconnector function

Removable current collectors having a disconnector function shall be so designed that the protective conductor circuit is interrupted only after the live conductors have been disconnected, and the continuity of the protective conductor circuit is re-established before any live conductor is reconnected (see also 8.2.3).

12.7.5 Clearances in air

Clearances between the respective conductors, and between adjacent systems, of conductor wires, conductor bars, slip-ring assemblies and their current collectors shall be suitable for at least a rated impulse voltage of an overvoltage category III in accordance with IEC 60664-1.

12.7.6 Creepage distances

Creepage distances between the respective conductors, between adjacent systems of conductor wires, conductor bars and slip-ring assemblies, and their current collectors shall be suitable for operation in the intended environment, for example open air ~~(IEC 60664-1)~~, inside buildings, protected by enclosures.

In abnormally dusty, moist or corrosive environments, the following creepage distance requirements apply:

– unprotected conductor wires, conductor bars, and slip-ring assemblies shall be equipped with insulators with a minimum creepage distance of 60 mm;
– enclosed conductor wires, insulated multipole conductor bars and insulated individual conductor bars shall have a minimum creepage distance of 30 mm.

The manufacturer's recommendations shall be followed regarding special measures to prevent a gradual reduction in the insulation values due to unfavourable ambient conditions (for example deposits of conductive dust, chemical attack).

12.7.7 Conductor system sectioning

Where conductor wires or conductor bars are arranged so that they can be divided into isolated sections, suitable design measures shall be employed to prevent the energization of adjacent sections by the current collectors themselves.

12.7.8 Construction and installation of conductor wire, conductor bar systems and slip-ring assemblies

Conductor wires, conductor bars and slip-ring assemblies in power circuits shall be grouped separately from those in control circuits.

Conductor wires, conductor bars and slip-ring assemblies, including their current collectors, shall be capable of withstanding, without damage, the mechanical forces and thermal effects of short-circuit currents.

Removable covers for conductor wire and conductor bar systems laid underground or underfloor shall be so designed that they cannot be opened by one person without the aid of a tool.

Where conductor bars are installed in a common metal enclosure, the individual sections of the enclosure shall be bonded together and connected to the protective bonding ~~conductor at several points depending upon their length~~ circuit. Metal covers of conductor bars laid underground or underfloor shall also be bonded together and connected to the protective bonding ~~conductor~~ circuit.

~~NOTE For the protective bonding together of covers or cover plates of metal enclosures or underfloor ducts, the metal hinges are considered sufficient to ensure continuity.~~

The protective bonding circuit shall include the covers or cover plates of metal enclosures or underfloor ducts. Where metal hinges form a part of the protective bonding circuit, their continuity shall be verified (see Clause 18).

~~Underground and underfloor~~ Conductor bar ducts that can be subject to accumulation of liquid such as oil or water shall have drainage facilities.

13 Wiring practices

13.1 Connections and routing

13.1.1 General requirements

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 nature of the conductors being terminated.

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

Soldered connections shall only be permitted where terminals are provided that are suitable for soldering.

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

NOTE IEC 61666 provides rules that can be used for the designation of terminals within the electrical equipment.

Where an incorrect electrical connection (for example, arising from replacement of devices) ~~can be~~ is identified as a source of risk that needs to be reduced and it is not practicable to reduce the possibility of incorrect connection by design measures, the conductors and/or terminations shall be identified ~~in accordance with 13.2.1~~.

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

Means of retaining conductor strands 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.

Shielded conductors shall be so terminated as to prevent fraying of strands and to permit easy disconnection.

Identification tags shall be legible, permanent, and appropriate for the physical environment.

Terminal blocks shall be mounted and wired so that the ~~internal and external~~ wiring does not cross over the terminals ~~(see IEC 60947-7-1)~~.

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 splices or joints for the purpose of 13.1.2.

Exception: Where it is impracticable to provide terminals in a junction box (for example on mobile machines, on machines having long flexible cables; cable connections exceeding a length which is not practical to be supplied by the cable manufacturer on one cable drum~~; repair of cable due to mechanical stresses during installation and operation~~), splices or joints may be used.

Where it is necessary to connect and disconnect cables and cable assemblies, 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 or in the same plug/socket combination provided that the arrangement does not impair the proper functioning of the respective circuits and:

- where those circuits operate at different voltages, the conductors ~~shall be~~ are separated by suitable barriers or ~~shall be~~;
- the conductors are insulated for the highest voltage to which any ~~conductor within~~ of the ~~same duct~~ conductors can be subjected, for example line to line voltage for unearthed systems and phase to earth voltage for earthed systems.

13.1.4 AC circuits – Electromagnetic effects (prevention of eddy currents)

Conductors of AC circuits installed in ferromagnetic enclosures shall be arranged so that all conductors of each circuit, including the protective conductor of each circuit, are contained in the same enclosure. Where such conductors enter a ferrous enclosure, they shall be arranged such that the conductors are not individually surrounded by ferromagnetic material.

Single-core cables armoured with steel wire or steel tape should not be used for AC circuits.

NOTE 1 The steel wire or steel tape armour of a single-core cable is regarded as a ferromagnetic enclosure. For single-core wire armoured cables, the use of aluminium armour is recommended.

NOTE 2 Derived from IEC 60364-5-52.

13.1.5 Connection between pick-up and pick-up converter of an inductive power supply system

The cable between the pick-up and the pick-up converter ~~as specified by the manufacturer of the inductive power supply~~ shall be:

– as short as practicable;

– adequately protected against mechanical damage.

NOTE The output of the pick-up can be a current source, therefore damage to the cable can result in a high voltage hazard.

13.2 Identification of conductors

13.2.1 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).

NOTE 1 Annex B can be used for agreement between supplier and user regarding a preferred method of identification.

NOTE 2 IEC 62491 provides rules and guidelines for the labelling of cables and cores/conductors used in industrial installations, equipment and products.

13.2.2 Identification of the protective conductor / protective bonding conductor

The protective conductor / protective bonding conductor shall be readily distinguishable from other conductors by shape, location, marking, 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 protective conductors/protective bonding conductors.

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(s) can be easily identified by its shape, position, or construction (for example a braided conductor, uninsulated stranded conductor), or where the insulated conductor is not readily accessible or is part of a multicore cable, colour coding throughout its length is not necessary. However, where the conductor is not clearly visible throughout its length, the ends or accessible locations shall be clearly identified by the graphical symbol IEC 60417-5019 ~~(DB:2002-10)~~:2006-08 (see Figure 16) or with the letters PE or by the bicolour combination GREEN-AND-YELLOW.

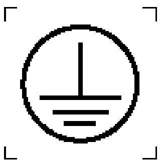


Figure 16 – Symbol IEC 60417-5019

Exception: Protective bonding conductors may be marked with the letters PB and/or the symbol IEC 60417-5021 (2002-10) (see Figure 17).

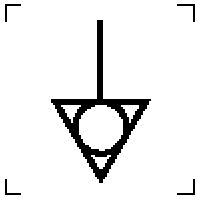


Figure 17 – Symbol IEC 60417-5021

13.2.3 Identification of the neutral conductor

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 6.2.2 of IEC ~~60446~~ 60445:2010). 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.

Where identification by colour is used, bare 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.

13.2.4 Identification by colour

Where colour-coding is used for identification of conductors (other than the protective conductor (see 13.2.2) and the neutral conductor (see 13.2.3)), the following colours may be used:

BLACK, BROWN, RED, ORANGE, YELLOW, GREEN, BLUE (including LIGHT BLUE), VIOLET, GREY, WHITE, PINK, TURQUOISE.

NOTE This list of colours is derived from IEC 60757.

It is recommended that, where colour is used for identification, 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 13.2.2).

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

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

- BLACK: AC and DC power circuits;
- RED: AC control circuits;
- BLUE: DC control circuits;
- ORANGE: excepted circuits in accordance with 5.3.5.

Exceptions: to the above are permitted where insulation is not available in the colours recommended (for example in multiconductor cables) ~~or multiconductor cable is used, but not the bicolour combination GREEN-AND-YELLOW~~.

13.3 Wiring inside enclosures

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 (see the IEC 60332 series).

It is recommended that electrical equipment mounted inside enclosures be designed and constructed in such a way as to permit modification of the wiring from the front of the 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 swingout panels shall be provided.

Connections to devices mounted on doors or to other movable parts shall be made using flexible conductors in accordance with 12.2 and 12.6 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).

Conductors and cables that do not run in ducts shall be adequately supported.

Terminal blocks or plug/socket combinations shall be used for control wiring that extends beyond the enclosure. For plug/socket combinations, see also 13.4.5 and 13.4.6.

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

13.4 Wiring outside enclosures

13.4.1 General requirements

The means of introduction of cables or ducts with their individual glands, bushings, etc., into an enclosure shall ensure that the degree of protection is not reduced (see 11.3).

Conductors of a circuit shall not be distributed over different multi-core cables, conduits, cable ducting systems or cable trunking systems. This is not required where a number of multi-core cables, forming one circuit, are installed in parallel. Where multi-core cables are installed in parallel, each cable shall contain one conductor of each phase and the neutral if any.

13.4.2 External ducts

Conductors and their connections external to the electrical equipment enclosure(s) shall be enclosed in suitable ducts (i.e. conduit or cable trunking systems) as described in 13.5 except for suitably protected cables that may be installed without ducts and with or without the use of ~~open~~ cable trays or cable support means. Where devices such as position switches or proximity switches are supplied with a dedicated cable, their cable need not be enclosed in a duct when the cable is suitable for the purpose, sufficiently short, and so located or protected, that the risk of damage is minimized.

Fittings used with ducts or ~~multiconductor~~ cables shall be suitable for the physical environment.

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

13.4.3 Connection to moving elements of the machine

~~Connections to frequently~~ The design of connections to moving parts shall take into account the foreseeable frequency of movement and shall be made using conductors in accordance with 12.2 and 12.6. Flexible cable and flexible conduit shall be so installed as to avoid excessive flexing and straining, particularly at the fittings.

Cables subject to movement shall be supported in such a way that there is no mechanical strain on the connection points nor any sharp flexing. When this is achieved by the provision of a loop, it shall have sufficient length to provide for a bending radius of the cable ~~of~~ as specified by the cable manufacturer or if no such specification is given, at least 10 times the diameter of the cable.

Flexible cables of machines shall be so installed or protected as to minimize the possibility of external damage due to factors that include the following cable use or potential abuse:

– being run over by the machine itself;
– being run over by vehicles or other machines;
– coming into contact with the machine structure during movements;
– running in and out of cable baskets, or on or off cable drums;
– acceleration forces and wind forces on festoon systems or suspended cables;
– excessive rubbing by cable collector;
– exposure to excessive radiated heat.

The cable sheath shall be resistant to the normal wear that can be expected from movement and to the effects of environmental contaminants (for example oil, water, coolants, dust).

Where cables subject to movement are close to moving parts, precautions shall be taken to maintain a space of at least 25 mm between the moving parts and the cables. Where that distance is not practicable, fixed barriers shall be provided between the cables and the moving parts.

The cable handling system shall be so designed that lateral cable angles do not exceed 5°, avoiding torsion in the cable when:

– being wound on and off cable drums; and
– approaching and leaving cable guidance devices.

Measures shall be taken to ensure that at least two turns of flexible cables always remain on a drum.

Devices serving to guide and carry a flexible cable shall be so designed that the inner bending radius at all points where the cable is bent is not less than the values given in Table 8, unless otherwise agreed with the cable manufacturer, taking into account the permissible tension and the expected fatigue life.

Table 8 – Minimum permitted bending radii for the forced guiding of flexible cables

Application	Cable diameter or thickness of flat cable (d) mm		
	$d \leq 8$	$8 < d \leq 20$	$d > 20$
Cable drums	6 d	6 d	8 d
Guide rollers	6 d	8 d	8 d
Festoon systems	6 d	6 d	8 d
All others	6 d	6 d	8 d

The straight section between two bends shall be at least 20 times the diameter of the cable.

Where flexible conduit is adjacent to moving parts, the construction and supporting means shall prevent damage to the flexible conduit under all conditions of operation.

Flexible conduit shall not be used for connections subject to rapid or frequent movements except when specifically designed for that purpose.

13.4.4 Interconnection of devices on the machine

Where several machine-mounted ~~switching~~ devices (for example position sensors, push-buttons) are connected in series or in parallel, it is recommended that the connections between those devices be made through terminals forming intermediate test points. Such terminals shall be conveniently placed, adequately protected, and shown on the relevant diagrams.

13.4.5 Plug/socket combinations

~~Where plug/socket combinations are provided, they shall fulfil one or more of the following requirements as applicable:~~

~~Exception:The following requirements do not apply to~~ Components or devices inside an enclosure, terminated by fixed plug/socket combinations (no flexible cable), or components connected to a bus system by a plug/socket combination, are not considered to be plug/socket combinations for the purpose of this 13.4.5.

~~When installed correctly~~ After installation in accordance with item a) below, 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 IP2X or IPXXB. PELV circuits are excepted from this requirement.

~~Have a first make last break protective bonding contact (earthing contact) (see also 6.3, 8.2.4) if used in TN- or TT-systems.~~

Where the plug/socket contains a contact for the protective bonding circuit, it shall have a first make last break contact (see also 8.2.4).

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 connection and disconnection is possible only when the switching device is in the OFF position.

Plug/socket combinations that are rated at more than 16 A shall have a retaining means to prevent unintended or accidental disconnection.

Where an unintended or accidental disconnection of plug/socket combinations can cause a hazardous situation, they shall have a retaining means.

The installation of plug/socket combinations shall fulfil the following requirements as applicable:

a) 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.

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

c) Plug/socket combinations intended to carry power loads but not to be disconnected during load conditions shall have a retaining means to prevent unintended or accidental disconnection and shall be clearly marked that they are not intended to be disconnected under load.

d) Where more than one plug/socket combination is provided in the same electrical equipment, the associated combinations shall be clearly identifiable. It is recommended that mechanical coding be used to prevent incorrect insertion.

e) Plug/socket combinations used in control circuits shall fulfil the applicable requirements of IEC 61984. ~~Exception: see item k).~~

~~k) Plug/socket combinations intended for household and similar general purposes shall not be used for control circuits.~~

Exception: In plug/socket combinations in accordance with IEC 60309-1, only those contacts shall be used for control circuits which are intended for those purposes. This exception does not apply to control circuits using high frequency signals superimposed on the power circuits.

~~Exception: The requirements of item k) do not apply to control functions using high frequency signals on the power supply.~~

13.4.6 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.

13.4.7 Additional conductors

Consideration should be given to providing additional conductors for maintenance or repair. When spare conductors are provided, they shall be connected to spare terminals or isolated in such a manner as to prevent contact with live parts.

13.5 Ducts, connection boxes and other boxes

13.5.1 General requirements

Ducts shall provide a degree of protection (see IEC 60529) suitable for the application.

All sharp edges, flash, burrs, rough surfaces, or threads with which the insulation of the conductors can come in contact shall be removed from ducts and fittings. Where necessary, additional protection consisting of a flame-retardant, oil-resistant insulating material shall be provided to protect conductor insulation.

Drain holes of 6 mm diameter are permitted in cable trunking systems, connection boxes, and other boxes used for wiring purposes that can be subject to accumulations of oil or moisture.

In order to prevent confusion of conduits with oil, air, or water piping, it is recommended that the conduits be either physically separated or suitably identified.

Ducts and cable trays shall be rigidly supported and positioned at a sufficient distance from moving parts and in such a manner so as to minimize the possibility of damage or wear. In areas where human passage is required, the ducts and cable trays shall be mounted at least 2 m above the working surface.

~~Ducts shall be provided only for mechanical protection (see 8.2.3 for requirements for connection to the protective bonding circuit).~~

Cable trays that are partially covered should not be considered to be ducts or cable trunking systems (see 13.5.6), and the cables used shall be of a type suitable for installation ~~with or without the use of~~ on open cable trays ~~or cable support means~~.

~~13.5.2 Percentage fill of ducts~~

~~Consideration of the percentage fill of ducts should be based on the straightness and length of the duct and the flexibility of the conductors.~~

It is recommended that the dimensions and arrangement of ducts be such as to facilitate the insertion of the conductors and cables.

13.5.2 Rigid metal conduit and fittings

Rigid metal conduit and fittings shall be of galvanized steel or of a corrosion-resistant material suitable for the conditions. The use of dissimilar metals in contact that can cause galvanic action should be avoided.

Conduits shall be securely held in place and supported at each end.

Fittings shall be compatible with the conduit and appropriate for the application. Fittings ~~shall~~ should be threaded unless structural difficulties prevent assembly. Where threadless fittings are used, the conduit shall be securely fastened to the equipment.

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

13.5.3 Flexible metal conduit and fittings

A flexible metal conduit shall consist of a flexible metal tubing or woven wire armour. It shall be suitable for the expected physical environment.

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

13.5.4 Flexible non-metallic conduit and fittings

Flexible non-metallic conduit shall be resistant to kinking and shall have physical characteristics similar to those of the sheath of multiconductor cables.

The conduit shall be suitable for use in the expected physical environment.

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

13.5.5 Cable trunking systems

Cable trunking systems external to enclosures shall be rigidly supported and clear of all moving ~~or contaminating portions~~ parts of the machine and of sources of contamination.

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 the IEC 61084 series.

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. Cable trunking systems shall not have opened but unused knockouts.

13.5.6 Machine compartments and cable trunking systems

The use of compartments or cable trunking systems within the column or base of a machine to enclose conductors is permitted provided the compartments or cable trunking systems are isolated from coolant or oil reservoirs and are entirely enclosed. Conductors run in enclosed compartments and cable trunking systems shall be so secured and arranged that they are not subject to damage.

13.5.7 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 machine is intended to operate (see 11.3).

Those boxes shall not have opened but unused knockouts nor any other openings and shall be so constructed as to exclude materials such as dust, flyings, oil, and coolant.

13.5.8 Motor connection boxes

Motor connection boxes shall enclose only connections to the motor and motor-mounted devices (for example brakes, temperature sensors, plugging switches, tachometer generators).

14 Electric motors and associated equipment

14.1 General requirements

Electric motors should conform to the relevant parts of IEC 60034 series.

The protection requirements for motors and associated equipment are given in 7.2 for overcurrent protection, in 7.3 for ~~overload~~ protection of motors against overheating, and in 7.6 for overspeed protection.

As many controllers do not switch off the supply to a motor when it is at rest, care shall be taken to ensure compliance with the requirements of 5.3, 5.4, 5.5, 7.5, 7.6 and 9.4. Motor control equipment shall be located and mounted in accordance with Clause 11.

14.2 Motor enclosures

~~It is recommended that motor enclosures be chosen from those included in~~ Enclosures for motors should be in accordance with IEC 60034-5.

The degree of protection shall be ~~at least IP23 (see IEC 60529) for all motors~~ dependent on the application and the physical environment (see 4.4). All motors shall be adequately protected from mechanical damage. ~~More stringent requirements can be needed depending on the application and the physical environment (see 4.4). Motors incorporated as an integral part of the machine shall be so mounted that they are adequately protected from mechanical damage.~~

14.3 Motor dimensions

As far as is practicable, the dimensions of motors shall 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 easily accessible for inspection, maintenance, adjustment and alignment, lubrication, and replacement. The motor mounting arrangement shall be such that all motor ~~hold-down~~ mounting means can be removed and all terminal boxes are accessible.

Motors shall be so mounted that proper cooling is ensured and the temperature rise remains within the limits of the insulation class (see IEC 60034-1).

Where practicable, motor compartments should be clean and dry, and when required, shall be ventilated directly to the exterior of the machine. The vents shall be such that ingress of swarf, dust, or water spray is at an acceptable level.

There shall be no opening between the motor compartment and any other compartment that does not meet the motor compartment requirements. Where a conduit or pipe is run into the motor compartment from another compartment not meeting the motor compartment requirements, any clearance around the conduit or pipe shall be sealed.

14.5 Criteria for motor selection

The characteristics of motors and associated equipment shall be selected in accordance with the anticipated service and physical environmental conditions (see 4.4). In this respect, the points that shall be considered include:

– type of motor;

– type of duty cycle (see IEC 60034-1);

– fixed speed or variable speed operation, (and the consequent variable influence of the ventilation);

– mechanical vibration;

– type of motor control;

– ~~influence of the harmonic spectrum of the voltage and/or current feeding the motor (particularly when it is supplied from a static convertor) on the temperature rise;~~

– temperature rise and other effects of the frequency spectrum of the voltage and/or current feeding the motor (particularly when it is supplied from a converter);

– method of starting and the possible influence of the inrush current on the operation of other users of the same power supply, taking also into account possible special considerations stipulated by the supply authority;

– variation of counter-torque load with time and speed;

– influence of loads with large inertia;

– influence of constant torque or constant power operation;

– possible need of inductive reactors between motor and converter.

14.6 Protective devices for mechanical brakes

Operation of the overload and overcurrent protective devices for mechanical brake actuators shall initiate the simultaneous de-energization (release) of the associated machine actuators.

NOTE Associated machine actuators are those associated with the same motion, for example cable drums and long-travel drives.

15 ~~Accessories~~ Socket-outlets and lighting

15.1 Socket-outlets for accessories

Where the machine or its associated equipment is provided with socket-outlets that are intended to be used for accessory equipment (for example hand-held power tools, test equipment), the following apply:

– the socket-outlets should conform to IEC 60309-1. Where that is not practicable, they should 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 and, when required, against overload in accordance with 7.2 and 7.3 separately from the protection of other circuits;

– where the power supply to the socket-outlet is not disconnected by the supply disconnecting device for the machine or the section of the machine, the requirements of 5.3.5 apply;

– where fault protection is provided by automatic disconnection of supply, the disconnection time shall be in accordance with Table A.1 for TN systems or Table A.2 for TT systems;

– circuits supplying socket-outlets with a current rating not exceeding 20 A shall be provided with residual current protection (RCDs) with a rated operating current not exceeding 30 mA.

~~NOTE 1 See also Annex B.~~

~~NOTE 2 Circuits for socket-outlets can be provided with residual current protective devices (RCDs).~~

15.2 Local lighting of the machine and of the equipment

15.2.1 General

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

The ON/OFF switch shall not be incorporated in the lampholder or in the flexible connecting cord.

Stroboscopic effects from lights shall be avoided by the selection of appropriate luminaires.

Where fixed lighting is provided in an enclosure, electromagnetic compatibility should be taken into account using the principles outlined in 4.4.2.

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 7.2.6):

– 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 ~~machine~~ circuit of the electrical equipment of the machine for lighting, 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 be permitted in control enclosures only, and for the machine work light(s) where their total power rating is not more than 3 kW;

– power supply units, for DC supply to LED light sources, fitted with isolating transformers (for example, in accordance with IEC 61558-2-6).

Exception: where fixed lighting is out of reach of operators during normal operations, the provisions of 15.2.2 do not apply.

15.2.3 Protection

Local lighting circuits shall be protected in accordance with 7.2.6.

15.2.4 Fittings

Adjustable lighting fittings shall be suitable for the physical environment.

The lampholders shall be:

– in accordance with the relevant IEC standard;
– constructed with an insulating material protecting the lamp cap so as to prevent unintentional contact.

Reflectors shall be supported by a bracket and not by the lampholder.

Exception: where fixed lighting is out of reach of operators during normal operation, the provisions of 15.2.4 do not apply.

16 Marking, warning signs and reference designations

16.1 General

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

16.2 Warning signs

16.2.1 Electric shock hazard

Enclosures that do not otherwise clearly show that they contain electrical equipment that can give rise to a risk of electric shock shall be marked with the graphical symbol ~~IEC 60417-5036 (DB:2002-10)~~ ISO 7010-W012 (see Figure 18).

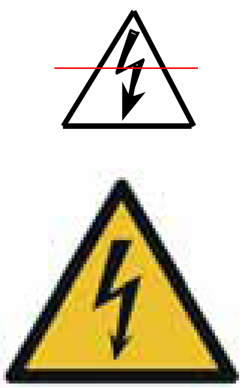


Figure 18 – Symbol ISO 7010-W012

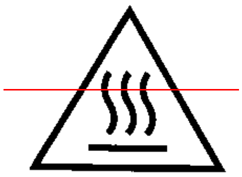
The warning sign shall be plainly visible on the enclosure door or cover.

The warning sign may be omitted (see also 6.2.2 b)) for:

– an enclosure equipped with a supply disconnecting device;
– an operator-machine interface or control station;
– a single device with its own enclosure (for example position sensor).

16.2.2 Hot surfaces hazard

Where the risk assessment shows the need to warn against the possibility of hazardous surface temperatures of the electrical equipment, the graphical symbol ~~IEC 60417-5041 (DB:2002-10)~~ ISO 7010-W017 shall be used (see Figure 19).



~~NOTE For electrical installations, this measure is dealt with in IEC 60364-4-42, Clause 423 and Table 42A.~~

Figure 19 – Symbol ISO 7010-W017

NOTE ISO 13732-1 gives guidance for the assessment of the risks of burns when humans might touch hot surfaces with their unprotected skin.

16.3 Functional identification

Control devices and visual indicators~~, and displays (particularly those related to safety)~~ shall be clearly and durably marked with regard to their functions either on or adjacent to the item. ~~Such markings may be as agreed between the user and the supplier of the equipment (see Annex B).~~

~~Preference should be given to the use of standard symbols given in~~ It is recommended that such markings are made in accordance with IEC 60417~~-DB:2002~~ and ISO 7000.

16.4 Marking of enclosures of electrical equipment

~~Equipment (for example controlgear assemblies)~~ The following information shall be legibly and durably marked in a way that is plainly visible after the equipment is installed on enclosures that receive incoming power supplies.~~ A nameplate giving the following information shall be attached to the enclosure adjacent to each incoming supply.~~

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

- name or trade mark of supplier;
- certification mark or other marking that can be required by local or regional legislation, when required;
- ~~short-circuit rating of the equipment;~~
- type designation or model, where applicable;

- serial number where applicable;
- main document number (see IEC 62023) where applicable;
- rated voltage, number of phases and frequency (if AC), and full-load current for each incoming supply.

~~Where only a single motor controller is used, that information may instead be provided on the machine nameplate where it is plainly visible.~~

It is recommended that this information is provided adjacent to the main incoming supply(ies).

16.5 Reference designations

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

17 Technical documentation

17.1 General

The information necessary for identification, transport, installation, ~~operation, and~~ use, maintenance, decommissioning and disposal of the electrical equipment ~~of a machine~~ shall be supplied ~~in the appropriate forms, for example, drawings, diagrams, charts, tables, instructions~~.

~~The information shall be in an agreed language (see also Annex B). The information provided may vary with the complexity of the electrical equipment. For very simple 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 electrical equipment of the machine.~~ Documentation is sometimes supplied in paper form, since it cannot be assumed that the user has access to the means of reading instructions supplied in electronic form or made available on an Internet site. However, it is often useful for the documentation to be made available in electronic form and on the Internet as well as in paper form, since this enables the user to download the electronic file if he so wishes and to recover the documentation if the paper copy has been lost. This practice also facilitates the updating of the documentation when this is necessary.

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

Annex I should be considered as guidance for the preparation of information and documents.

17.2 Information ~~to be provided~~ related to the electrical equipment

~~The information provided with the electrical equipment shall include:~~

~~a) A main document (parts list or list of documents);~~

~~b) Complementary documents including:~~

~~1) a clear, comprehensive description of the equipment, installation and mounting, and the connection to the electrical supply(ies);~~

~~2) electrical supply(ies) requirements;~~

~~3) information on the physical environment (for example lighting, vibration, noise levels, atmospheric contaminants) where appropriate;~~

~~4) overview (block) diagram(s) where appropriate;~~

~~5) circuit diagram(s);~~

~~6) information (as applicable) on:~~

- ~~programming, as necessary for use of the equipment;~~

- ~~sequence of operation(s);~~
- ~~frequency of inspection;~~
- ~~frequency and method of functional testing;~~
- ~~guidance on the adjustment, maintenance, and repair, particularly of the protective devices and circuits;~~
- ~~recommended spare parts list; and~~
- ~~list of tools supplied.~~

~~7) a description (including interconnection diagrams) of the safeguards, interlocking functions, and interlocking of guards against hazards, particularly for machines operating in a co-ordinated manner;~~

~~8) a description of the safeguarding and of the means provided where it is necessary to suspend the safeguarding (for example for setting or maintenance), (see 9.2.4);~~

~~9) instructions on the procedures for securing the machine for safe maintenance; (see also 17.8);~~

~~10) information on handling, transportation and storage;~~

~~11) information regarding load currents, peak starting currents and permitted voltage drops, as applicable;~~

~~12) 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.~~

The following shall be supplied:

a) where more than one document is provided, a main document for the electrical equipment as a whole, listing the complementary documents associated with the electrical equipment;

b) identification of the electrical equipment (see 16.4);

c) information on installation and mounting including:

- a description of the electrical equipment's installation and mounting, and its connection to the electrical supplies and where relevant other supplies;
- short-circuit current rating of the electrical equipment for each incoming power supply;
- rated voltage, number of phases and frequency (if AC.), type of distribution system (TT, TN, IT) and full-load current for each incoming supply;
- any additional electrical supply(ies) requirements (for example maximum supply source impedance, leakage current) for each incoming supply;
- space required for the removal or servicing of the electrical equipment;
- installation requirements where needed to ensure that the arrangements for cooling are not impaired;
- environmental limitations (for example lighting, vibration, EMC environment, atmospheric contaminants) where appropriate;
- functional limitations (for example peak starting currents and permitted voltage drop(s)) as applicable;
- precautions to be taken for the installation of the electrical equipment relevant to the electromagnetic compatibility;

d) an instruction for the connection of simultaneously accessible extraneous-conductive-parts in the vicinity of the machine (for example, within 2,5 metres) such as the following to the protective bonding circuit:

- metallic pipes;
- fences;

- ladders;
- handrails.

e) information on the functioning and operation, including as applicable:
- an overview of the structure of the electrical equipment (for example by structure diagram or overview diagram);
- procedures for programming or configuring, as necessary for the intended use;
- procedures for restarting after an unexpected stop;
- a sequence of operation;

f) information on maintenance of the electrical equipment, as appropriate, including:
- frequency and method of functional testing;
- instructions on the procedures for safe maintenance and where it is necessary to suspend a safety function and/or protective measure (see 9.3.6);
- guidance on the adjustment, repair, and frequency and method of preventive maintenance;
- details of the interconnections of the electrical components subject to replacement (for example by circuit diagrams and/or connection tables);
- information on required special devices or tools;
- information on spare parts;
- information on possible residual risks, indication of whether any particular training is required and specification of any necessary personal protective equipment;
- where applicable, instructions to restrict availability of key(s) or tool(s) to skilled or instructed persons only;
- settings (DIP-switches, programmable parameter values, etc);
- information for validation of safety related control functions after repair or modification, and for periodic testing where necessary;

g) information on handling, transportation and storage as appropriate (for example dimensions, weight, environmental conditions, possible ageing constraints);

h) information for proper disassembly and handling of components (for example for recycling or disposal).

~~**17.3 Requirements applicable to all documentation**~~

~~Unless otherwise agreed between manufacturer and user:~~

- ~~the documentation shall be in accordance with relevant parts of IEC 61082;~~
- ~~reference designations shall be in accordance with relevant parts of IEC 61346;~~
- ~~instructions/manuals shall be in accordance with IEC 62079.~~
- ~~parts lists where provided shall be in accordance with IEC 62027, class B.~~

~~NOTE See item 13 of Annex B.~~

~~For referencing of the different documents, the supplier shall select one of the following methods:~~

- ~~where the documentation consists of a small number of documents (for example less than 5) each of the documents shall carry as a cross-reference the document numbers of all other documents belonging to the electrical equipment; or~~
- ~~for single level main documents only (see IEC 62023), all documents shall be listed with document numbers and titles in a drawing or document list; or~~
- ~~all documents of a certain level (see IEC 62023) of the document structure shall be listed, with document numbers and titles, in a parts list belonging to the same level.~~

~~17.4 Installation documents~~

~~The installation documents shall give all information necessary for the preliminary work of setting up the machine (including commissioning). In complex cases, it may be necessary to refer to the assembly drawings for details.~~

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

~~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 of the machine shall be stated (see 7.2.2).~~

~~Where necessary, the size, purpose, and location of any ducts in the foundation that are to be provided by the user shall be detailed (see Annex B).~~

~~The size, type, and purpose of ducts, cable trays, or cable supports between the machine and the associated equipment that are to be provided by the user shall be detailed (see Annex B).~~

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

~~NOTE 1 Examples of installation diagrams can be found in IEC 61082-4.~~

~~In addition, where it is appropriate, an interconnection diagram 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 more than one source of electrical supply, the interconnection diagram or table shall indicate the modifications or interconnections required for the use of each supply.~~

~~NOTE 2 Examples of interconnection diagrams/tables can be found in IEC 61082-3.~~

~~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 series.~~

~~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 61082-2.~~

~~17.6 Circuit diagrams~~

~~A circuit diagram(s) shall be provided. This diagram(s) shall show the electrical circuits on the machine and its associated electrical equipment. Any graphical symbol not shown in IEC 60617-DB:2001 shall be separately shown and described on the diagrams or supporting documents. The symbols and identification of components and devices shall be consistent throughout all documents and on the machine.~~

~~Where appropriate, a diagram showing the terminals for interface connections 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 shown.~~

~~Switch symbols shall be shown on the electromechanical diagrams with all supplies turned off (for example electricity, air, water, lubricant) and with the machine and its electrical equipment ready for a normal start.~~

~~Conductors shall be identified in accordance with 13.2.~~

~~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 manual~~

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

~~Where the operation of the equipment can be programmed, detailed information on methods of programming, equipment required, program verification, and additional safety procedures (where required) shall be provided.~~

~~17.8 Maintenance manual~~

~~The technical documentation shall contain a maintenance manual detailing proper procedures for adjustment, servicing and preventive inspection, and repair. Recommendations on maintenance/service intervals and records should be part of that manual. Where methods for the verification of proper operation are provided (for example software testing programs), the use of those methods shall be detailed.~~

~~17.9 Parts list~~

~~The parts list, where provided, shall comprise, as a minimum, information necessary for ordering spare or replacement parts (for example components, devices, software, test equipment, technical documentation) required for preventive or corrective maintenance including those that are recommended to be carried in stock by the user of the equipment.~~

18 Verification

18.1 General

~~This part of IEC 60204 gives general requirements for the electrical equipment of machines.~~

The extent of verification will be given in the dedicated product standard for a particular machine. Where there is no dedicated product standard for the machine, the verifications shall always include the items a), b), c) and h) and may include one or more of the items d) to g):

a) verification that the electrical equipment complies with its technical documentation;
b) verification of continuity of the protective bonding circuit (Test 1 of 18.2.2);
c) in case of fault protection ~~against indirect contact~~ by automatic disconnection of supply, conditions for protection by automatic disconnection shall be verified according to 18.2;
d) insulation resistance test (see 18.3);
e) voltage test (see 18.4);
f) protection against residual voltage (see 18.5);
g) verification that the relevant requirements of 8.2.6 are met;
h) functional tests (see 18.6).

When these tests are performed, it is recommended that they follow the sequence listed above.

When the electrical equipment is modified, the requirements stated in 18.7 shall apply.

~~The tests shall be carried out by measuring equipment in accordance with relevant IEC standards. For tests in accordance with 18.2 and 18.3, measuring equipment in accordance with the IEC 61557 series is applicable.~~

For verifications that include measurement, measuring equipment in accordance with the IEC 61557 series is recommended.

The results of the verification shall be documented.

18.2 Verification of conditions for protection by automatic disconnection of supply

18.2.1 General

The conditions for automatic disconnection of supply (see 6.3.3) shall be verified by tests.

Test 1 verifies the continuity of the protective bonding circuit.

Test 2 verifies the conditions for protection by automatic disconnection of the supply in TN systems.

For TN-systems, those test methods are described in 18.2.2 and 18.2.3; their application for different conditions of supply are specified in 18.2.4.

For TT systems, see Clause A.2.

For IT systems, see IEC 60364-6.

Where RCDs are used in the electrical equipment, their function shall be verified in accordance with the manufacturer's instructions. The test procedure and test interval shall be specified in the maintenance instructions.

~~18.2.2 Test methods in TN-systems~~

~~Test 1 verifies the continuity of the protective bonding circuit. Test 2 verifies the conditions for protection by automatic disconnection of the supply.~~

18.2.2 Test 1 – Verification of the continuity of the protective bonding circuit

The resistance ~~of each protective bonding circuit~~ between the PE terminal (see 5.2 and Figure 4) and relevant points that are part of ~~each~~ the protective bonding circuit shall be measured with a current between at least 0,2 A and approximately 10 A derived from an electrically separated supply source (for example SELV, see 414 of IEC 60364-4-41:2005) having a maximum no-load voltage of 24 V AC or DC. ~~It is recommended not to use a PELV supply since such supplies can produce misleading results in this test.~~

The resistance measured shall be in the expected range according to the length, the cross sectional area and the material of the related protective conductors and protective bonding conductor(s).

Earthed PELV supplies can produce misleading results in this test and therefore shall not be used.

NOTE Larger currents used for the continuity test increases the accuracy of the test result, especially with low resistance values, i.e. larger cross sectional areas and/or lower conductor lengths.

18.2.3 Test 2 – Fault loop impedance verification and suitability of the associated overcurrent protective device

The connections of ~~the~~ each power supply ~~and of the incoming external~~ including the connection of the associated protective conductor to the PE terminal of the machine, shall be verified by inspection.

The conditions for the protection by automatic disconnection of supply in accordance with 6.3.3 and Annex A shall be verified by both:

a) verification of the fault loop impedance by:
   – calculation, or
   – measurement in accordance with A.1.4, and
b) confirmation that the setting and characteristics of the associated overcurrent protective device are in accordance with the requirements of Annex A, and where a power drive system (PDS) is used, confirmation that the setting and characteristics of the protective device(s) associated with a PDS are in accordance with the converter manufacturer's and protective device manufacturer's instructions.

~~NOTE 2 A fault loop impedance measurement can be carried out for circuits where the conditions of protection by automatic disconnection requires a current I_a up to about 1 kA (I_a is the current causing the automatic operation of the disconnecting device within the time specified in Annex A).~~

18.2.4 Application of the test methods for TN-systems

~~Test 1 of 18.2.2 shall be carried out on each protective bonding circuit of a machine.~~

When Test 2 of 18.2.3 is carried out by measurement, it shall always be preceded by Test 1 of 18.2.2.

NOTE A discontinuity of the protective bonding circuit can cause a hazardous situation for the tester or other persons, or damage to the electrical equipment during the loop impedance test.

The tests that are necessary for machines of different status are specified in Table 9. ~~Table 10 can be used to enable determination of the machine status.~~

Table 9 – Application of the test methods for TN-systems

Procedure	Machine status	Verification on site
A	Electrical equipment of machines, erected and connected on site, where the continuity of the protective bonding circuits has not been confirmed following erection and connection on site.	Test 1 (see 18.2.2) and test 2 (see 18.2.3) Exception: ~~If previous calculations of the fault loop impedance or resistance by the manufacturer are available and~~ Test 2 is not required where: – test 1 is performed on the protective bonding conductors of the machine that are connected on site, and; – the connections of each incoming power supply and of the associated protective conductor (PE) to the PE-terminal of the machine, are verified by inspection, and previous calculations of the fault loop impedance (or resistance) by the manufacturer of the electrical equipment are available, and; – the arrangement of the installations permits the verification of the length and cross-sectional area of the conductors used for the calculation, and – it can be confirmed through calculation or measurement, or by information supplied by the customer, that the supply source impedance on site ~~is less than or equal to that of the supply used for the value assumed for the calculation by the manufacturer~~ does not exceed the value specified by the manufacturer of the electrical equipment. See 17.2 c), fourth bullet). ~~Test 1 (see 18.2.2) of the protective bonding circuits connected on site and verification by inspection of the connections of the power supply and of the incoming external protective conductor to the PE-terminal of the machine is sufficient.~~
B	Machine supplied with confirmation of the verification (see 18.1) of continuity of the protective bonding circuits by test 1 or with the results of a test 2 by measurement, having protective bonding circuits exceeding the cable length for which examples are given in Table 10. Case B1) supplied fully assembled and not dismantled for shipment, Case B2) supplied dismantled for shipment, where the continuity of protective conductors is ensured after dismantling, transportation and reassembly (for example by the use of plug/socket connections).	Test 2 (see 18.2.3) Exception: Where it can be confirmed through calculation or measurement, or by information supplied by the customer, that the supply source impedance on site ~~is less than or equal to that used for the calculation~~ does not exceed the value specified by the manufacturer of the electrical equipment, or that of the test supply during a test 2 by measurement, no test is required on site apart from verification of the connections: • in case B1) of ~~the power supply and of the incoming external~~ of each incoming power supply and of the associated protective conductor to the PE terminal of the machine; • in case B2) of ~~the power supply and of the incoming external~~ each incoming power supply and of the associated protective conductor to the PE terminal of the machine and of all connections of the protective conductor(s) that were disconnected for shipment.

C	Machine having protective bonding circuits not exceeding the cable length for which examples are given in Table 10, supplied with confirmation of the verification (see 18.1) of continuity of the protective bonding circuits by test 1~~ or test 2 (see 18.2.2) by measurement~~. Case C1) supplied fully assembled and not dismantled for shipment. Case C2) supplied dismantled for shipment, where the continuity of protective conductors is ensured after dismantling, transportation and reassembly (for example by the use of plug/socket combination(s)).	For case C1 or C2, no test is required on site. For a machine not connected to the power supply by a plug/socket combination, the correct connection of the~~ incoming~~ external protective conductor to the PE-terminal of the machine shall be verified by visual inspection. In case C2), the installation documents (see 17.2) shall require that all connections of the protective conductor(s) that were disconnected for shipment are verified, for example by visual inspection.

Table 10 – Examples of maximum cable lengths from ~~each~~ protective devices to ~~its~~ their loads for TN-systems

1 ~~Supply~~ Maximum source impedance of the supply to ~~each~~ the protective device	2 Minimum cross-sectional area	3 Maximum nominal rating or setting of the protective device I_N	4 Fuse disconnect time 5 s	5 Fuse disconnect time 0,4 s	6 Miniature circuit-breaker char.B ~~[4]~~ $I_a = 5 \times I_N$ ~~disconnect time 0,1 s~~	7 Miniature circuit-breaker char.C ~~[5]~~ $I_a = 10 \times I_N$ ~~disconnect time 0,1 s~~	8 Miniature circuit-breaker char.D $I_a = 20 \times I_N$	9 Adjustable circuit-breaker $I_a = 8 \times I_N$ ~~disconnect time 0,1 s~~
mΩ	mm²	A	Maximum cable length in m from each protective device to its load					
500	1,5	16	97	53	76	30	7	~~28~~ 31
500	2,5	20	115	57	94	34	3	36
500	4,0	25	135	66	114	35		38
400	6,0	32	145	59	133	40		42
300	10	50	125	41	132	33		37
200	16	63	175	73	179	55		61
200	25 (line)/16 (PE)	80	133					38
100	35 (line)/16 (PE)	100	136					73
100	50 (line)/25 (PE)	125	141					66
100	70 (line)/35 (PE)	160	138					46
50	95 (line)/50 (PE)	200	152					98
50	120 (line)/70 (PE)	250	157					79

The values of the maximum cable length in Table 10 are based on the following assumptions:

- PVC cable with copper conductors, conductor temperature under short-circuit conditions 160 °C (see Table D.5);
- cables with line conductors up to 16 mm² provide a protective conductor of equal cross sectional area to that of the line conductors;
- cables above 16 mm² provide a reduced size protective conductor as shown;
- 3-phase system, nominal voltage of the power supply 400 V (U_0 = 230 V);
- ~~maximum supply source impedance to each protective device in accordance with column 1;~~
- column 3 values are correlated with Table 6 (see 12.4).
- disconnection time for circuit-breakers is ≤ 0,4 s (columns 6 – 9)

A deviation from these assumptions can require a complete calculation or measurement of the fault loop impedance. Further information is available from IEC 60228 and IEC TR 61200-53.

18.3 Insulation resistance tests

When insulation resistance tests are performed, the insulation resistance measured at 500 V DC between the power circuit conductors and the protective bonding circuit shall be not less than 1 MΩ. 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.

~~[4] In accordance with the IEC 60898 series.~~

~~[5] In accordance with the IEC 60898 series.~~

If the electrical equipment of the machine contains surge protection devices which are likely to operate during the test, it is permitted to either:

– disconnect these devices, or
– reduce the test voltage to a value lower than the voltage protection level of the surge protection devices, but not lower than the peak value of the upper limit of the supply (phase to neutral) voltage.

18.4 Voltage tests

When voltage tests are performed, test equipment in accordance with IEC 61180-2 should be used.

The test voltage shall be at a nominal frequency of 50 Hz or 60 Hz.

The maximum test voltage shall have a value of twice the rated supply voltage of the equipment or 1 000 V, whichever is the greater. The maximum test voltage shall be applied between the power circuit conductors and the protective bonding circuit for ~~a period of approximately~~ at least 1 s. The requirements are satisfied if no disruptive discharge occurs.

Components and devices that are not rated to withstand the test voltage and surge protection devices which are likely to operate during the test shall be disconnected during testing.

Components and devices that have been voltage tested in accordance with their product standards may be disconnected during testing.

18.5 Protection against residual voltages

Where appropriate, tests shall be performed to ensure compliance with 6.2.4.

18.6 Functional tests

The functions of electrical equipment shall be tested.

~~The function of circuits for electrical safety (for example earth fault detection) shall be tested.~~

18.7 Retesting

Where a portion of the machine ~~and~~ or its associated equipment is changed or modified, ~~that portion shall be reverified and retested, as appropriate (see 18.1)~~ the need for re-verification and testing of the electrical equipment shall be considered.

Particular attention should be given to the possible adverse effects that retesting can have on the equipment (for example overstressing of insulation, disconnection/reconnection of devices).

Annex A
(normative)

~~**Protection against indirect contact in TN-systems**~~
~~**(Derived from IEC 60364-4-41:2001, and IEC 60364-6-61:2001)**~~

Fault protection by automatic disconnection of supply

A.1 Fault protection for machines supplied from TN-systems

A.1.1 General

The provisions in the Annex A are derived from IEC 60364-4-41:2005, and IEC 60364-6:2006.

Fault protection ~~against indirect contact~~ shall be provided by an overcurrent protective device that automatically disconnects the supply to the circuit or equipment in the event of a fault between a live part and an exposed conductive part or a protective conductor in the circuit or equipment, within a sufficiently short disconnecting time. A disconnecting time not exceeding 5 s is considered sufficiently short for machines that are neither hand-held nor portable.

~~Exception:~~ Where this disconnecting time cannot be assured, ~~measures shall be implemented (for example~~ supplementary protective bonding~~) to~~ shall be provided in accordance with A.1.3 that can prevent a prospective touch voltage from exceeding 50 V AC or 120 V ripple-free DC between simultaneously accessible conductive parts. ~~See A.3.~~

NOTE The use of supplementary protective bonding does not preclude the need to disconnect the supply for other reasons, for example protection against fire, thermal stresses in equipment, etc.

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 a machine 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~~

~~[a)] U_o is the nominal a.c. r.m.s. voltage to earth.~~

~~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.~~

System	50 V < U_0 ≤ 120 V		120 V < U_0 ≤ 230 V		230 V < U_0 ≤ 400 V		U_0 > 400 V	
	s		s		s		s	
	AC	DC	AC	DC	AC	DC	AC	DC
TN	0,8	NOTE 1	0,4	5	0,2	0,4	0,1	0,1

U_o is the nominal AC or DC line to earth voltage.

NOTE 1 Disconnection may be required for reasons other than protection against electric shock.

NOTE 2 For voltages which are within the tolerance band stated in IEC 60038, the disconnecting time appropriate to the nominal voltage applies.

NOTE 3 For intermediate values of voltage, the next higher value in the above table is to be used.

A.1.2 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~~ line 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 general condition fulfils this requirement:

$$Z_s \times I_a \leq U_0$$

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 AC 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)~~ in the following equation:

$$Z_{s\,(n)} \leq \frac{2}{3} \times \frac{U_0}{I_a}$$

where Z_s(n) is the measured or calculated value of Z_s under normal operating conditions.

Where the value of the fault loop impedance exceeds $2U_0/3I_a$, a more precise assessment can be made in accordance with the procedure described in C.61.3.6.2 of IEC 60364-6:2006.

~~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.1.3 Condition for protection by reducing the touch voltage below 50 V

Where the requirements of A.1.2 cannot be assured, supplementary protective bonding ~~is~~ can be selected as the means of ensuring ~~protection against hazardous~~ that touch voltages~~, the condition for this protection is that the touch voltage has been reduced to below~~ will not exceed 50 V. This is achieved when the impedance of the protective bonding 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 between the equipment anywhere in the installation and the PE terminal of the machine (see 5.2 and Figure 4) or between simultaneously accessible exposed conductive parts and/or extraneous-conductive-parts.

Confirmation of this condition can be achieved by using the method of Test 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:

$$R_{\mathbf{PE}} \leq \frac{50}{I_{\mathbf{a(5s)}}}$$

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 4) and the equipment anywhere on the machine, or between simultaneously accessible exposed conductive parts and/or extraneous-conductive-parts.

NOTE 1 Supplementary protective bonding is considered as an addition to fault 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.1.4 Verification of conditions for protection by automatic disconnection of the supply

A.1.4.1 General

The effectiveness of the measures for fault protection ~~against indirect contact~~ by automatic disconnection of supply in accordance with A.1.2 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). See Figure A.1.

Exception: Verification of the continuity of the protective conductors may replace the measurement 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.

Where a power drive system (PDS) is used, the disconnection time for fault protection shall meet the relevant requirements of this Annex A at the incoming supply terminals of the basic drive module (BDM) of the PDS. See Figure A.2.

A.1.4.2 Measurement of the fault loop impedance

Where measurement of the fault loop impedance ~~shall be~~ is performed, ~~using~~ it is recommended that the measuring equipment comply 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 machine 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.

~~NOTE~~ If it is not practicable for the motor to be connected during the test, the two ~~phase~~ line conductors not used in the test ~~can~~ may be opened, for example, by removing fuses.

The measured value of the fault loop impedance shall ~~comply~~ be in accordance with A.1.2.

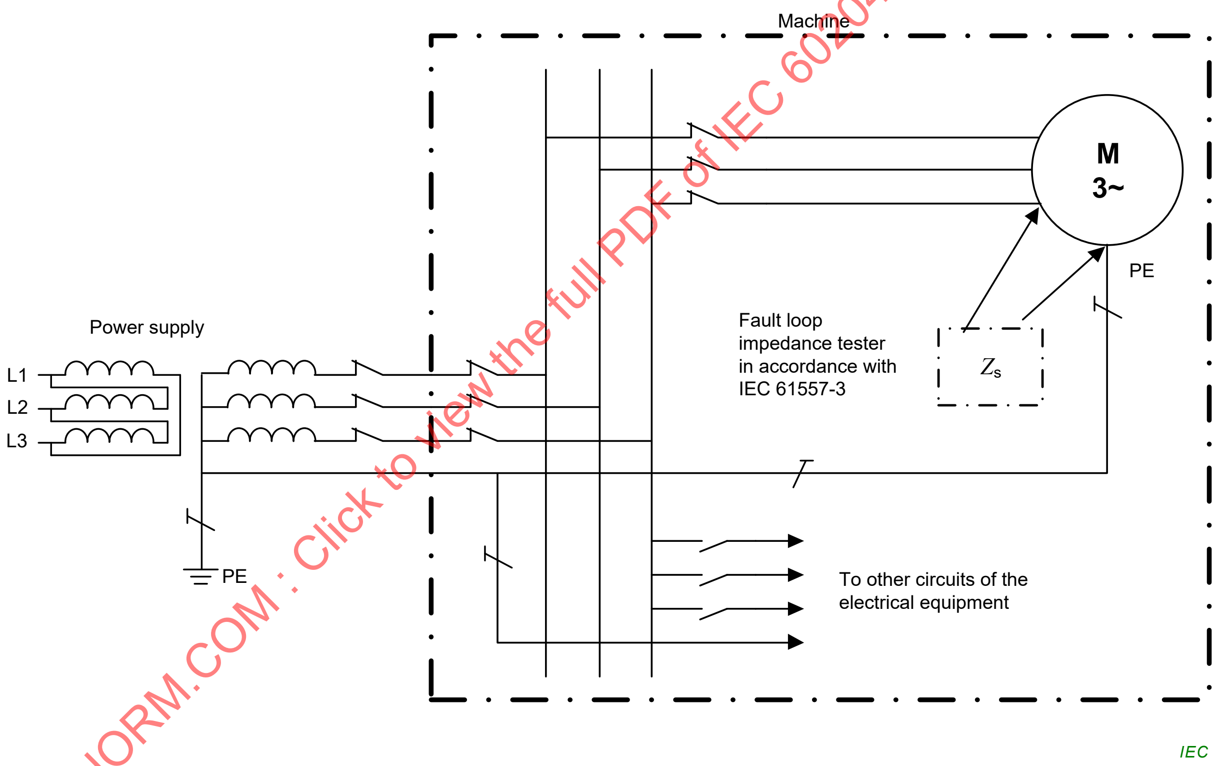


Figure A.1 – Typical arrangement for fault loop impedance (Z_s) measurement in TN systems

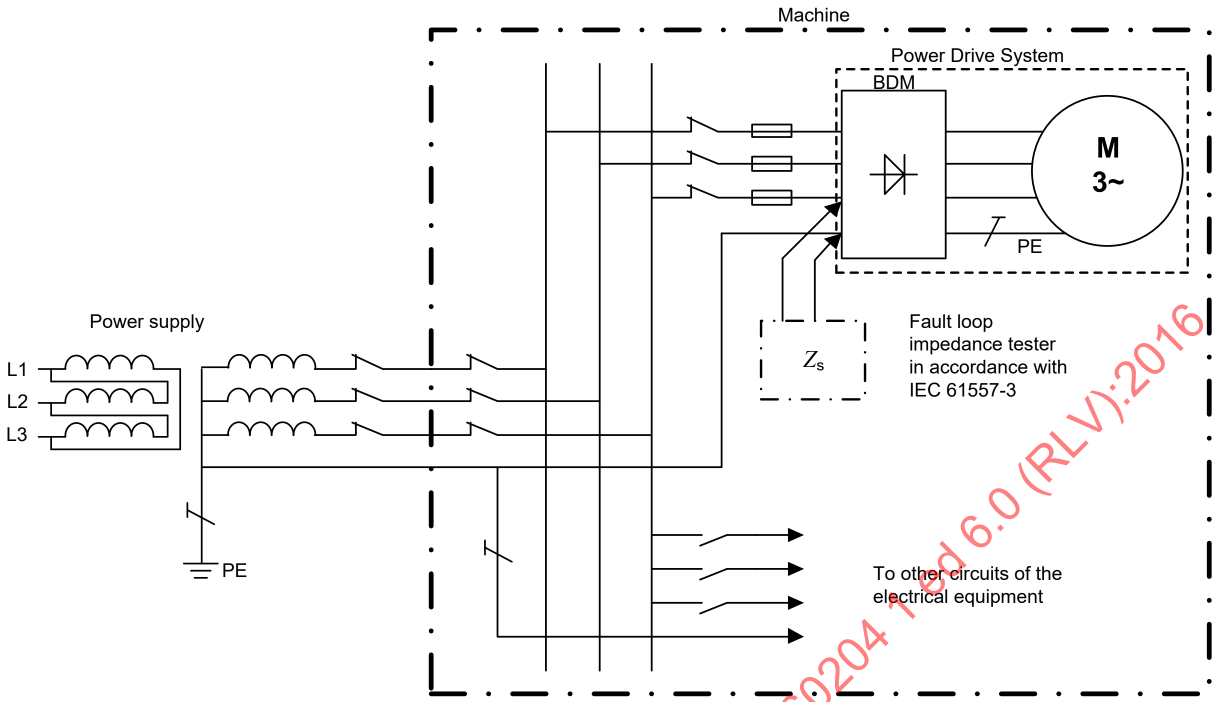


Figure A.2 – Typical arrangement for fault loop impedance (Z_s) measurement for power drive system circuits in TN systems

~~A.4.3 Consideration of the difference between the measured value of resistance of the conductors and the actual value under fault conditions~~

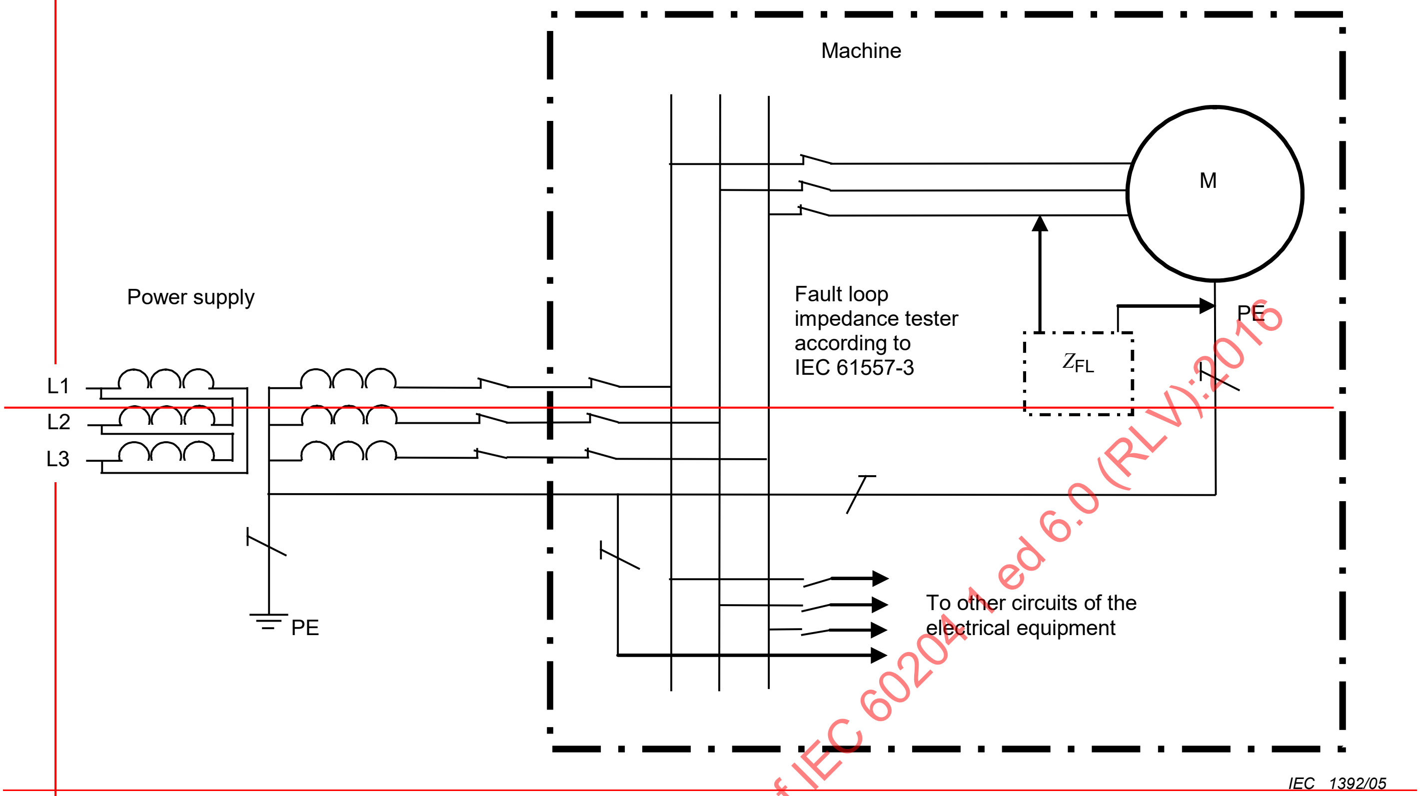
~~NOTE As the measurements are made at ambient temperature, with low currents, it is necessary to take into account the increase of resistance of the conductors with the increase of temperature under fault conditions, to verify the compliance of the measured value of the fault loop impedance with the 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:~~

$$\cancel{Z_{\mathrm{s}}(\mathrm{m}) \leq \frac{2}{3} \times \frac{U_0}{I_{\mathrm{a}}}}$$

~~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 60364-6-61.~~



~~Figure A.1 – Typical arrangement for fault loop impedance measurement~~

A.2 Fault protection for machines supplied from TT-systems

A.2.1 Connection to earth

All exposed-conductive-parts and all extraneous-conductive-parts shall be bonded to the protective bonding circuit.

Exception: see 8.2.5.

In addition to the requirements of 5.2, provision for additional earthing of machine elements and/or the PE conductor of the electrical equipment may be provided.

NOTE In a TT system, the neutral point or the mid-point of the power supply system is earthed, or where a neutral point or mid-point is not available or not accessible, a line conductor is earthed (derived from IEC 60364-4-41:2005, 411.5.1).

A.2.2 Fault protection for TT systems

A.2.2.1 General

Generally in TT systems, RCDs shall be used for fault protection. Alternatively, overcurrent protective devices may be used for fault protection provided a suitably low value of Z_s is permanently and reliably assured. Z_s is the impedance of the fault loop.

NOTE In some countries the use of overcurrent protective devices is not permitted as the means of fault protection in TT systems.

Where automatic disconnection of supply is used as a measure for fault protection, the electrical equipment designer may either:

a) use in the design calculations a value of earth electrode resistance or earth fault loop impedance measured in accordance with IEC 60364-6 or declared by the intended user of the equipment (see Annex B); or

b) for series-manufactured machines, specify a value of the earth electrode resistance or earth fault loop impedance suitable for the intended installations;

and shall state in the installation instructions the value of earth electrode resistance or earth fault loop impedance used for the design of the electrical equipment, specifying that this is the maximum value to which the machine can be connected.

Where a power drive system (PDS) is used, the disconnection time for fault protection shall meet the relevant requirements of this Annex A at the incoming supply terminals of the basic drive module (BDM) of the PDS. See Figure A.4.

A.2.2.2 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) disconnection time as required by Table A.2, and

b) $R_A \times I_{\Delta n} \leq 50$ V

where:

R_A is the sum of the resistances of the earth electrode and the protective conductor for each exposed conductive-part,

$I_{\Delta n}$ is the rated residual operating current of the RCD.

Exception: a disconnection time not exceeding 1 s is permitted for distribution circuits and for circuits not covered by Table A.2.

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, information is given in 535.3 of IEC 60364-5-53:2001.

NOTE 3 The disconnection times in accordance with Table A.2 relate to prospective residual fault currents significantly higher than the rated residual operating current of the RCD (typically 5 $I_{\Delta n}$).

NOTE 4 The definition of R_A is extracted from IEC 60364-4-41. In this part of IEC 60204, the term "earth electrode" in the definition of R_A is considered to mean the "earth-return path" as defined by IEC 60050-195:1998, 195-02-30.

A.2.2.3 Protection by overcurrent protective devices

Where an overcurrent protective device is used the following condition shall be fulfilled:

$$Z_s \times I_a \leq U_o$$

where:

Z_s is the impedance of the fault loop comprising:

the source,

the line conductor up to the point of the fault,

the protective conductor of each exposed-conductive-part,

the earthing conductor,

the earth electrode of the installation and the earth electrode of the source;

I_a is the current causing the automatic operation of the disconnecting device within the time specified in Table A.2.

Exception: a disconnection time not exceeding 1 s is permitted for circuits not covered by Table A.2.

U_o is the nominal AC or DC line to earth voltage.

The maximum disconnection times stated in Table A.2 shall be applied to circuits not exceeding 32 A. Maximum disconnection times shall not exceed 1 s for circuits 32 A or greater.

Table A.2 – Maximum disconnecting time for TT-systems

System	50 V < U_o ≤ 120 V		120 V < U_o ≤ 230 V		230 V < U_o ≤ 400 V		U_o > 400 V	
	s		s		s		s	
	AC	DC	AC	DC	AC	DC	AC	DC
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 all extraneous-conductive-parts will be connected to the protective bonding circuit, the maximum disconnection times specified in Table A.1 may be used.

U_o is the nominal AC or DC line to earth voltage.

NOTE Disconnection can be required for reasons other than protection against electric shock.

A.2.3 Verification of protection by automatic disconnection of supply using a residual current protective device

Fault protection in a TT system by automatic disconnection of supply using a residual current protective device shall be verified by the following:

- inspection of the rated residual current for tripping value, and the disconnecting time value of the residual current protective device, and
- 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.

A.2.4 Measurement of the fault loop impedance (Z_s)

Where measurement of the fault loop impedance is performed the measuring equipment should comply 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.

The measurement shall be performed with the electrical equipment connected to a supply of between 99 % and 101 % the nominal frequency of the supply at the intended installation.

NOTE 1 Figure A.3 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 line conductors not used in the test may be opened, for example, by removing fuses.

NOTE 2 Figure A.4 illustrates a typical arrangement for measuring the fault loop impedance when a power drive system is used.

The measured value of the fault loop impedance shall be in accordance with A.2.2.3.

NOTE 3 Information on the verification of performance of a residual current protective device and measurement of earth fault loop impedance can be found in IEC 60364-6.

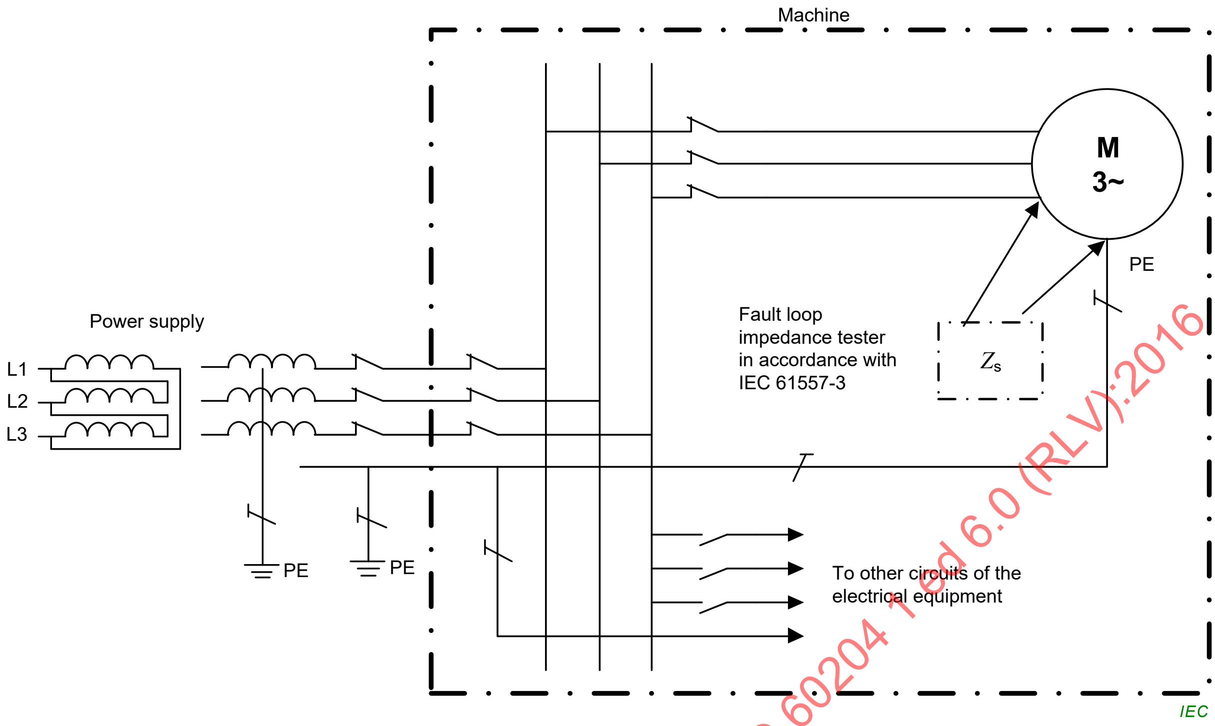


Figure A.3 – Typical arrangement for fault loop impedance (Z_s) measurement in TT systems

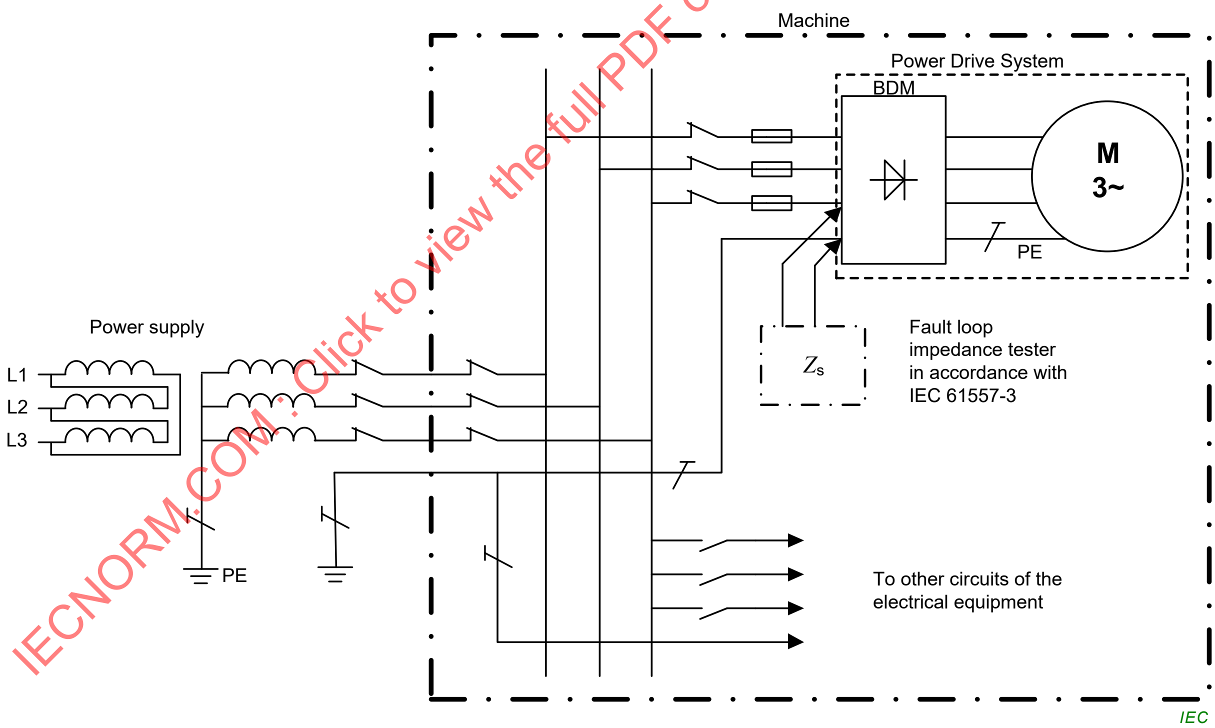


Figure A.4 – Typical arrangement for fault loop impedance (Z_s) measurement for power drive system circuits in TT systems

Annex B
(informative)

Enquiry form for the electrical equipment of machines

~~It is recommended that the following information be provided by the intended user of the equipment. It~~ The use of this enquiry form can facilitate an ~~agreement~~ exchange of information between the user and supplier on basic conditions and additional user requirements to enable ~~proper~~ suitable design, application and utilization of the electrical equipment of the machine (see 4.1) particularly when the conditions on site can deviate from those generally expected.

Annex B can also serve as an internal checklist for serial manufactured machines.

Name of manufacturer/supplier				
Name of end user				
Tender/order number			Date	
Type of machine	Type designation		Serial number	
1. Special conditions (see Clause 1)				
a) Is the machine to be used in the open air?	Yes/No		~~No~~ If yes, specification	
b) Will the machine use, process or produce explosive or flammable material?	Yes/No		If yes, specification	
c) Is the machine for use in potentially explosive or flammable atmospheres?	Yes/No		If yes, specification	
d) Can the machine present special hazards when producing or consuming certain materials?	Yes/No		If yes, specification	
e) Is the machine for use in mines?	Yes/No		~~No~~ If yes, specification	
2. Electrical supplies and related conditions (see 4.3)				
a) Anticipated voltage fluctuations (if more than ±10 %)				
b) Anticipated frequency fluctuations (if more than ±2 %)	Continuous		Short time	
c) Indicate possible future changes in electrical equipment that will require an increase in the electrical supply requirements				
d) Specify voltage interruptions in supply if longer than specified in Clause 4 where electrical equipment has to maintain operation under such conditions				
3. Physical environment and operating conditions (see 4.4)				
a) Electromagnetic environment (see 4.4.2)	Residential, commercial or light industrial environment		Industrial environment	
Special EMC conditions or requirements				
b) Ambient temperature range				
c) Humidity range				
d) Altitude				
e) Special environmental conditions (for example corrosive atmospheres, dust, wet environments)				

f) Radiation				
g) Vibration, shock				
h) Special installation and operation requirements (for example flame-retardant cables and conductors)				
i) Transportation and storage (for example, temperatures outside the range specified in 4.5)				
k) restrictions related to size, weight or point load				
4. Incoming electrical supplies				
Specify for each source of supply:				
a) Nominal voltage (V)	AC		DC	
	If AC, number of phases		Frequency (Hz)	
Value of the supply source impedance (Ω) at the point of connection to the electrical equipment				
Prospective short-circuit current (kA r.m.s.) at the point of ~~supply to the machine (kA r.m.s.)~~ connection to the electrical equipment (see also item 2)				
b) Type of ~~power supply earthing~~ distribution system (see IEC 60364-1)	TN (system with one point directly earthed, with a protective conductor (PE) directly connected to that point); specify if the earthed point is the neutral point (centre of the star) or another point)		TT (system with one point directly earthed but the protective conductor (PE) of the machine not connected to that earth point of the system)	
	IT (system that is not directly earthed)			
In the case of IT systems, is insulation monitoring/fault location to be provided by the supplier of the electrical equipment?	Yes		No	
c) Is the electrical equipment to be connected to a neutral (N) supply conductor? (See 5.1)	Yes		No	
Maximum current (A) allowed				
d) Supply disconnecting device				
Is disconnection of the neutral (N) conductor required?	Yes		No	
Is a removable link for disconnecting the neutral (N) required?	Yes		No	
Type of supply disconnecting device to be provided				
e) Cross sectional area and material of external protective (PE) conductor				
f) Is an RCD provided in the installation?	Yes/No		If yes, type and rated residual operating current	
5. Protection against electric shock (see Clause 6)				
a) For which of the following classes of persons is access to the interior of enclosures required during normal operation of the equipment?	Electrically skilled persons		Electrically instructed persons	
b) Are locks with removable keys to be provided for securing the doors ~~or covers~~? (see 6.2.2)	Yes		No	

Type of locking device				
Basic lock unit (except key cylinder) to be supplied and installed by				
Key cylinder to be supplied and installed by				
6. Protection of equipment (see Clause 7)				
a) Will the user or the supplier of the electrical equipment provide supply conductors and the overcurrent protection ~~of~~ for the supply conductors? (see 7.2.2)				
Type and rating of overcurrent protective devices				
b) Largest (kW) three-phase AC motor that may be started direct-on-line				
c) May the number of motor overload detection devices be reduced? (see 7.3.2)	Yes		No	
d) Is overvoltage protection to be provided?	Yes/No		If yes, specification	
7. Operation				
For cableless control systems, specify the time delay before automatic machine shutdown is initiated in the absence of a valid signal.				
8. Operator interface and machine-mounted control devices (see Clause 10)				
Special colour preferences (for example to align with existing machinery):	Start		Stop	
	Other			
9. Controlgear				
Degree of protection of enclosures (see 11.3) or special conditions:				
10. Wiring practices (see Clause 13)				
Is there a specific method of identification to be used for the conductors? (see 13.2.1)	Yes		No	
Type				
11. Accessories and lighting (see Clause 15)				
a) Is a particular type of socket-outlet required?	Yes		No	
If yes, which type?				
~~b) Are the socket-outlets for maintenance to be provided with additional protection by the use of Residual Current protective Devices (RCD)?~~	~~Yes~~		~~No~~	
b) Where the machine is equipped with local lighting:	Highest permissible voltage (V)		If lighting circuit voltage is not obtained directly from the power supply, state preferred voltage	
12. Marking, warnings and reference designations (see Clause 16)				
a) Functional identification (see 16.3)				
Specifications:				
b) Inscriptions/special markings	On electrical equipment?		In which language?	

c) ~~Mark of certification~~ Specific local regulations that must be complied with	Yes		No	
If yes, which one?				
13. Technical documentation (see Clause 17)				
a) Technical documentation (see 17.1)	On what media/?		In which language?	
	File format?			
b) Instructions for use (see 17.1)	On what media?		In which language?	
	File format?			
c) Size, location and purpose of ducts, open cable trays or cable supports to be provided by the user ~~(see 17.5)~~				
d) Indicate if special limitations on the size or weight affect the transport of a particular machine or controlgear assemblies to the installation site:	Maximum dimensions		Maximum weight	
e) In the case of specially built machines, is a certificate of operating tests with the loaded machine to be supplied?	Yes		No	
f) In the case of other machines, is a certificate of operating type tests on a loaded prototype machine to be supplied?	Yes		No	

Annex C
(informative)

Examples of machines covered by this part of IEC 60204

The following list shows examples of machines whose electrical equipment should conform to this part of IEC 60204. The list is not intended to be exhaustive but is consistent with the definition of machinery (3.1.40). This part of IEC 60204 need not be applied to machines that are household and similar domestic appliances within the scope of the IEC 60335 series of standards.

Metalworking machinery

- metal cutting machines
- metal forming machines

Plastics and rubber machinery

- injection moulding machines
- extrusion machines
- blow moulding machines
- thermoset moulding machines
- size reduction machines

Wood machinery

- woodworking machines
- laminating machines
- sawmill machines

Assembly machines

Material handling machines

- robots
- conveyors
- transfer machines
- storage and retrieval machines

Textile machines

Refrigeration and air-conditioning machines

Food machinery

- dough breaks
- mixing machines
- pie and tart machines
- meat processing machines

Printing, paper and board machinery

- printing machines
- finishing machines, guillotines, folders
- reeling and slitting machines
- folder box gluing machines
- paper and board making machines

Inspecting/testing machinery

- co-ordinate measuring machines
- in-process gauging machines

Compressors

Packaging machinery

- palletizers/depalletizers
- wrapping and shrink-wrapping machines

Laundry machines

Heating and ventilating machines

Leather/imitation leather goods and footwear machinery

- cutting and punching machines
- roughing, scouring, buffing, trimming and brushing machines
- footwear moulding machines
- lasting machines

Hoisting machinery (see IEC 60204-32)

- cranes
- hoists

Machinery for transportation of persons

- escalators
- ropeways for transportation of persons, for example chairlifts, ski lifts
- passenger lifts

Power-operated doors

Leisure machinery

- fairground and amusement rides

Pumps

Agriculture and forestry machines

Construction and building materials machinery

- tunnelling machines
- concrete batching machines
- brick-making machines
- stone, ceramic and glass-making machines

Transportable machinery

- wood working machines
- metal working machines

Mobile machinery

- lifting platforms
- fork lift trucks
- construction machines

Machines for hot metal processing

Tanning machinery

- multi-roller machines
- bandknife machines
- hydraulic tanning machines

Mining and quarrying machines

Annex D
(informative)

Current-carrying capacity and overcurrent protection of conductors and cables in the electrical equipment of machines

D.1 General

The purpose of this Annex A is to provide additional information on the selection of conductor sizes where the conditions given for Table 6 (see Clause 12) have to be modified (see notes to Table 6).

D.2 General operating conditions

D.2.1 Ambient air temperature

The current carrying capacity for PVC insulated conductors given in Table 6 is related to an ambient air temperature of +40 °C. For other ambient air temperatures, the correction factors are given in Table D.1.

The correction factors for rubber insulated cables are given by the manufacturer.

Table D.1 – Correction factors

Ambient air temperature °C	Correction factor
30	1,15
35	1,08
40	1,00
45	0,91
50	0,82
55	0,71
60	0,58

NOTE The correction factors are derived from IEC 60364-5-52.

The maximum temperature under normal conditions for PVC 70 °C.

D.2.2 Methods of installation

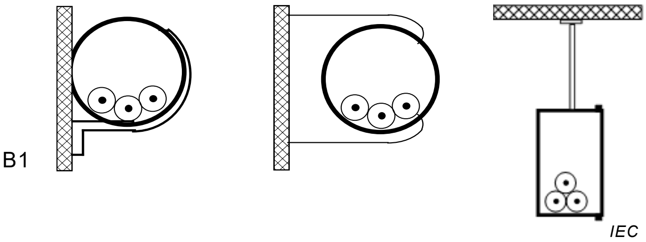
In machines, the methods of conductor and cable installation between enclosures and individual items of the equipment shown in Figure D.1 are assumed to be typical (the letters used are in accordance with IEC 60364-5-52~~:2001~~):

– Method B1: using conduits (3.1.9) and cable trunking systems (3.1.6) for holding and protecting conductors or single core cables;

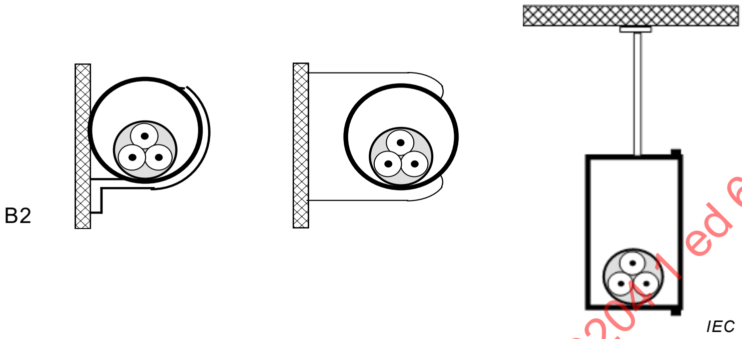
– Method B2: same as B1 but used for multicore cables;

– Method C: multicore cables installed in free air, horizontal or vertical without gap between cables on walls;

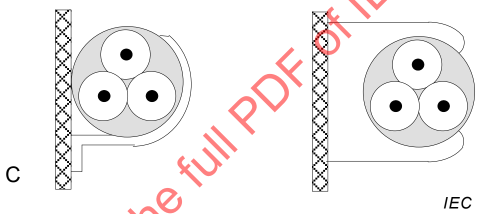
– Method E: multicore cables in free air, horizontal or vertical laid on open cable trays (3.1.5).



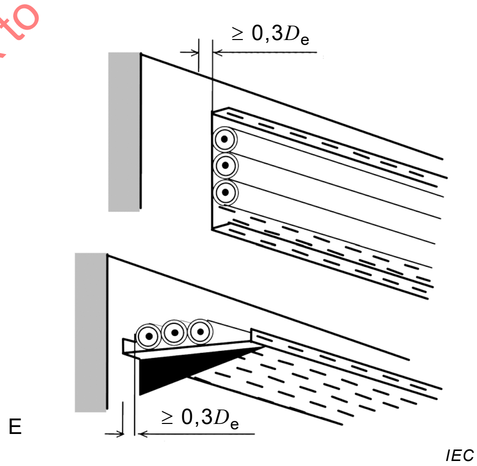
a) **Conductors/single core cables in conduit and cable trunking systems**



b) **Cables in conduit and cable trunking systems**



c) **Cables on walls**



d) **Cables on open cable trays**

Figure D.1 – Methods of conductor and cable installation independent of number of conductors/cables

D.2.3 Grouping

Where more loaded conductors in cables or conductor pairs are installed, derate the values of I_z, given in Table 6 or by the manufacturer in accordance with Tables D.2 or D.3.

NOTE Circuits with I_b < 30 % of I_z need not be derated.

Table D.2 – Derating factors ~~from~~ for I_z for grouping

Methods of installation (see Figure D.1) (see Note 3)	Number of loaded circuits/cables			
	2	**4**	**6**	**9**
B1 (~~circuits~~ conductors or single core cables) and B2 (multicore cables)	0,80	0,65	0,57	0,50
C single layer with no gap between cables	0,85	0,75	0,72	0,70
E single layer on one perforated tray without gap between cables	0,88	0,77	0,73	0,72
E as before but with 2 to 3 trays, with a vertical spacing between each tray of 300 mm (see Note 4)	0,86	0,76	0,71	0,66
Control circuit pairs ≤ 0,5mm² independent of methods of installation	0,76	0,57	0,48	0,40

NOTE 1 These factors are applicable to

– cables, all equally loaded, the circuit itself symmetrically loaded;

– groups of circuits of insulated conductors or cables having the same allowable maximum operating temperature.

NOTE 2 The same factors are applied to

– groups of two or three single-core cables;

– multicore cables.

NOTE 3 Factors derived from IEC 60364-5-52:~~2001~~ 2009.

NOTE 4 A perforated cable tray is a tray where the holes occupy more than 30 % of the area of the base. (Derived from IEC 60364-5-52:~~2001~~ 2009).

Table D.3 – Derating factors ~~from~~ for I_z for multicore cables up to 10 mm²

Number of loaded conductors or pairs	Conductors (~~>~~≥1 mm²) (see Note 3)	Pairs (0,25 mm² to 0,75 mm²)
1	–	1,0
3	1,0	~~-~~ 0,5
5	0,75	0,39
7	0,65	0,34
10	0,55	0,29
24	0,40	0,21

NOTE 1 Applicable to multicore cables with equally loaded conductors/pairs.

NOTE 2 For grouping of multicore cables, see derating factors of Table D.2.

NOTE 3 Factors derived from IEC 60364-5-52:~~2001~~ 2009.

D.2.4 Classification of conductors

Table D.4 – Classification of conductors

Class	Description	Use/application
1	Solid copper or aluminium conductors	Fixed installations
2	Stranded copper or aluminium conductors	
5	Flexible stranded copper conductors	Machine installations with presence of vibration; connection to moving parts
6	Flexible stranded copper conductors conductors that are more flexible than class 5	For frequent movements
NOTE Derived from IEC 60228.		

D.3 Co-ordination between conductors and protective devices providing overload protection

Figure D.2 illustrates the relationship between the parameters of conductors and the parameters of protective devices providing overload protection.

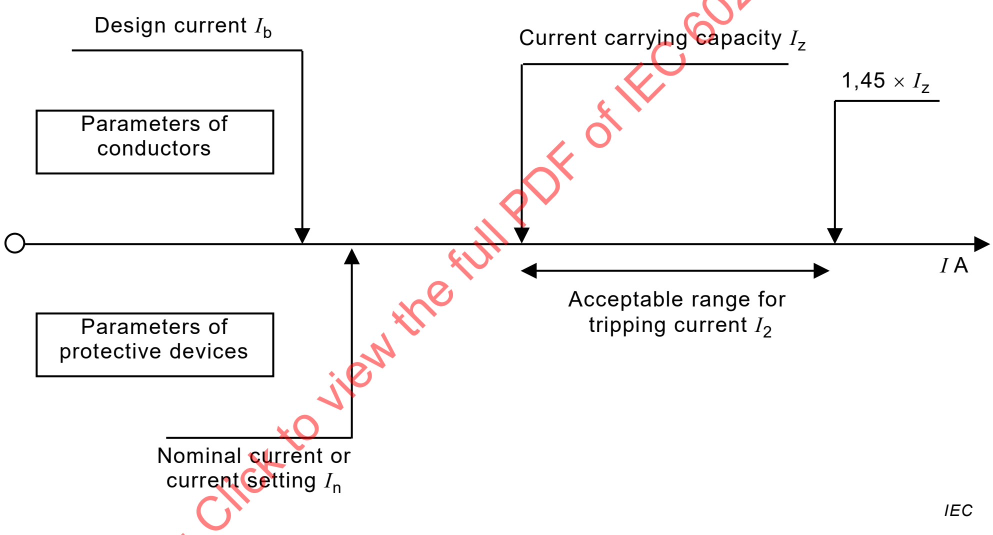


Figure D.2 – Parameters of conductors and protective devices

Correct protection of a cable requires that the operating characteristics of a protective device (for example overcurrent protective device, motor overload protective device) protecting the cable against overload satisfy the two following conditions:

$$I_b \leq I_n \leq I_z$$

$$I_2 \leq 1{,}45 \times I_z$$

where

I_b is the current for which the circuit is designed;

I_Z is the effective current-carrying capacity, in amperes, of the cable for continuous service according to Table 6 for the particular installation conditions:

- temperature, derating of I_Z see Table D.1;
- grouping, derating of I_Z see Table D.2;
- multicore cables, derating of I_Z see Table D.3.

I_n is the nominal current of the protective device;

NOTE 1 For adjustable protective devices, the nominal current I_n is the current setting selected.

I_2 is the minimum current ensuring effective operation of the protective device within a specified time (for example 1 h for protective devices up to 63 A).

The current I_2 ensuring effective operation of the protective device is given in the product standard or may be provided by the manufacturer.

NOTE 2 For motor circuit conductors, overload protection for conductor(s) can be provided by the overload protection for the motor(s) whereas the short-circuit protection is provided by short-circuit protective devices.

Where a device that provides both overload and short-circuit protection is used in accordance with Clause D.3 for conductor overload protection, it does not ensure complete protection in all cases (for example overload with currents less than I_2), nor will it necessarily result in an economical solution. Therefore, such a device can be unsuitable where overloads with currents less than I_2 are likely to occur.

D.4 Overcurrent protection of conductors

All conductors are required to be protected against overcurrent (see 7.2) by protective devices inserted in all live conductors so that any short-circuit current flowing in the cable is interrupted before the conductor has reached the maximum allowable temperature.

NOTE Information on neutral conductors can be found in 7.2.3, third paragraph.

Table D.5 – Maximum allowable conductor temperatures under normal and short-circuit conditions

Type of insulation	Maximum temperature under normal conditions °C	Ultimate short-time conductor temperature under short-circuit conditions [a)] °C
Polyvinyl chloride (PVC)	70	160
Rubber	60	200
Cross-linked polyethylene (XLPE)	90	250
Ethylene propylene compound (EPR)	90	250
Silicone rubber (SiR)	180	350
NOTE For ultimate short-time conductor temperatures greater than 200 °C, neither tinned nor bare copper conductors are suitable. Silver-plated or nickel-plated copper conductors are suitable for use above 200 °C.		
a) These values are based on the assumption of adiabatic behaviour for a period of not more than 5 s.		

In practice, the requirements of 7.2 are fulfilled when the protective device at a current I causes the interruption of the circuit within a time that in no case exceeds the time t where $t < 5$ s.

The value of the time t in seconds ~~shall~~ can be calculated using the following formula:

$$t = (k \times S/I)^2$$

where:

S is the cross-sectional area in square millimetres;

I is the effective short-circuit current in amperes expressed for AC as the r.m.s. value;

k is the factor shown for copper conductors when insulated with the following material:

PVC 115

Rubber	141
SiR	132
XLPE	143
EPR	143

~~The use of fuses with characteristics gG or gM (see IEC 60269-1) and circuit-breakers with characteristics B and C in accordance with the IEC 60898 series, ensures that the temperature limits in Table D.5 will not be exceeded, provided that the nominal current I_n is chosen in accordance with Table 6 where $I_n \leq I_z$.~~

D.5 Effect of harmonic currents on balanced three-phase systems

In case of circuits feeding single phase loads with load current including harmonics, the neutral conductor of the circuit might be additionally loaded and a reduction of the current carrying capacity of that cable might be necessary. For reference see IEC 60364-5-52:2009, Annex E.

Annex E
(informative)

Explanation of emergency operation functions

NOTE The concepts below are included here to give the reader an understanding of these terms even though in this part of IEC 60204 only two of them are used.

- **Emergency operation**

  Emergency operation includes separately or in combination:

  – emergency stop;

  – emergency start;

  – emergency switching off;

  – emergency switching on.

- **Emergency stop**

  An emergency operation intended to stop a process or a movement that has become hazardous.

- **Emergency start**

  An emergency operation intended to start a process or a movement to remove or to avoid a hazardous situation.

- **Emergency switching off**

  An emergency operation intended to switch off the supply of electrical energy to all or a part of an installation where a risk of electric shock or another risk of electrical origin is involved.

- **Emergency switching on**

  An emergency operation intended to switch on the supply of electrical energy to a part of an installation that is intended to be used for emergency situations.

Annex F
(informative)

Guide for the use of this part of IEC 60204

~~F.1 General~~

This part of IEC 60204 gives a large number of general requirements that may or may not be applicable to the electrical equipment of a particular machine. A simple reference without any qualification to the complete standard IEC 60204-1 is therefore not sufficient. Choices need to be made to cover all requirements of this part of IEC 60204. A technical committee preparing a product family or a dedicated product standard (type C in ISO and CEN), and the supplier of a machine for which no product family or dedicated product standard exists, should use this part of IEC 60204:

a) by reference; and

b) by selection of the most appropriate option(s) from the requirements given in the relevant clauses; and

c) by modification of certain clauses, as necessary, where the particular requirements for the equipment of the machine are adequately covered by other relevant standards,

providing the options selected and the modifications made do not adversely affect the level of protection required for that machine according to the risk assessment.

When applying the three principles a), b) and c) listed above, it is recommended that:

– reference be made to the relevant clauses and subclauses of this standard:
  - that are complied with, indicating where relevant the applicable option;
  - that have been modified or extended for the specific machine or equipment requirements; and
– reference be made directly to the relevant standard, for those requirements for the electrical equipment that are adequately covered by that standard.

~~In all cases,~~ Specific expertise ~~is essential to be able~~ can be necessary to:

– perform the necessary risk assessment of the machine;
– read and understand all of the requirements of this part of IEC 60204;
– choose the applicable requirements from this part of IEC 60204 where alternatives are given;
– identify alternative or additional particular requirements that differ from or are not included in the requirements of this part of IEC 60204, and that are determined by the machine and its use; and
– specify precisely those particular requirements.

Figure 1 of this part of IEC 60204 is a block diagram of a typical machine and can be used as the starting point of this task. It indicates the Clauses and Subclauses dealing with particular requirements/equipment. However, this part of IEC 60204 is a complex document and Table F.1 can help identify the application options for a particular machine and gives reference to other relevant standards.

Table F.1 – Application options

Subject	Clause or Subclause	i)	ii)	iii)	iv)
Scope	1		X		
General requirements	4	X	X	X	ISO 12100 ~~(all parts)~~ ~~ISO 14121~~
Selection of equipment	4.2.2		X	X	IEC ~~60439~~ 61439 series
Supply disconnecting (isolating) device	5.3	X			
Excepted circuits	5.3.5	X		X	ISO 12100 ~~(all parts)~~
Prevention of unexpected start-up, isolation	5.4, 5.5 and 5.6	X	X	X	ISO 14118
Protection against electric shock	6	X			IEC 60364-4-41
Emergency operations	9.2.3.4	X		X	ISO 13850
Two-hand control	9.2.3.8	X	X		ISO 13851
Cableless control	9.2.4	X	X	X	IEC 62745
Control functions in the event of failure	9.4	X	X	X	ISO ~~14121~~ 12100 ISO 13849 (all parts) IEC 62061
Position sensors	10.1.4	X	X	X	ISO 14119
Colours and markings of operator interface devices	10.2, 10.3 and 10.4	X	X		IEC 60073 IEC 61310 (all parts)
Emergency stop	9.2.3.4.2	X			ISO 13850
Emergency stop devices	10.7	X	X		~~ISO 13850~~ IEC 60947-5-5
Emergency switching off devices	10.8	X	X		IEC 60364-5-53
Controlgear – protection against ingress of contaminants, etc.	10.1.3 and 11.3	X	X	X	IEC 60529
Identification of conductors	13.2	X	X		IEC 62491
Verification	18	X	X	X	IEC 60364-6
Additional user requirements	Annex B		X	X	
Fault protection in TN systems	Annex A (A.1)	X			IEC 60364-4-41 IEC 60364-6
Fault protection in TT systems	Annex A (A.2)	X			IEC 60364-4-41 IEC 60364-6

Clauses and Subclauses of this part of IEC 60204 where action should be considered (shown by X) with respect to:

i) selection from the measures given;

ii) additional requirements;

iii) different requirements;

iv) examples of other standards that can be relevant.

Annex G
(informative)

Comparison of typical conductor cross-sectional areas

Table G.1 provides a comparison of the conductor cross-sectional areas of the American Wire Gauge (AWG) with square millimetres, square inches, and circular mils.

Table G.1 – Comparison of conductor sizes

Wire size	Gauge No	Cross-sectional area		DC resistance of copper at 20 °C	Circular mils
mm^2	(AWG)	mm^2	$inches^2$	Ohms per km	
0,2		0,196	0,000 304	91,62	387
	24	0,205	0,000 317	87,60	404
0,3		0,283	0,000 438	63,46	558
	22	0,324	0,000 504	55,44	640
0,5		0,500	0,000 775	36,70	987
	20	0,519	0,000 802	34,45	1 020
0,75		0,750	0,001 162	24,80	1 480
	18	0,823	0,001 272	20,95	1 620
1,0		1,000	0,001 550	18,20	1 973
	16	1,31	0,002 026	13,19	2 580
1,5		1,500	0,002 325	12,20	2 960
	14	2,08	0,003 228	8,442	4 110
2,5		2,500	0,003 875	7,56	4 934
	12	3,31	0,005 129	5,315	6 530
4		4,000	0,006 200	4,700	7 894
	10	5,26	0,008 152	3,335	10 380
6		6,000	0,009 300	3,110	11 841
	8	8,37	0,012 967	2,093	16 510
10		10,000	0,001 550	1,840	19 735
	6	13,3	0,020 610	1,320	26 240
16		16,000	0,024 800	1,160	31 576
	4	21,1	0,032 780	0,829 5	41 740
25		25,000	0,038 800	0,734 0	49 338
	2	33,6	0,052 100	0,521 1	66 360
35		35,000	0,054 200	0,529 0	69 073
	1	42,4	0,065 700	0,413 9	83 690
50		47,000	0,072 800	0,391 0	92 756

The resistance for temperatures other than 20°C can be found using the formula:

$$R = R1\ [1 + 0{,}003\ 93\ (t - 20)]$$

where:

$R1$ is the resistance at 20 °C;

R is the resistance at a temperature t°C.

Annex H
(informative)

Measures to reduce the effects of electromagnetic influences

H.1 Definitions

For the purposes of Annex H only, the following terms and definitions apply.

H.1.1 apparatus

finished device or combination thereof made commercially available as a single functional unit, intended for the end user and liable to generate electromagnetic disturbance, or the performance of which is liable to be affected by such disturbance

H.1.2 fixed installation

particular combination of several types of apparatus and, where applicable, other devices, which are assembled, installed and intended to be used permanently at a predefined location

H.2 General

This Annex H provides recommendations to improve electromagnetic immunity and reduce emission of electromagnetic disturbances.

For EMC purposes, electrical equipment for machinery is deemed to be either apparatus or fixed installations. Where electrical safety and electromagnetic compatibility result in different requirements, electrical safety always has the higher priority.

Electromagnetic Interference (EMI) can disturb or damage process monitoring, control and automation systems. Currents due to lightning, switching operations, short-circuits and other electromagnetic phenomena can cause overvoltages and electromagnetic interference.

These effects can occur for example:

- where large conductive loops exist,
- where different electrical wiring systems are installed in common routes, e.g. power supply, communication, control or signal cables.

Cables carrying large currents with a high rate of change of current (di/dt) can induce overvoltages in other cables, which can influence or damage the connected electrical equipment.

H.3 Mitigation of electromagnetic interference (EMI)

H.3.1 General

Consideration should be given, in the design of the electrical equipment to the measures described below for reducing the electromagnetic influences on electrical equipment.

Only electrical equipment which meets the requirements of the appropriate EMC standards, or the EMC requirements of the relevant product standard, should be used.

H.3.2 Measures to reduce EMI

The following measures reduce electromagnetic interference:

a) The installation of surge protection devices and/or filters for equipment sensitive to electromagnetic influences is recommended to improve electromagnetic compatibility with regard to conducted electromagnetic phenomena;

b) Conductive sheaths (e.g. armouring, screens) of cables should be bonded to the protective bonding circuit;

c) Inductive loops should be avoided by selection of common routes for power, signal and data circuits wiring while maintaining circuit separation in accordance with Clause H.4;

d) Power cables should be kept separate from signal or data cables;

e) Where it is necessary for power and signal or data cables to cross each other they should be crossed at right-angles;

f) Use of cables with concentric conductors to reduce currents induced into the protective conductor;

g) Use of symmetrical multicore cables (e.g. screened cables containing separate protective conductors) for the electrical connections between motors and converters;

h) Use of signal and data cables according to the EMC requirements of the manufacturer's instructions;

i) Where screened signal or data cables are used, care should be taken to reduce current flowing through the screens of signal cables, or data cables, which are earthed. It can be necessary to install a by-pass conductor; see Figure H.1;

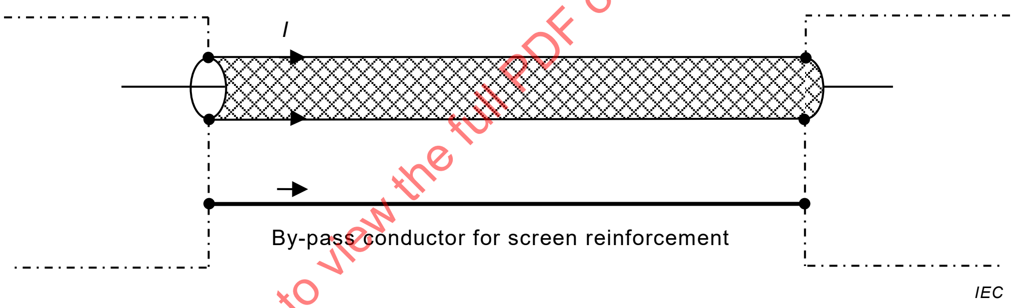


Figure H.1 – By-pass conductor for screen reinforcement

NOTE A good equipotential bonding of the components of the machine reduces the need for by-pass conductors.

j) Equipotential bonding connections should have an impedance as low as practicable by being as short as practicable and where applicable braided to conduct higher frequencies;

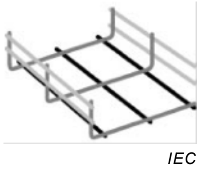
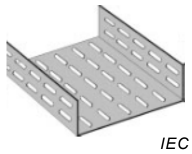
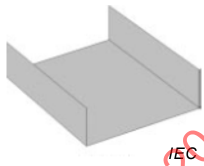
k) If electronic equipment requires a reference voltage at about earth potential in order to function correctly; this reference voltage is provided by the functional earthing conductor. For equipment operating at high frequencies, the connections shall be kept as short as practicable.

H.4 Separation and segregation of cables

Power cables and data cables which share the same route should be installed according to the requirements of this Annex H.

Where no other information is available, then the cable separation distance between the power and data cables should be in accordance with Table H.1 and Figure H.2.

Table H.1 – Minimum separation distances using metallic containment as illustrated in Figure H.2

Separation without metallic containment	A Mesh metallic containment	B Perforated metallic containment	C Solid metallic containment
			
≥ 200 mm	≥ 150 mm	≥ 100 mm	0 mm

A Screening performance (DC-100 MHz) equivalent to welded mesh steel basket of mesh size 50 mm × 100 mm (excluding ladders). This screening performance is also achieved with steel tray even if the wall thickness is less than 1 mm and/or the evenly distributed perforated area is greater than 20 %.

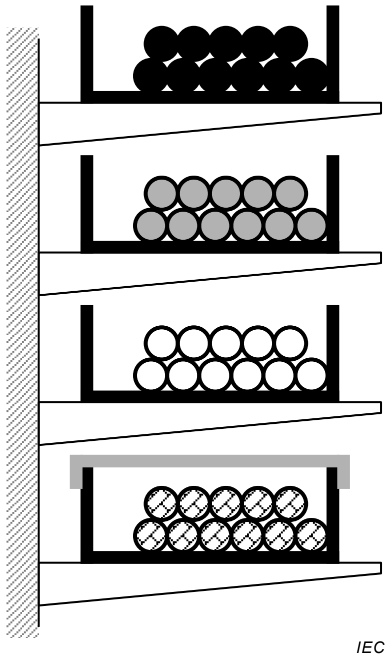
B Screening performance (DC-100 MHz) equivalent to steel tray of at least 1 mm wall thickness and no more than 20 % evenly distributed perforated area. This screening performance is also achieved with screened power cables.

No part of the cable within the metallic containment should be less than 10 mm below the top of the metallic containment.

C Screening performance (DC-100 MHz) equivalent to a steel conduit of at least 1 mm wall thickness. Separation specified is in addition to that provided by any divider/screen.

The minimum separation requirement specified in Table H.1 applies to the horizontal or vertical separation between adjacent cable trays or cable trunking systems. Where data cables and power supply cables are required to cross and required minimum separation cannot be maintained then the angle of their crossing should be maintained at 90 degrees on either side of the crossing for a distance no less than the applicable minimum separation requirement.

Figures H.2 and H.3 show examples of separation and segregation.



For distances see Table H.1.

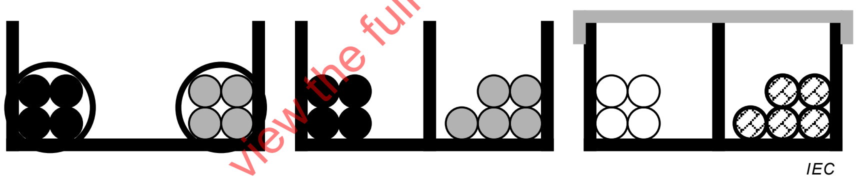
= power supply cabling

= data cabling

= auxiliary circuits

= sensitive circuits (e.g. measurement)

Figure H.2 – Examples of vertical separation and segregation



For distances see Table H.1.

Figure H.3 – Examples of horizontal separation and segregation

Usable space within the cable tray or cable trunking system should allow for an agreed quantity of additional cables to be installed (see Annex B). The cable bundle height should be lower than the side-walls of the cable tray or cable trunking system, as shown in Figure H.4 below. The overlapping lid of cable trunking systems improves the electromagnetic compatibility performance.

For a U-shape cable tray, the magnetic field decreases near the two corners. For this reason, deep side-walls are preferred.

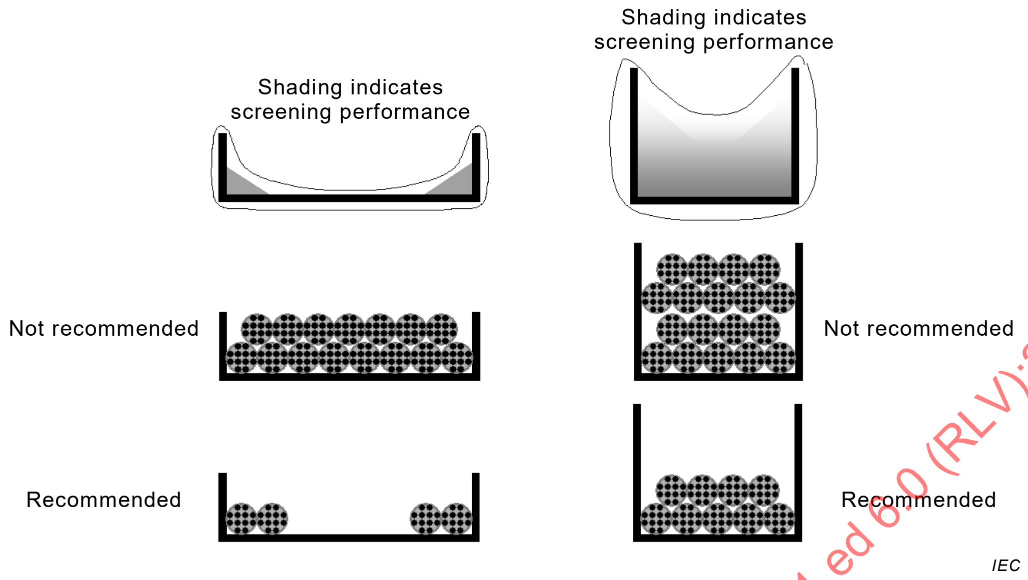


Figure H.4 – Cable arrangements in metal cable trays

Metal cable trays or cable trunking systems which are intended to provide electromagnetic compatibility shall always be connected to the local equipotential bonding system at both ends. For long distances, for example greater than 50 m, additional connections to the equipotential bonding system are recommended. All connections to the equipotential bonding system should have low impedance.

Where metal cable trays or cable trunking systems are constructed from several elements, care should be taken to ensure continuity by effective bonding between adjacent elements.

The shape of the metallic section should achieve continuity of shielding throughout its length. All interconnections should have low impedance; see Figure H.5.

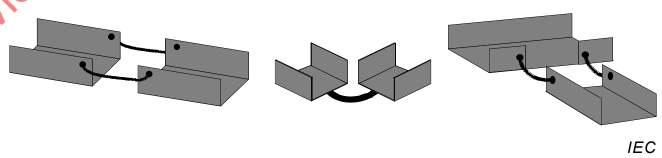
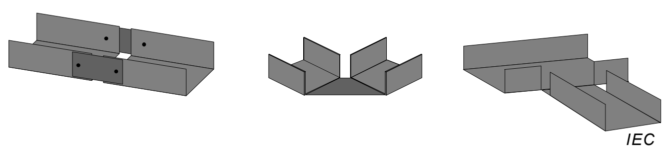
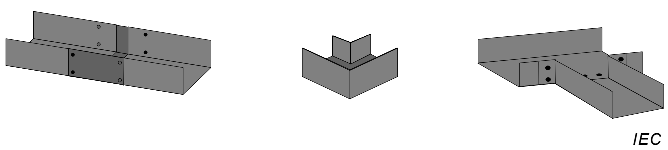
a	Non-conformant	
b	Conformant	
c	Recommended	

Figure H.5 – Connections between metal cable trays or cable trunking systems

Where metallic covers for metallic cable trunking systems are used, a cover over the full length is preferred. If that is not possible, the covers should be connected to the cable tray at least at both ends by short connections less than 10 cm, e.g. braided or mesh straps.

Figure H.6 shows a metal cable tray crossing a wall at which a fire barrier is to be installed. Where metal cable trays are required to be interrupted to pass through building structures, a low impedance interconnection should be provided between the two metallic sections. Regulations with respect to fire barriers take precedence over EMC considerations.

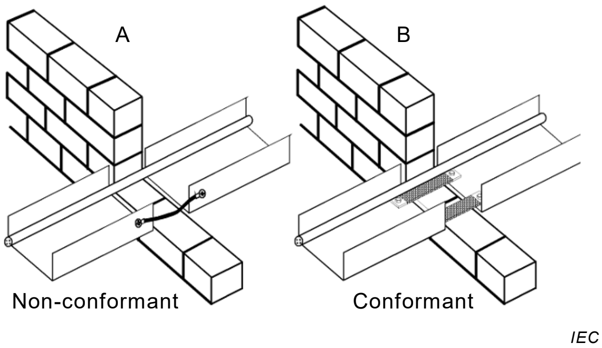


Figure H.6 – Interruption of metal cable trays at fire barriers

H.5 Power supply of a machine by parallel sources

Where a machine is supplied with power by parallel sources, see IEC 60364-1.

H.6 Supply impedance where a Power Drive System (PDS) is used

Connection of a PDS to too high a supply source impedance can lead to conducted emission problems.

Annex I
(informative)

Documentation / Information

A list of available standards applicable to documentation and information is provided in Table I.1.

Brief definitions of a set of internationally standardized document kinds are given in the publicly available database IEC 61355 DB (http://std.iec.ch/iec61355).

Table I.1 – Documentation / Information that can be applicable

Type of information for the electrical equipment	Recommended standard
Structuring principles	IEC 81346-1: *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules*
Structuring of documents	IEC 62023: *Structuring of technical information and documentation* (see note)
Parts list	IEC 62027: *Preparation of object lists, including parts lists*
List of documents	IEC 62027: *Preparation of object lists, including parts lists*
Specification of the properties of the electrical equipment	IEC PAS 62569-1: *Generic specification of information on products – Part 1: Principles and methods*
Instructions for handling, transportation and storage	IEC 82079-1: *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*
Instructions for installation, erection, assembling on site, dismantling, etc.	IEC 82079-1: *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*
Instructions for use	IEC 82079-1: *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*
Instructions for service and maintenance	IEC 82079-1: *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*
Reference designations	IEC 81346-1: *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules* and IEC 81346-2: *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 2: Classification of objects and codes for classes*
Terminal designations	IEC 61666: *Industrial systems, installations and equipment and industrial products – Identification of terminals within a system*
Designations of cables and cores	IEC 62491: *Industrial systems, installations and equipment and industrial products – Labelling of cables and cores*
Circuit diagrams	IEC 61082-1: *Preparation of documents used in electrotechnology – Part 1: Rules*
Layout of equipment and overall dimensions	IEC 61082-1: *Preparation of documents used in electrotechnology – Part 1: Rules*
Interconnection diagram, terminal list, cable list, cable tray layout	IEC 61082-1: *Preparation of documents used in electrotechnology – Part 1: Rules*
Spare parts list for a specified period	IEC 62027: *Preparation of object lists, including parts lists*
List of parameters (e.g. of converters)	(No standard exists)

Type of information for the electrical equipment	Recommended standard
List of tools	IEC 82079: *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*
Identification systems	IEC 62507-1: *Identification systems enabling unambiguous information interchange – Requirements – Part 1: Principles and methods*
NOTE For simple equipment IEC 62023 allows all information to be contained within one single document.	

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6 Under consideration.

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~~Index~~

~~This index lists, in alphabetical order, the terms defined in Clause 3 and indicates the subclauses where they are used in the text of this part of IEC 60204. The number of each definition is given in bold text.~~

IEC 60204-1

Edition 6.0 2016-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Safety of machinery – Electrical equipment of machines – Part 1: General requirements

Sécurité des machines – Équipement électrique des machines – Partie 1: Exigences générales

IEC 60204-1:2016-10(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SAFETY OF MACHINERY –
ELECTRICAL EQUIPMENT OF MACHINES –

Part 1: General requirements

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60204-1 has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects.

This sixth edition cancels and replaces the fifth edition published in 2005. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) added requirements to address applications involving power drive systems (PDS);
b) revised electromagnetic compatibility (EMC) requirements;
c) clarified overcurrent protection requirements;
d) requirements for determination of the short circuit current rating of the electrical equipment;

e) revised protective bonding requirements and terminology;

f) reorganization and revision to Clause 9, including requirements pertaining to safe torque off of PDS, emergency stop, and control circuit protection;

g) revised symbols for actuators of control devices;

h) revised technical documentation requirements;

i) general updating to current special national conditions, normative standards, and bibliographical references.

The text of this standard is based on the following documents:

FDIS	Report on voting
44/765/FDIS	44/771/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60204 series, published under the general title *Safety of machinery – Electrical equipment of machines*, can be found on the IEC website.

The following differing practices of a less permanent nature exist in the countries indicated below.

4.3.1: The voltage characteristics of electricity supplied by public distribution systems in Europe are given in EN 50160:2010.

5.1: Exception is not allowed (USA).

5.1: TN-C systems are not permitted in low-voltage installations in buildings (Norway).

5.2: Terminals for the connection of the protective earthing conductors may be identified by the colour green, the letters “G” or “GR” or “GRD” or “GND”, or the word “ground” or “grounding”, or with the graphical symbol IEC 60417-5019:2006-08 or any combination (USA).

6.3.3 b), 13.4.5 b), 18.2.1: TT power systems are not allowed (USA).

6.3.3, 18.2, Annex A: TN systems are not used. TT systems are the national standard (Japan).

6.3.3 b): The use of residual current protective devices with a rated residual operating current not exceeding 1 A is mandatory in TT systems as a means for fault protection by automatic disconnection of supply (Italy).

7.2.3: Disconnection of the neutral conductor is mandatory in a TN-S system (France and Norway).

7.2.3: Third paragraph: distribution of a neutral conductor with an IT system is not allowed (USA and Norway).

7.10: For evaluation of short circuit ratings the requirements of UL 508A Supplement SB, may be used (USA).

8.2.2: See IEC 60364-5-54:2011, Annex E List of notes concerning certain countries.

9.1.2: Maximum nominal AC control circuit voltage is 120 V (USA).

12.2: Only stranded conductors are allowed on machines, except for 0,2 mm^2 solid conductors within enclosures (USA).

12.2: The smallest power circuit conductor allowed on machines is 0,82 mm^2 (AWG 18) in multiconductor cables or in enclosures (USA).

Table 5: Cross-sectional area is specified in NFPA 79 using American Wire Gauge (AWG) (USA). See Annex G.

13.2.2: For the protective conductor, the colour identification GREEN (with or without YELLOW stripes) is used as equivalent to the bicolour combination GREEN-AND-YELLOW (USA and Canada).

13.2.3: The colour identification WHITE or GREY is used for earthed neutral conductors instead of the colour identification BLUE (USA and Canada).

15.2.2: First paragraph: Maximum value between conductors 150 V (USA).

15.2.2: Second paragraph, 5th bullet: The full load current rating of lighting circuits does not exceed 15 A (USA).

16.4: Nameplate marking requirements (USA).

A.2.2.2: The permissible maximum value of R_A is regulated (e.g. when $U_o \geq 300$ V, R_A shall be less than 10 Ω, when $U_o < 300$ V, R_A shall be less than 100 Ω, U_o is the nominal AC line to earth voltage in volts (V) (Japan).

A.2.2.2: The maximum permissible value of R_A is 83 Ω (Netherlands).

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This part of IEC 60204 provides requirements and recommendations relating to the electrical equipment of machines so as to promote:

– safety of persons and property;
– consistency of control response;
– ease of operation and maintenance.

More guidance on the use of this part of IEC 60204 is given in Annex F.

Figure 1 has been provided as an aid to the understanding of the inter-relationship of the various elements of a machine and its associated equipment. Figure 1 is a block diagram of a typical machine and associated equipment showing the various elements of the electrical equipment addressed in this part of IEC 60204. Numbers in parentheses ( ) refer to Clauses and Subclauses in this part of IEC 60204. It is understood in Figure 1 that all of the elements taken together including the safeguards, tooling/fixturing, software, and the documentation, constitute the machine, and that one or more machines working together with usually at least one level of supervisory control constitute a manufacturing cell or system.

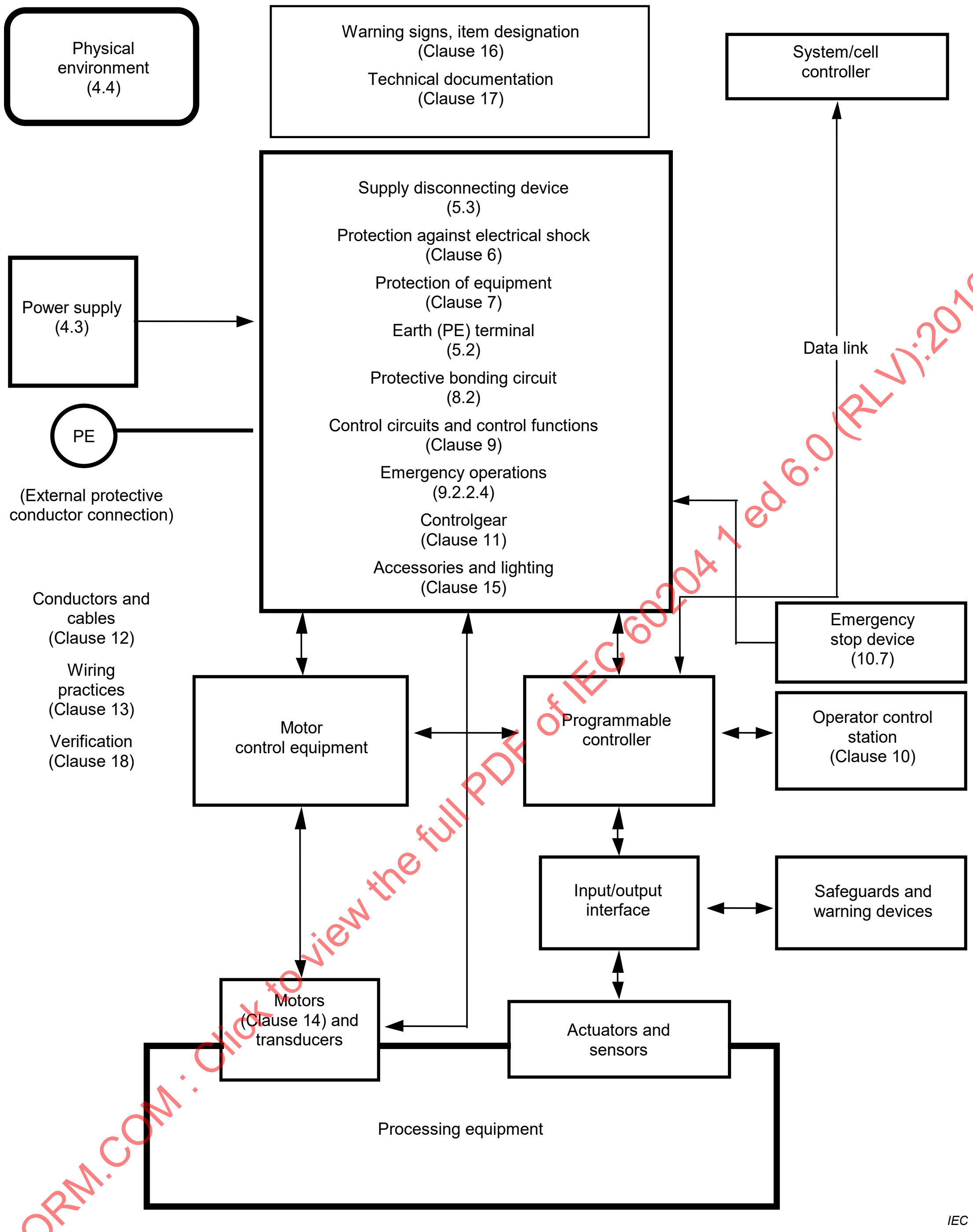

Figure 1 – Block diagram of a typical machine

SAFETY OF MACHINERY –
ELECTRICAL EQUIPMENT OF MACHINES –

Part 1: General requirements

1 Scope

This part of IEC 60204 applies to electrical, electronic and programmable electronic equipment and systems to machines not portable by hand while working, including a group of machines working together in a co-ordinated manner.

NOTE 1 This part of IEC 60204 is an application standard and is not intended to limit or inhibit technological advancement.

NOTE 2 In this part of IEC 60204, the term "electrical" includes electrical, electronic and programmable electronic matters (i.e. "electrical equipment" means electrical, electronic and programmable electronic equipment).

NOTE 3 In the context of this part of IEC 60204, 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 use and care of the machine in question.

The equipment covered by this part of IEC 60204 commences at the point of connection of the supply to the electrical equipment of the machine (see 5.1).

NOTE 4 The requirements for the electrical supply installation are given in the IEC 60364 series.

This part of IEC 60204 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 (AC) and not exceeding 1 500 V for direct current (DC), and with nominal supply frequencies not exceeding 200 Hz.

NOTE 5 Information on electrical equipment or parts of the electrical equipment that operate with higher nominal supply voltages can be found in IEC 60204-11.

This part of IEC 60204 does not cover all the requirements (for example guarding, interlocking, or control) that are needed or required by other standards or regulations in order to protect persons from hazards other than electrical hazards. Each type of machine has unique requirements to be accommodated to provide adequate safety.

This part of IEC 60204 specifically includes, but is not limited to, the electrical equipment of machines as defined in 3.1.40.

NOTE 6 Annex C lists examples of machines whose electrical equipment can be covered by this part of IEC 60204.

This part of IEC 60204 does not specify additional and special requirements that can apply to the electrical equipment of machines that, for example:

– are intended for use in open air (i.e. outside buildings or other protective structures);
– use, process, or produce potentially explosive material (for example paint or sawdust);
– are intended for use in potentially explosive and/or flammable atmospheres;
– have special risks when producing or using certain materials;
– are intended for use in mines;
– are sewing machines, units, and systems (which are covered by IEC 60204-31);
– are hoisting machines (which are covered by IEC 60204-32);
– are semiconductor fabrication equipment (which are covered by IEC 60204-33).

Power circuits where electrical energy is directly used as a working tool are excluded from this part of IEC 60204.

2 Normative references

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

IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60072 (all parts), *Dimensions and output series for rotating electrical machines*

IEC 60309-1, *Plugs, socket-outlets, and couplers for industrial purposes – Part 1: General requirements*

IEC 60364-1, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

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

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IEC 60364-5-52:2009, *Low-voltage electrical installations – Part 5-52: Selection and erection of electrical equipment – Wiring systems*

IEC 60364-5-53:2001, *Electrical installations of buildings – Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control*
IEC 60364-5-53:2001/AMD1:2002

IEC 60364-5-54:2011, *Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*

IEC 60417, *Graphical symbols for use on equipment.* Available from: http://www.graphical-symbols.info/equipment

IEC 60445:2010, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

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

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60947-2, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors, and fuse-combination units*

IEC 60947-5-1:2003, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*
IEC 60947-5-1:2003/AMD1:2009

IEC 60947-5-5, *Low-voltage switchgear and controlgear – Part 5-5: Control circuit devices and switching elements – Electrical emergency stop device with mechanical latching function*

IEC 60947-6-2, *Low-voltage switchgear and controlgear – Part 6-2: Multiple function equipment – Control and protective switching devices(or equipment) (CPS)*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

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

IEC 61439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61558-1:2005, *Safety of power transformers, power supplies, reactors and similar products – Part 1: General requirements and tests*
IEC 61558-1:2005/AMD1:2009

IEC 61558-2-6, *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 61984, *Connectors – Safety requirements and tests*

IEC 62023, *Structuring of technical information and documentation*

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

ISO 7010:2011, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

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

ISO 13849-2, *Safety of machinery – Safety-related parts of control systems – Part 2: Validation*

ISO 13850:2006, *Safety of machinery – Emergency stop function – Principles for design*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

3.1.1
actuator
part of a device to which an external action is to be applied

Note 1 to entry: The actuator may take the form of a handle, knob, push-button, roller, plunger, etc.

Note 2 to entry: There are some actuating means that do not require an external actuating force, but only an action, e.g. touchscreens.

Note 3 to entry: See also 3.1.39.

3.1.2
ambient temperature
temperature of the air or other medium where the equipment is to be used

3.1.3
barrier
part providing protection against contact with live parts from any usual direction of access

3.1.4
basic protection
protection against electric shock under fault-free conditions

Note 1 to entry: Previously referred to as "protection against direct contact"

[SOURCE: IEC 60050-195:1998, 195-06-01, modified – The note has been added.]

3.1.5
cable tray
cable support consisting of a continuous base and raised edges and no covering

Note 1 to entry: A cable tray may be perforated or non-perforated.

[SOURCE: IEC 60050-826:2004,826-15-08]

3.1.6
cable trunking system
system of closed enclosures comprising a base with a removable cover intended for the complete surrounding of insulated conductors or cables

3.1.7
concurrent
occurring or operating at the same time (but not necessarily synchronously)

3.1.8
conductor wire
conductor bar
conductive wire or bar of a feeder system with a sliding current collector

3.1.9
conduit
part of a closed wiring system of circular or non-circular cross-section for insulated conductors and/or cables in electrical installations

Note 1 to entry: Conduits should be sufficiently close-jointed so that the insulated conductors and/or cables can only be drawn in and not inserted laterally.

[SOURCE: IEC 60050-442:1998, 442-02-03, modified – The definition has been amended and the note has been added.]

3.1.10
control circuit, <of a machine>
circuit used for the control, including monitoring, of a machine and the electrical equipment

3.1.11
control device
device connected into the control circuit and used for controlling the operation of the machine

EXAMPLE Position sensor, manual control switch, relay, contactor, magnetically operated valve.

3.1.12
control station
operator control station
assembly of one or more control actuators (see 3.1.1) fixed on the same panel or located in the same enclosure

Note 1 to entry: A control station may also contain related equipment, for example, potentiometers, signal lamps, instruments, display devices, etc.

[SOURCE: IEC 60050-441:1984, 441-12-08, modified – The second preferred term has been added, the word "switches" has been replaced by "actuators" in the definition and the note has been added.]

3.1.13
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 in principle for the control of electrical energy consuming equipment

[SOURCE: IEC 60050-441:1984, 441-11-03]

3.1.14
controlled stop
stopping of machine motion with power to the machine actuators maintained during the stopping process

3.1.15
direct contact
contact of persons or livestock with live parts

Note 1 to entry: See 3.1.4.

[SOURCE: IEC 60050-826:2004, 826-12-03, modified – The note has been added.]

3.1.16
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)

[SOURCE: IEC 60947-5-1:2003, K.2.2]

3.1.17
duct
enclosed channel designed expressly for holding and protecting electrical conductors, cables, and busbars

Note 1 to entry: Conduits (see 3.1.9), cable trunking systems (see 3.1.6) and underfloor channels are types of duct.

3.1.18
earth
local earth
ground (US)
local ground (US)
part of the Earth which is in electric contact with an earth electrode and the electrical potential of which is not necessarily equal to zero

[SOURCE: IEC 60050-195:1998,195-01-03]

3.1.19
electrical operating 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 without the use of a key or tool, and which is clearly marked by appropriate warning signs

3.1.20
electronic equipment
part of the electrical equipment containing circuitry dependent for its operation on electronic devices and components

3.1.21
emergency stop device
manually actuated control device used to initiate an emergency stop function

Note 1 to entry: See 9.2.3.4.2.

[SOURCE: ISO 13850:2006, 3.2, modified – The note has been added.]

3.1.22
emergency switching off device
manually actuated control device used to switch off or to initiate the switching off of the supply of electrical energy to all or a part of an installation where a risk of electric shock or another risk of electrical origin is involved

Note 1 to entry: See 9.2.3.4.3.

3.1.23
enclosed electrical operating area
room or location for electrical equipment to which access is intended to be restricted to skilled or instructed persons by the use of a key or tool to open a door, or remove a barrier, and which is clearly marked by appropriate warning signs

3.1.24
enclosure
part providing protection of equipment against certain external influences and, in any direction, basic protection as protection against direct contact

Note 1 to entry: The existing definition taken from the IEV needs the following explanations within the scope of this part of IEC 60204:

a) Enclosures provide protection of persons or livestock 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.

[SOURCE: IEC 60050-195:1998, 195-02-35, modified – The definition has been amended.]

3.1.25
electrical equipment
items used in connection with the utilisation of electricity by machines or parts of machines, for example material, fittings, devices, components, appliances, fixtures, apparatus, and similar

3.1.26
equipotential bonding
provision of electric connections between conductive parts, intended to achieve equipotentiality

[SOURCE: IEC 60050-195:1998, 195-01-10]

3.1.27
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

[SOURCE: IEC 60050-826:2004, 826-12-10, modified – The definition has been amended.]

3.1.28
extraneous-conductive-part
conductive part not forming part of the electrical installation and liable to introduce an electric potential, generally the electric potential of a local earth

[SOURCE: IEC 60050-195:1998, 195-06-11]

3.1.29
failure
termination of the ability of an item to perform a required function

Note 1 to entry: After failure, the item has a fault.

Note 2 to entry: "Failure" is an event, as distinguished from "fault", which is a state.

Note 3 to entry: This concept as defined does not apply to items consisting of software only.

Note 4 to entry: In practice, the terms fault and failure are often used synonymously.

[SOURCE: IEC 60050-191:1990, 191-04-01]

3.1.30
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 to entry: A fault is often the result of a failure of the item itself, but may exist without prior failure.

Note 2 to entry: In English, the term “fault” and its definition are identical with those given in IEC 60050-191:1990, 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.

3.1.31
fault protection
protection against electric shock under single-fault conditions

Note 1 to entry: Previously referred to as “protection against indirect contact”

[SOURCE: IEC 60050-195:1998, 195-06-02, modified – the Note has been added]

3.1.32
functional bonding
equipotential bonding necessary for proper functioning of electrical equipment

3.1.33
hazard
potential source of physical injury or damage to health

Note 1 to entry: 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 to entry: 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).

[SOURCE: ISO 12100:2010, 3.6, modified – The word “harm" has been replaced by " physical injury or damage to health" in the definition and Note 3 has been removed]

3.1.34
indirect contact
contact of persons or livestock with exposed conductive parts which have become live under fault conditions

Note 1 to entry: See 3.1.31.

[SOURCE: IEC 60050-826:2004, 826-12-04, modified – The definition has been amended.]

3.1.35
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 1 to entry: The track conductor and the pick-up are analogous to the primary and secondary of a transformer respectively.

3.1.36
instructed person, <in electricity>
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

[SOURCE: IEC 60050-826:2004, 826-18-02, modified – “an electrically skilled person” has been used to replace “electrically skilled persons”]

3.1.37
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

3.1.38
live part
conductor or conductive part intended to be energized in normal use, including a neutral conductor, but, by convention, not a PEN conductor

3.1.39
machine actuator
power mechanism of the machine used to effect motion (for example, motor, solenoid, pneumatic or hydraulic cylinder)

3.1.40
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

Note 1 to entry: 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.

Note 2 to entry: The term "component" is used here in a general sense and it does not refer only to electrical components.

[SOURCE: ISO 12100:2010, 3.1, modified – The definition has been amended and Note 2 referring to an Annex has been removed and replaced by the present Note 2 to entry.]

3.1.41
marking
signs or inscriptions primarily for the purpose of identifying equipment, components and/or devices

3.1.42
neutral conductor
N
conductor electrically connected to the neutral point and capable of contributing to the distribution of electrical energy

[SOURCE: IEC 60050-195:1998, 195-02-06]

3.1.43
obstacle
part preventing unintentional direct contact with live parts, but not preventing direct contact by deliberate action

[SOURCE: IEC 60050-195:1998, 195-06-16, modified – The words “(electrically) protective” have been removed from the term.]

3.1.44
overcurrent
current exceeding the rated value

Note 1 to entry: For conductors, the rated value is considered as equal to the current-carrying capacity.

[SOURCE: IEC 60050-826:2004, 826-11-14, modified – The definition has been amended.]

3.1.45
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 1 to entry: Overload should not be used as a synonym for overcurrent.

3.1.46
plug/socket combination
component and a suitable mating component, appropriate to terminate conductors, intended for connection or disconnection of two or more conductors

Note 1 to entry: 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.

3.1.47
power circuit
circuit that supplies power to units of equipment used for productive operation and to transformers supplying control circuits

3.1.48
prospective short-circuit current
***I*cp**
r.m.s. value of the current which would flow when the supply conductors to the electrical equipment are short-circuited by a conductor of negligible impedance located as near as practicable to the supply terminals of the electrical equipment

[SOURCE: IEC 61439-1: 2011, 3.8.7, modified – “assembly” has been replaced by “electrical equipment”]

3.1.49
protective bonding
equipotential bonding for protection against electric shock

Note 1 to entry: Measures for protection against electric shock can also reduce the risk of burns or fire.

Note 2 to entry: Protective bonding can be achieved with protective conductors and protective bonding conductors and by conductive joining of conductive parts of the machine and its electrical equipment.

3.1.50
protective bonding circuit
protective conductors and conductive parts connected together to provide protection against electric shock in the event of an insulation failure

3.1.51
protective conductor
conductor providing a primary fault current path from the exposed conductive parts of the electrical equipment to a protective earthing (PE) terminal

3.1.52
redundancy
application of more than one device or system, or part of a device or system, with the objective of ensuring that in the event of one failing to perform its function, another is available to perform that function

3.1.53
reference designation
distinctive code which serves to identify an object in the documentation and on the equipment

3.1.54
risk
combination of the probability of occurrence of harm (i.e. physical injury or damage to health) and the severity of that harm

[SOURCE: ISO 12100:2010, 3.12, modified – The text in parentheses has been added]

3.1.55
safeguard
guard or protective device provided as a means to protect persons from a hazard

[SOURCE: ISO 12100:2010, 3.26, modified – The words "provided as a means to protect persons from a hazard" have been added.]

3.1.56
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

[SOURCE: ISO 12100:2010, 3.21]

3.1.57
safety function
function of a machine whose failure can result in an immediate increase of the risk(s)

[SOURCE: ISO 12100:2010, 3.30; IEC 62061:2005, 3.2.15]

3.1.58
servicing level
level on which persons stand when operating or maintaining the electrical equipment

3.1.59
short-circuit current
overcurrent resulting from a short-circuit due to a fault or an incorrect connection in an electric circuit

[SOURCE: IEC 60050-441:1984, 441-11-07]

3.1.60
short-circuit current rating
value of prospective short-circuit current that can be withstood by the electrical equipment for the total operating time (clearing time) of the short-circuit protective device (SCPD) under specified conditions

[SOURCE: IEC 61439-1: 2011, 3.8.10.4, modified – The word "rated" is removed from the term, and the reference to "assembly" removed from the definition.]

3.1.61
skilled person
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

[SOURCE: IEC 60050-826:2004, 826-18-01, modified – The parentheses have been removed and "training" has been added.]

3.1.62
supplier
entity (for example manufacturer, contractor, installer, integrator) who provides equipment or services associated with the machine

Note 1 to entry: The user organization may also act in the capacity of a supplier to itself.

3.1.63
switching device
device designed to make and/or break the current in one or more electric circuits

Note 1 to entry: A switching device may perform one or both of these actions.

[SOURCE: IEC 60050-441:1984, 441-14-01]

3.1.64
uncontrolled stop
stopping of machine motion by removing electrical power to the machine actuators

Note 1 to entry: This definition does not imply any particular state of other stopping devices, for example mechanical or hydraulic brakes.

3.1.65
user
entity who utilizes the machine and its associated electrical equipment

3.2 Abbreviated terms

AWG	American Wire Gauge
AC	Alternating Current
BDM	Basic Drive Module
CCS	Cableless Control System
DC	Direct Current
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
IFLS	Insulation Fault Location System
MMI	Man-Machine interface
PDS	Power Drive System
PELV	Protective Extra-Low Voltage
RCD	Residual Current protective Device
SPD	Surge Protective Devices
SCPD	Short-Circuit Protective Device
SELV	Safe Extra-Low Voltage
SLP	Safely-Limited Position
STO	Safe Torque Off

4 General requirements

4.1 General

This standard specifies requirements for the electrical equipment of machines.

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 machine. This will:

– identify the need for risk reduction; and
– determine adequate risk reductions; and
– determine the necessary protective measures

for persons who can be exposed to those hazards, while still maintaining an appropriate performance of the machine and its 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, arc, or fire;
– failures or faults in control circuits (or components and devices associated with those circuits) resulting in the malfunctioning of the machine;
– disturbances or disruptions in power sources as well as failures or faults in the power circuits resulting in the malfunctioning of the machine;
– loss of continuity of circuits that can result in a failure of a safety function, for example those that depend on sliding or rolling contacts;
– electrical disturbances for example, electromagnetic, electrostatic either from outside the electrical equipment or internally generated, resulting in the malfunctioning of the machine;
– release of stored energy (either electrical or mechanical) resulting in, for example, electric shock, unexpected movement that can cause injury;
– acoustic noise and mechanical vibration at levels that cause health problems to persons;
– 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.

The design and development process shall identify hazards and the risks arising from them. 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.

It is recommended that, where the user is known, Annex B be used to facilitate an exchange of information between the user and the supplier(s) on basic conditions and additional user specifications related to the electrical equipment.

NOTE Those additional specifications can:

– provide additional features that are dependent on the type of machine (or group of machines) and the application;
– facilitate maintenance and repair; and
– improve the reliability and ease of operation.

4.2 Selection of equipment

4.2.1 General

Electrical components and devices shall:

– be suitable for their intended use; and
– conform to relevant IEC standards where such exist; and
– be applied in accordance with the supplier’s instructions.

4.2.2 Switchgear

In addition to the requirements of IEC 60204-1, depending upon the machine, its intended use and its electrical equipment, the designer may select parts of the electrical equipment of the machine that are in compliance with relevant parts of the IEC 61439 series (see also Annex F).

4.3 Electrical supply

4.3.1 General

The electrical equipment shall be designed to operate correctly with the conditions of the supply:

– as specified in 4.3.2 or 4.3.3, or
– as otherwise specified by the user, or
– as specified by the supplier of a special source of supply (see 4.3.4)

4.3.2 AC supplies

Voltage	Steady state voltage: 0,9 to 1,1 of nominal voltage.
Frequency	0,99 to 1,01 of nominal frequency continuously; 0,98 to 1,02 short time.
Harmonics	Harmonic distortion not exceeding 12 % of the total r.m.s. voltage between live conductors for the sum of the 2nd through to the 30th harmonic.
Voltage unbalance	Neither the voltage of the negative sequence component nor the voltage of the zero sequence component in three-phase supplies exceeding 2 % of the positive sequence component.
Voltage interruption	Supply interrupted or at zero voltage for not more than 3 ms at any random time in the supply cycle with more than 1 s between successive interruptions.
Voltage dips	Voltage dips not exceeding 20 % of the rms voltage of the supply for more than one cycle with more than 1 s between successive dips.

4.3.3 DC supplies

From batteries:

Voltage	0,85 to 1,15 of nominal voltage; 0,7 to 1,2 of nominal voltage in the case of battery-operated vehicles.
Voltage interruption	Not exceeding 5 ms.

From converting equipment:

Voltage	0,9 to 1,1 of nominal voltage.
Voltage interruption	Not exceeding 20 ms with more than 1 s between successive interruptions.

NOTE This is a variation to IEC Guide 106 to ensure proper operation of electronic equipment.

Ripple (peak-to-peak)	Not exceeding 0,15 of nominal voltage.

4.3.4 Special supply systems

For special supply systems (e.g. on-board generators, DC bus, etc.) the limits given in 4.3.2 and 4.3.3 may be exceeded provided that the equipment is designed to operate correctly with those conditions.

4.4 Physical environment and operating conditions

4.4.1 General

The electrical equipment shall be suitable for the physical environment and operating conditions of its intended use. The requirements of 4.4.2 to 4.4.8 cover the physical environment and operating conditions of the majority of machines covered by this part of

IEC 60204. When special conditions apply or the limits specified are exceeded, an exchange of information between user and supplier (see 4.1) can be necessary.

4.4.2 Electromagnetic compatibility (EMC)

The electrical equipment shall not generate electromagnetic disturbances above levels that are appropriate for its intended operating environment. In addition, the electrical equipment shall have a sufficient level of immunity to electromagnetic disturbances so that it can function in its intended environment.

Immunity and/or emission tests are required on the electrical equipment unless the following conditions are fulfilled:

- the incorporated devices and components comply with the EMC requirements for the intended EMC environment specified in the relevant product standard (or generic standard where no product standard exists), and;
- the electrical installation and wiring are consistent with the instructions provided by the supplier of the devices and components with regard to mutual influences, (cabling, screening, earthing etc.) or with informative Annex H if such instructions are not available from the supplier.

NOTE 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.

4.4.3 Ambient air temperature

Electrical equipment shall be capable of operating correctly in the intended ambient air temperature. The minimum requirement for all electrical equipment is correct operation in ambient air temperatures outside of enclosures (cabinet or box) between +5 °C and +40 °C.

4.4.4 Humidity

The electrical equipment shall be capable of operating correctly when the relative humidity does not exceed 50 % at a maximum temperature of +40 °C. Higher relative humidities are permitted at lower temperatures (for example 90 % at 20 °C).

Harmful effects of occasional condensation shall be avoided by design of the equipment or, where necessary, by additional measures (for example built-in heaters, air conditioners, drain holes).

4.4.5 Altitude

Electrical equipment shall be capable of operating correctly at altitudes up to 1 000 m above mean sea level.

For equipment to be used at higher altitudes, it is necessary to take into account the reduction of:

– the dielectric strength, and;
– the switching capability of the devices, and;
– the cooling effect of the air.

It is recommended that the manufacturer is consulted regarding the correction factors to be used where the factors are not specified in product data.

4.4.6 Contaminants

Electrical equipment shall be adequately protected against the ingress of solids and liquids (see 11.3).

The electrical equipment shall be adequately protected against contaminants (for example dust, acids, corrosive gases, salts) that can be present in the physical environment in which the electrical equipment is to be installed.

4.4.7 Ionizing and non-ionizing radiation

When equipment is subject to radiation (for example microwave, ultraviolet, lasers, X-rays), additional measures shall be taken to avoid malfunctioning of the equipment and accelerated deterioration of the insulation.

4.4.8 Vibration, shock, and bump

Undesirable effects of vibration, shock and bump (including those generated by the machine and its associated equipment and those created by the physical environment) shall be avoided by the selection of suitable equipment, by mounting it away from the machine, or by provision of anti-vibration mountings.

4.5 Transportation and storage

Electrical equipment shall be designed to withstand, or suitable precautions shall be taken to protect against, the effects of transportation and storage temperatures within a range of –25 °C to +55 °C and for short periods not exceeding 24 h at up to +70 °C. Suitable means shall be provided to prevent damage from humidity, vibration, and shock.

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

4.6 Provisions for handling

Heavy and bulky electrical equipment that has to be removed from the machine for transport, or that is independent of the machine, shall be provided with suitable means for handling, including where necessary means for handling by cranes or similar equipment.

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

5.1 Incoming supply conductor terminations

It is recommended that, where practicable, the electrical equipment of a machine is connected to a single incoming supply. Where another supply is necessary for certain parts of the 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 of the machine. For large complex machinery there can be a need for more than one incoming supply depending upon the site supply arrangements (see 5.3.1).

Unless a plug is provided with the machine for the connection to the supply (see 5.3.2 e)), it is recommended that the supply conductors are terminated at the supply disconnecting device.

Where a neutral conductor is used it shall be clearly indicated in the technical documentation of the machine, such as in the installation diagram and in the circuit diagram, and a separate insulated terminal, labelled N in accordance with 16.1, shall be provided for the neutral conductor. The neutral terminal may be provided as part of the supply disconnecting device.

There shall be no connection between the neutral conductor and the protective bonding circuit inside the electrical equipment.

Exception: a connection may be made between the neutral terminal and the PE terminal at the point of the connection of the electrical equipment to a TN-C supply system.

For machines supplied from parallel sources, the requirements of IEC 60364-1 for multiple source systems apply.

Terminals for the incoming supply connection shall be clearly identified in accordance with IEC 60445. The terminal for the external protective conductor shall be identified in accordance with 5.2.

5.2 Terminal for connection of the external protective conductor

For each incoming supply, a terminal shall be provided in the same compartment as the associated line conductor terminals for connection of the machine to the external protective conductor.

The terminal shall be of such a size as to enable the connection of an external protective copper conductor with a cross-sectional area determined in relation to the size of the associated line conductors in accordance with Table 1.

Table 1 – Minimum cross-sectional area of copper protective conductors

Cross-sectional area of line conductors S mm^2	Minimum cross-sectional area of the corresponding protective conductor (PE) S_p mm^2
$S \leq 16$	S
$16 < S \leq 35$	16
$S > 35$	$S/2$

Where an external protective conductor of a material other than copper is used, the terminal size and type shall be selected accordingly.

At each incoming supply point, the terminal for connection of external protective conductor shall be marked or labelled with the letters PE (see IEC 60445).

5.3 Supply disconnecting (isolating) device

5.3.1 General

A supply disconnecting device shall be provided:

– for each incoming supply to (a) machine(s);

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

– for each on-board power supply.

The supply disconnecting device shall disconnect (isolate) the electrical equipment of the machine from the supply when required (for example for work on the machine, including the electrical equipment).

Where two or more supply disconnecting devices are provided, protective interlocks for their correct operation shall also be provided in order to prevent a hazardous situation, including damage to the machine or to the work in progress.

5.3.2 Type

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

a) switch-disconnector, with or without fuses, in accordance with IEC 60947-3, utilization category AC-23B or DC-23B;

b) control and protective switching device suitable for isolation, in accordance with IEC 60947-6-2;

c) a circuit-breaker suitable for isolation in accordance with IEC 60947-2;

d) any other switching device in accordance with an IEC product standard for that device and which meets the isolation requirements and the appropriate utilization category and/or specified endurance requirements defined in the product standard;

e) a plug/socket combination for a flexible cable supply.

5.3.3 Requirements

Where the supply disconnecting device is one of the types specified in 5.3.2 a) to d) it shall fulfil all of the following requirements:

– 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);

– 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;

– have an operating means (see 5.3.4);

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

– 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 (when used) is compulsory;

– 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 other loads. The calculated breaking capacity may be reduced by the use of a proven diversity factor. Where motor(s) are supplied by converter(s) or similar devices, the calculation should take into account the possible effect on the required breaking capacity.

Where the supply disconnecting device is a plug/socket combination, it shall comply with the requirements of 13.4.5 and shall have the breaking capacity, or be interlocked with a switching device that has 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 other loads. The calculated breaking capacity may be reduced by the use of a proven diversity factor. Where the interlocked switching device is electrically operated (for example a contactor) it shall have an appropriate utilisation category. Where motor(s) are supplied by converter(s) or similar devices, the calculation should take into account the possible effect on the required breaking capacity.

NOTE A suitably rated plug and socket-outlet, cable coupler, or appliance coupler, in accordance with IEC 60309-1 can fulfil these requirements.

Where the supply disconnecting device is a plug/socket combination, a switching device with an appropriate utilisation category shall be provided for switching the machine on and off. This can be achieved by the use of the interlocked switching device described above.

5.3.4 Operating means of the supply disconnecting device

The operating means (for example, a handle) of the supply disconnecting device shall be external to the enclosure of the electrical equipment.

Exception: power-operated switchgear need not be provided with a handle outside the enclosure where other means (e.g. pushbuttons) are provided to open the supply disconnecting device from outside the enclosure.

The operating means of the supply disconnecting device shall be easily accessible and located between 0,6 m and 1,9 m above the servicing level. An upper limit of 1,7 m is recommended.

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

Where the external operating means is intended for emergency operation, see 10.7.3 or 10.8.3.

Where the external operating means is not intended for emergency operations:

- it is recommended that it be coloured BLACK or GREY (see 10.2)
- a supplementary cover or door that can be readily opened without the use of a key or tool may be provided, for example for protection against environmental conditions or mechanical damage. Such a cover/door shall clearly show that it provides access to the operating means. This can be achieved, for example, by use of the relevant symbol IEC 60417-6169-1 (2012-08) (Figure 2) or IEC 60417-6169-2 (2012-08), (Figure 3).

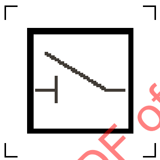


Figure 2 – Disconnector isolator

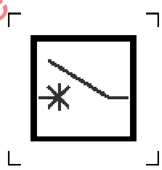


Figure 3 – Disconnecting circuit breaker

5.3.5 Excepted circuits

The following circuits need not be disconnected by the supply disconnecting device:

- lighting circuits for lighting needed during maintenance or repair;
- socket outlets for the exclusive connection of repair or maintenance tools and equipment (for example hand drills, test equipment) (see 15.1);
- undervoltage protection circuits that are only provided for automatic tripping in the event of supply failure;
- circuits supplying equipment that should normally remain energized for correct operation (for example temperature controlled measuring devices, heaters, program storage devices).

It is recommended, however, that such circuits be provided with their own disconnecting device.

Control circuits supplied via another supply disconnecting device, regardless of whether that disconnecting device is located in the electrical equipment or in another machine or other electrical equipment, need not be disconnected by the supply disconnecting device of the electrical equipment.

Where excepted circuits are not disconnected by the supply disconnecting device:

– permanent warning label(s) shall be appropriately placed in proximity to the operating means of the supply disconnecting device to draw attention to the hazard;
– a corresponding statement shall be included in the maintenance manual, and one or more of the following shall apply:
  • the conductors are identified by colour taking into account the recommendation of 13.2.4;
  • excepted circuits are separated from other circuits;
  • excepted circuits are identified by permanent warning label(s).

5.4 Devices for removal of power for prevention of unexpected start-up

Devices for removal of power for the prevention of unexpected start-up shall be provided where a start-up of the machine or part of the machine can create a hazard (for example during maintenance). Such devices shall be appropriate and convenient for the intended use, be suitably placed, and readily identifiable as to their function and purpose. Where their function and purpose is not otherwise obvious (e.g. by their location) these devices shall be marked to indicate the extent of removal of power.

NOTE 1 This part of IEC 60204 does not address all provisions for prevention of unexpected start up. Further information is provided in ISO 14118.

NOTE 2 Removal of power means removal of the connection to the source of electrical energy but does not imply isolation.

The supply disconnecting device or other devices in accordance with 5.3.2 may be used for prevention of unexpected start-up.

Disconnectors, withdrawable fuse links and withdrawable links may be used for protection of unexpected start-up only if they are located in an enclosed electrical operating area (see 3.1.23).

Devices that do not fulfil the isolation function (for example a contactor switched off by a control circuit, or Power Drive System (PDS) with a Safe Torque Off (STO) function in accordance with IEC 61800-5-2) may only be used for prevention of unexpected start-up during tasks such as:

– inspections;
– adjustments;
– work on the electrical equipment where:
  • there is no hazard arising from electric shock (see Clause 6) and burn;
  • the switching off means remains effective throughout the work;
  • the work is of a minor nature (for example, replacement of plug-in devices without disturbing existing wiring).

The selection of a device will be dependent on the risk assessment, taking into account the intended use of the device, and the persons who are intended to operate them.

5.5 Devices for isolating electrical equipment

Devices shall be provided for isolating (disconnecting) the electrical equipment or part(s) of the electrical equipment to enable work to be carried out when it is de-energised and isolated. Such devices shall be:

– appropriate and convenient for the intended use;
– suitably placed;

– readily identifiable as to which part(s) or circuit(s) of the equipment is served. Where their function and purpose is not otherwise obvious (e.g. by their location) these devices shall be marked to indicate the extent of the equipment that they isolate.

The supply disconnecting device (see 5.3) may, in some cases, fulfil that function. However, where it is necessary to work on individual parts of the electrical equipment of a machine, or on one of the machines fed by a common conductor bar, conductor wire or inductive power supply system, a disconnecting device shall be provided for each part, or for each machine, requiring separate isolation.

In addition to the supply disconnecting device, the following devices that fulfil the isolation function may be provided for this purpose:

– devices described in 5.3.2;
– disconnectors, withdrawable fuse links and withdrawable links only if located in an enclosed electrical operating area (see 3.1.23) and relevant information is provided with the electrical equipment (see Clause 17).

5.6 Protection against unauthorized, inadvertent and/or mistaken connection

Where the devices described in 5.4 and 5.5 are located outside an enclosed electrical operating area they shall be equipped with means to secure them in the OFF position (disconnected state), (for example by provisions for padlocking, trapped key interlocking). When so secured, remote as well as local reconnection shall be prevented.

Where the devices described in 5.4 and 5.5 are located inside an enclosed electrical operating area other means of protection against reconnection (for example warning labels) can be sufficient.

However, when a plug/socket combination according to 5.3.2 e) is so positioned that it can be kept under the immediate supervision of the person carrying out the work, means for securing in the disconnected state need not be provided.

6 Protection against electric shock

6.1 General

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

– basic protection (see 6.2 and 6.4), and;
– fault protection (see 6.3 and 6.4).

The measures for protection given in 6.2, 6.3, and, for PELV, in 6.4, are a selection from IEC 60364-4-41. Where those measures are not practicable, for example due to the physical or operational conditions, other measures from IEC 60364-4-41 may be used (e.g. SELV).

6.2 Basic protection

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.

Exception: where those measures are not appropriate, other measures for basic protection (for example by using barriers, by placing out of reach, using obstacles, using construction or installation techniques that prevent access) as defined in IEC 60364-4-41 may be applied (see also 6.2.5 and 6.2.6).

Where the equipment is located in places open to all persons, which can include children, measures of either 6.2.2 with a minimum degree of protection against contact with live parts corresponding to IP4X or IPXXD (see IEC 60529), or 6.2.3 shall be applied.

6.2.2 Protection by enclosures

Live parts shall be located inside enclosures that provide protection against contact with live parts of at least IP2X or IPXXB (see IEC 60529).

Where the top surfaces of the enclosure are readily accessible, the minimum degree of protection against contact with live parts provided by the top surfaces shall be IP4X or IPXXD.

Opening an enclosure (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 1 The use of a key or tool is intended to restrict access to skilled or instructed persons (see 17.2 f)).

All live parts, (including those on the inside of doors) that are likely to be touched when resetting or adjusting devices intended for such operations while the equipment is still connected, shall be protected against contact to at least IP2X or IPXXB. Other live parts on the inside of doors shall be protected against unintentional direct contact to at least IP1X or IPXXA.

b) The disconnection of live parts inside the enclosure before the enclosure can be opened.

This may be accomplished by interlocking the door with a disconnecting device (for example, the supply disconnecting device) so that the door can only be opened when the disconnecting device is open and so that the disconnecting device can only be closed when the door is closed.

Exception: a key or tool as prescribed by the supplier can be used to defeat the interlock provided that the following conditions are met:

– it is possible at all times while the interlock is defeated to open the disconnecting device and lock the disconnecting device in the OFF (isolated) position or otherwise prevent unauthorised closure of the disconnecting device;

– upon closing the door, the interlock is automatically restored;

– all live parts, (including those on the inside of doors) that are likely to be touched when resetting or adjusting devices intended for such operations while the equipment is still connected, are protected against unintentional contact with live parts to at least IP2X or IPXXB and other live parts on the inside of doors are protected against unintentional contact to at least IP1X or IPXXA;

– relevant information about the procedures for the defeat of the interlock is provided with the instructions for use of the electrical equipment (see Clause 17).

– means are provided to restrict access to live parts behind doors that are not directly interlocked with the disconnecting means to skilled or instructed persons. (See 17.2 b)).

All parts that are still live after switching off the disconnecting device(s) (see 5.3.5) shall be protected against direct contact to at least IP2X or IPXXB (see IEC 60529). Such parts shall be marked with a warning sign in accordance with 16.2.1 (see also 13.2.4 for identification of conductors by colour), except for:

– parts that can be live only because of connection to interlocking circuits and that are distinguished by colour as potentially live in accordance with 13.2.4;

– the supply terminals of the supply disconnecting device when the latter is mounted alone in a separate enclosure.

c) Opening without the use of a key or a tool and without disconnection of live parts shall be possible only when all live parts are protected against contact to at least IP2X or IPXXB (see IEC 60529). Where barriers provide this protection, either they shall require a tool for their removal or all live parts protected by them shall be automatically disconnected when the barrier is removed. Where protection against contact is achieved in accordance with 6.2.2 c), and a hazard can be caused by manual actuation of devices (for example manual closing of contactors or relays), such actuation should be prevented by barriers or obstacles that require a tool for their removal.

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 when the supply is disconnected shall be discharged to 60 V or less within a time period of 5 s provided that this rate of discharge does not interfere with the proper functioning of the equipment. Exempted from this requirement are components having a stored charge of 60 μC or less. Where this specified rate of discharge would interfere with the proper functioning of the equipment, a durable warning notice drawing attention to the hazard and stating the delay required before the enclosure may be opened shall be displayed at an easily visible location on or immediately adjacent to the enclosure that contains the live parts.

In the case of plugs or similar devices, the withdrawal of which results in the exposure of conductors (for example pins), the discharge time to 60 V shall not exceed 1 s, otherwise such conductors shall be protected 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 (for example in the case of removable collectors on conductor wires, conductor bars, or slip-ring assemblies, see 12.7.4), additional switching devices or an appropriate warning, for example a warning sign drawing attention to the hazard and stating the delay required shall be provided. When the equipment is located in places open to all persons, which can include children, warnings are not sufficient and therefore a minimum degree of protection against contact with live parts to IP4X or IPXXD is required.

NOTE Frequency converters and DC bus supplies could have typically a longer discharge time than 5 s.

6.2.5 Protection by barriers

For protection by barriers, the requirements of IEC 60364-4-41 shall apply.

6.2.6 Protection by placing out of reach or protection by obstacles

For protection by placing out of reach, the requirements of IEC 60364-4-41 shall apply. For protection by obstacles, the requirements of IEC 60364-4-41 shall apply.

For conductor wire systems or conductor bar systems with a degree of protection less than IP2X or IPXXB, see 12.7.1.

6.3 Fault protection

6.3.1 General

Fault protection (3.31) 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 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 IEC 61140 provides information about classes of equipment and protective provisions.

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.

This protection is provided by one or more of the following:

– class II electrical devices or apparatus (double insulation, reinforced insulation or by equivalent insulation in accordance with IEC 61140);
– switchgear and controlgear assemblies having total insulation in accordance with IEC 61439-1;
– supplementary or reinforced insulation in accordance with IEC 60364-4-41.

6.3.2.3 Protection by electrical separation

Electrical separation of an individual circuit is intended to prevent a 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.

For this type of protection, the requirements of IEC 60364-4-41 apply.

6.3.3 Protection by automatic disconnection of supply

Automatic disconnection of the supply of any circuit affected by an insulation fault is intended to prevent a hazardous situation resulting from a touch voltage.

This measure consists of the interruption of one or more of the line conductors by the automatic operation of a protective device in case of a fault. This interruption shall occur within a sufficiently short time to limit the duration of a touch voltage to a time within the limits specified in Annex A for TN and TT systems.

This measure necessitates co-ordination between:

– the type of supply system, the supply source impedance and the earthing system;
– the impedance values of the different elements of the line and of the associated fault current paths through the protective bonding circuit;
– the characteristics of the protective devices that detect insulation fault(s).

NOTE 1 Details of verification of conditions for protection by automatic disconnection of supply are provided in 18.2.

This protective measure comprises both:

– protective bonding of exposed conductive parts (see 8.2.3),
– and one of the following:
  a) In TN systems, the following protective devices may be used:
     - overcurrent protective devices;
     - residual current protective devices (RCDs) and associated overcurrent protective device(s).

  NOTE 2 The preventive maintenance can be enhanced by use of a residual current monitoring device, RCM, complying with IEC 62020.

  b) in TT systems, either:
     - RCDs and associated overcurrent protective device(s) 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, or
     - overcurrent protective devices may be used for fault protection provided a suitably low value of the fault loop impedance Z_s (see A.2.2.3) is permanently and reliably assured;

  NOTE 3 The preventive maintenance can be enhanced by use of a residual current monitoring device, RCM, complying with IEC 62020.

  c) In IT systems the relevant requirements of IEC 60364-4-41 shall be fulfilled. During an insulation fault, an acoustic and optical signal shall be sustained. After annunciation, the acoustic signal may then be manually muted. This can require an agreement between the supplier and user regarding the provision of insulation monitoring devices and/or insulation fault location system(s).

  NOTE 4 In large machines, the provision of an insulation fault location system (IFLS) in accordance with IEC 61557-9 can facilitate maintenance.

Where automatic disconnection is provided in accordance with a), and disconnection within the time specified in A.1.1 cannot be assured, supplementary protective bonding shall be provided as necessary to meet the requirements of A.1.3.

Where a power drive system (PDS) is provided, fault protection shall be provided for those circuits of the power drive system that are supplied by the converter. Where this protection is not provided within the converter, the necessary protection measures shall be in accordance with the converter manufacturer's instructions.

6.4 Protection by the use of PELV

6.4.1 General requirements

The use of PELV (Protective Extra-Low Voltage) is to protect persons against electric shock from indirect contact and limited area direct contact (see 8.2.1).

PELV circuits shall satisfy all of the following conditions:

a) the nominal voltage shall not exceed:
   - 25 V AC r.m.s. or 60 V ripple-free DC when the 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 AC r.m.s. or 15 V ripple-free DC 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.

7 Protection of equipment

7.1 General

This Clause 7 details the measures to be taken to protect equipment against the effects of:

– overcurrent arising from 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 where the current in any circuit 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 selected are detailed in 7.2.10.

7.2.2 Supply conductors

Unless otherwise specified by the user, the supplier of the electrical equipment is not responsible for providing the supply conductors and the overcurrent protective device for the supply conductors to the electrical equipment.

The supplier of the electrical equipment shall state in the installation documents the data necessary for conductor dimensioning (including the maximum cross-sectional area of the supply conductor that can be connected to the terminals of the electrical equipment) and for selecting the overcurrent protective device (see 7.2.10 and 17).

7.2.3 Power circuits

Devices for detection and interruption of overcurrent, selected in accordance with 7.2.10, shall be applied to each live conductor including circuits supplying control circuit transformers.

The following conductors, as applicable, shall not be disconnected without disconnecting all associated live conductors:

– the neutral conductor of AC power circuits;
– the earthed conductor of DC power circuits;
– DC power conductors bonded to exposed conductive parts of mobile machines.

Where the cross-sectional area of the neutral conductor is at least equal to or equivalent to that of the line conductors, it is not necessary to provide overcurrent detection for the neutral conductor nor a disconnecting device for that conductor. For a neutral conductor with a cross-sectional area smaller than that of the associated line conductors, the measures detailed in 524 of IEC 60364-5-52:2009 shall apply.

In IT systems, it is recommended that the neutral conductor is not used. However, where a neutral conductor is used, the measures detailed in 431.2.2 of IEC 60364-4-43:2008 shall apply.

7.2.4 Control circuits

Conductors of control circuits directly connected to the supply voltage shall be protected against overcurrent in accordance with 7.2.3.

Conductors of control circuits supplied by a transformer or DC supply shall be protected against overcurrent (see also 9.4.3.1.1):

– in control circuits connected to the protective bonding circuit, by inserting an overcurrent protective device into the switched conductor;
– in control circuits not connected to the protective bonding circuit;
  • where all control circuits of the equipment have the same current carrying capacity, by inserting an overcurrent protective device into the switched conductor, or;
  • where different control circuits of the equipment have different current carrying capacity, by inserting an overcurrent protective device into both switched and common conductors of each control circuit.

Exception: Where the supply unit provides current limiting below the current carrying capacity of the conductors in a circuit and below the current rating of connected components, no separate overcurrent protective device is required.

7.2.5 Socket outlets and their associated conductors

Overcurrent protection shall be provided for the circuits feeding the general purpose socket outlets intended primarily for supplying power to maintenance equipment. Overcurrent protective devices shall be provided in the unearthed live conductors of each circuit feeding such socket outlets. See also 15.1.

7.2.6 Lighting circuits

All unearthed conductors of circuits supplying lighting shall be protected against the effects of short-circuits by the provision of overcurrent devices separate from those protecting other circuits.

7.2.7 Transformers

Transformers shall be protected by an overcurrent protective device having a type and setting in accordance with the transformer manufacturer's instructions. Such protection shall (see also 7.2.10):

– avoid nuisance tripping due to transformer magnetizing inrush currents;

– avoid a winding temperature rise in excess of the permitted value for the insulation class of transformer when it is subjected to the effects of a short-circuit at its secondary terminals.

7.2.8 Location of overcurrent protective devices

An overcurrent protective device shall be located at the point where a reduction in the cross-sectional area of the conductors or another change reduces the current-carrying capacity of the conductors, except where all the following conditions are satisfied:

– the current carrying capacity of the conductors is at least equal to that of the load;

– the part of the conductor(s) between the point of reduction of current-carrying capacity and the position of the overcurrent protective device is no longer than 3 m;

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

7.2.9 Overcurrent protective devices

The rated short-circuit breaking capacity shall be at least equal to the prospective fault current at the point of installation. 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.

NOTE Information on co-ordination under short-circuit conditions between a circuit-breaker and another short-circuit protective device is provided in Annex A of IEC 60947-2:2006, IEC 60947-2:2006/AMD1:2009 and IEC 60947-2:2006/AMD2:2013.

Where fuses are provided as overcurrent protective devices, a type readily available in the country of use shall be selected, or arrangements shall be made for the supply of spare parts.

7.2.10 Rating and setting of overcurrent protective devices

The rated current of fuses or the setting current of other overcurrent protective devices shall be selected as low as possible 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.

The rated current or setting of an overcurrent protective device for conductors is determined by the current carrying capacity of the conductors to be protected in accordance with 12.4, Clause D.3 and the maximum allowable interrupting time t in accordance with Clause D.4, taking into account the needs of co-ordination with other electrical devices in the protected circuit.

7.3 Protection of motors against overheating

7.3.1 General

Protection of motors against overheating shall be provided for each motor rated at more than 0,5 kW.

Exception: In applications where an automatic interruption of the motor operation is unacceptable (for example fire pumps), the means of detection shall give a warning signal to which the operator can respond.

Protection of motors against overheating can be achieved by:

– overload protection (7.3.2),

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), or

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

– current-limiting protection.

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 or to the work in progress.

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.

However, where the motor overload detection is not used for cable overload protection (see also Clause D.2), detection of overload may be omitted in one of the live conductors. For motors having single-phase or DC 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.

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 (for example dusty environments). Depending upon the type 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 are either 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 Protection against abnormal temperature

Equipment shall be protected against abnormal temperatures that can result in a hazardous situation.

7.5 Protection against the effects of supply interruption or voltage reduction and subsequent restoration

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

Where the operation of the machine 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 machine.

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

Where only a part of the machine or of the group of machines working together in a co-ordinated manner is affected by the voltage reduction or supply interruption, the undervoltage protection shall initiate appropriate control commands to ensure co-ordination.

7.6 Motor overspeed protection

Overspeed protection shall be provided where overspeeding can occur and could possibly cause a hazardous situation taking into account measures in accordance with 9.3.2. Overspeed protection shall initiate appropriate control responses and shall prevent automatic restarting.

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

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

7.7 Additional 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 equipment due to earth fault currents less than the detection level of the overcurrent protection.

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

If fault currents with DC components are possible, an RCD of type B in accordance with IEC TR 60755 can be required.

7.8 Phase sequence protection

Where an incorrect phase sequence of the supply voltage can cause a hazardous situation or damage to the machine, protection shall be provided.

NOTE Conditions of use that can lead to an incorrect phase sequence include:

- a machine transferred from one supply to another;
- a mobile machine with a facility for connection to an external power supply.

7.9 Protection against overvoltages due to lightning and to switching surges

Surge protective devices (SPDs) can be provided to protect against the effects of overvoltages due to lightning or to switching surges.

Where provided:

– SPDs for the suppression of overvoltages due to lightning shall be connected to the incoming terminals of the supply disconnecting device.
– SPDs for the suppression of overvoltages due to switching surges shall be connected as necessary for equipment requiring such protection.

NOTE 1 Information about the correct selection and installation of SPDs is given for example in IEC 60364-4-44, IEC 60364-5-53, IEC 61643-12, IEC 62305-1 and IEC 62305-4.

NOTE 2 Equipotential bonding of the machine, its electrical equipment and extraneous-conductive-parts to a common bonding network of the building/site can help mitigate electromagnetic interference, including the effects of lightning, on the equipment.

7.10 Short-circuit current rating

The short-circuit current rating of the electrical equipment shall be determined. This can be done by the application of design rules or by calculation or by test.

NOTE The short-circuit current rating may be determined, for example, in accordance with IEC 61439-1, IEC 60909-0, IEC/TR 60909-1, or IEC/TR 61912-1.

8 Equipotential bonding

8.1 General

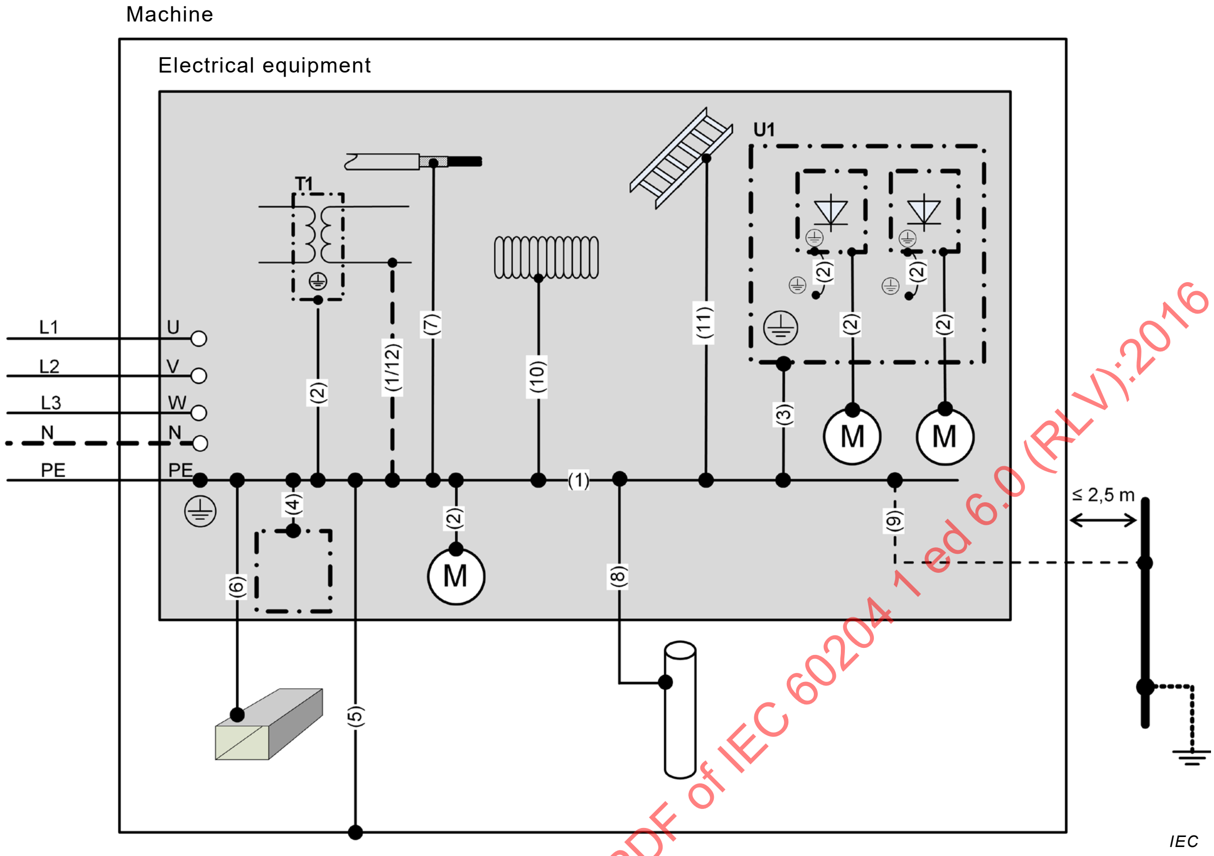
This Clause 8 provides requirements for protective bonding and functional bonding. Figure 4 illustrates those concepts.

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

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

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

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



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

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

8.2 Protective bonding circuit

8.2.1 General

The protective bonding circuit consists of the interconnection of:

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

Exception: see 8.2.5.

- conductive structural parts of the machine.

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

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

– 2,5 mm^2 Cu or 16 mm^2 Al if protection against mechanical damage is provided,

– 4 mm^2 Cu or 16 mm^2 Al if protection against mechanical damage is not provided.

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

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

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

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

– they cannot be touched on large surfaces or grasped with the hand and they are small in size (less than approximately 50 mm × 50 mm); or

– they are located so that either contact with live parts, or an insulation failure, is unlikely.

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

8.2.2 Protective conductors

Protective conductors shall be identified in accordance with 13.2.2.

Copper conductors are preferred. Where a conductor material other than copper is used, its electrical resistance per unit length shall not exceed that of the allowable copper conductor and such conductors shall be not less than 16 mm^2 in cross-sectional area for reasons of mechanical durability.

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

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

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

Each protective conductor shall:

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

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

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

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

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

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

8.2.3 Continuity of the protective bonding circuit

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

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

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

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

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

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

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

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

8.2.4 Protective conductor connecting points

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

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

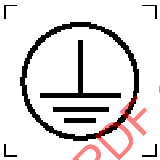


Figure 5 – Symbol IEC 60417-5019: Protective earth

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

8.2.5 Mobile machines

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

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

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

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

a) the protective conductor is completely enclosed within electrical equipment enclosures or otherwise protected throughout its length against mechanical damage;

b) the protective conductor has a cross-sectional area of at least 10 mm^2 Cu or 16 mm^2 Al;

c) where the protective conductor has a cross-sectional area of less than 10 mm^2 Cu or 16 mm^2 Al, a second protective conductor of at least the same cross-sectional area is provided up to a point where the protective conductor has a cross-sectional area not less than 10 mm^2 Cu or 16 mm^2 Al. This can require that the electrical equipment has a separate terminal for a second protective conductor.

d) the supply is automatically disconnected in case of loss of continuity of the protective conductor;

e) where a plug-socket combination is used, an industrial connector in accordance with IEC 60309 series, with adequate strain relief and a minimum protective earthing conductor cross-section of 2,5 mm^2 as part of a multi-conductor power cable is provided.

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

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

8.3 Measures to restrict the effects of high leakage current

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

8.4 Functional bonding

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

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

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

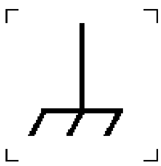


Figure 6 – Symbol IEC 60417-5020: Frame or chassis

9 Control circuits and control functions

9.1 Control circuits

9.1.1 Control circuit supply

Where control circuits are supplied from an AC source, transformers having separate windings shall be used to separate the power supply from the control supply.

Examples include:

- control transformers having separate windings in accordance with IEC 61558-2-2,
- switch mode power supply units in accordance with IEC 61558-2-16 fitted with transformers having separate windings,

- low voltage power supplies in accordance with IEC 61204-7 fitted with transformers having separate windings.

Where several transformers are used, it is recommended that the windings of those transformers be connected in such a manner that the secondary voltages are in phase.

Exception: Transformers or switch mode power supply units fitted with transformers are not mandatory for machines with a single motor starter and/or a maximum of two control devices (for example, interlock device, start/stop control station).

Where DC control circuits derived from an AC supply are connected to the protective bonding circuit (see 8.2.1), they shall be supplied from a separate winding of the AC control circuit transformer or by another control circuit transformer.

9.1.2 Control circuit voltages

The nominal value of the control voltage shall be consistent with the correct operation of the control circuit.

The nominal voltage of AC control circuits should preferably not exceed

– 230 V for circuits with 50 Hz nominal frequency,
– 277 V for circuits with 60 Hz nominal frequency.

The nominal voltage of DC control circuits should preferably not exceed 220 V.

9.1.3 Protection

Control circuits shall be provided with overcurrent protection in accordance with 7.2.4 and 7.2.10.

9.2 Control functions

9.2.1 General

NOTE Subclause 9.2 does not specify requirements for the devices used to implement control functions. Examples of requirements for devices are given in Clause 10.

9.2.2 Categories of stop functions

There are three categories of stop functions as follows:

– stop category 0: stopping by immediate removal of power to the machine actuators (i.e. an uncontrolled stop – see 3.1.64);
– stop category 1: a controlled stop (see 3.1.14) 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 with power remaining available to the machine actuators.

NOTE For removal of power it can be sufficient to remove the power needed to generate a torque or force. This can be achieved by declutching, disconnecting, switching off, or by electronic means (e.g. a PDS in accordance with IEC 61800 series), etc.

9.2.3 Operation

9.2.3.1 General

Safety functions and/or protective measures (for example interlocks (see 9.3)) shall be provided where required to reduce the possibility of hazardous situations.

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

9.2.3.2 Start

Start functions shall operate by energizing the relevant circuit.

The start of an operation shall be possible only when all relevant safety functions and/or protective measures are in place and are operational, except for conditions as described in 9.3.6.

For those machines (for example mobile machines) where safety functions and/or protective measures cannot be applied for certain operations, starting of such operations shall be by hold-to-run controls, together with enabling devices, as appropriate.

The provision of acoustic and/or visual warning signals before the starting of hazardous machine operation should be considered.

Suitable interlocks shall be provided where necessary for correct sequential starting.

In the case of machines requiring the use of more than one control station to initiate a start, each of these control stations shall have a separate manually actuated start control device. The conditions to initiate a start shall be:

- all required conditions for machine operation shall be met, and
- all start control devices shall be in the released (off) position, then
- all start control devices shall be actuated concurrently (see 3.1.7).

9.2.3.3 Stop

Stop category 0 and/or stop category 1 and/or stop category 2 stop functions shall be provided as indicated by the risk assessment and the functional requirements of the machine (see 4.1).

NOTE 1 The supply disconnecting device (see 5.3) when operated achieves a stop category 0.

Stop functions shall override related start functions.

Where more than one control station is provided, stop commands from any control station shall be effective when required by the risk assessment of the machine.

NOTE 2 When stop functions are initiated, it can be necessary to discontinue machine functions other than motion.

9.2.3.4 Emergency operations (emergency stop, emergency switching off)

9.2.3.4.1 General

Emergency stop and emergency switching off are complementary protective measures that are not primary means of risk reduction for hazards (for example trapping, entanglement, electric shock or burn) at a machine (see ISO 12100).

This part of IEC 60204 specifies the requirements for the emergency stop and the emergency switching off functions of the emergency operations listed in Annex E, both of which are intended to be initiated by a single human action.

Once active operation of an emergency stop (see 10.7) or emergency switching off (see 10.8) actuator has ceased following a stop or switching off command, the effect of this command shall be sustained until it is reset. This reset shall be possible only by a manual action at the device where the command has been initiated. The reset of the command shall not restart the machinery but only permit restarting.

It shall not be possible to restart the machinery until all emergency stop commands have been reset. It shall not be possible to reenergize the machinery until all emergency switching off commands have been reset.

9.2.3.4.2 Emergency stop

Requirements for functional aspects of emergency stop equipment are given in ISO 13850.

The emergency stop shall function either as a stop category 0 or as a stop category 1. The choice of the stop category of the emergency stop depends on the results of a risk assessment of the machine.

Exception: In some cases, to avoid creating additional risks, it can be necessary to perform a controlled stop and maintain the power to machine actuators even after stopping is achieved. The stopped condition shall be monitored and upon detection of failure of the stopped condition, power shall be removed without creating a hazardous situation.

In addition to the requirements for stop given in 9.2.3.3, the emergency stop function has the following requirements:

- it shall override all other functions and operations in all modes;
- it shall stop the hazardous motion as quickly as practicable without creating other hazards;
- reset shall not initiate a restart.

9.2.3.4.3 Emergency switching off

The functional aspects of emergency switching off are given in 536.4 of IEC 60364-5-53:2001.

Emergency switching off should be provided where:

- basic protection (for example for conductor wires, conductor bars, slip-ring assemblies, controlgear in electrical operating areas) is achieved only by placing out of reach or by obstacles (see 6.2.6); or
- there is the possibility of other hazards or damage caused by electricity.

Emergency switching off is accomplished by switching off the relevant supply by electromechanical switching devices, effecting a stop category 0 of machine actuators connected to this incoming supply. When a machine cannot tolerate this category 0 stop, it may be necessary to provide other measures, for example basic protection, so that emergency switching off is not necessary.

9.2.3.5 Operating modes

Each machine can have one or more operating modes (for example manual mode, automatic mode, setting mode, maintenance mode) determined by the type of machine and its application.

Where machinery has been designed and constructed to allow its use in several control or operating modes requiring different protective measures and having a different impact on safety, it shall be fitted with a mode selector which can be locked in each position (for example key operated switch). Each position of the selector shall be clearly identifiable and shall correspond to a single operating or control mode.

The selector may be replaced by another selection method which restricts the use of certain functions of the machinery to certain categories of operator (for example access code).

Mode selection by itself shall not initiate machine operation. A separate actuation of the 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).

9.2.3.6 Monitoring of command actions

Movement or action of a machine or part of a machine that can result in a hazardous situation shall be monitored by providing, for example, overtravel limiters, motor overspeed detection, mechanical overload detection or anti-collision devices.

NOTE On some manually controlled machines (for example, manual drilling machine), operators provide monitoring.

9.2.3.7 Hold-to-run controls

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

9.2.3.8 Two-hand control

Three types of two-hand control are defined in ISO 13851, the selection of which is determined by the risk assessment. These shall 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;
- machine operation 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 machine operation 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 machine operation can be initiated.

9.2.3.9 Enabling control

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

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

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 machine operation may be reinitiated.

9.2.3.10 Combined start and stop controls

Push-buttons and similar control devices that, when operated, alternately initiate and stop motion shall only be provided for functions which cannot result in a hazardous situation.

9.2.4 Cableless control system (CCS)

9.2.4.1 General requirements

Subclause 9.2.4 deals with the functional requirements of control systems employing cableless (for example radio, infra-red) techniques for transmitting control signals and data between operator control station(s) and other parts of the control system(s).

NOTE 1 Reference to a machine in 9.2.4 is intended to be read as "machine or part(s) of a machine".

Transmission reliability requirements can be necessary for safety functions of a CCS that rely on data transmission (for example, safety-related active stop, motion commands).

The CCS shall have functionality and a response time suitable for the application based on the risk assessment.

NOTE 2 IEC 61784-3 describes communication failures of communication networks and requirements for safety-related data transmission.

NOTE 3 Further requirements for cableless control systems are under development by IEC TC 44 in draft IEC 62745[1].

9.2.4.2 Monitoring the ability of a cableless control system to control a machine

The ability of a cableless control system (CCS) to control a machine shall be automatically monitored, either continuously or at suitable intervals. The status of this ability shall be clearly indicated (for example, by an indicating light, a visual display indication, etc.)

If the communication signal is degraded in a manner that might lead to the loss of the ability of a CCS to control a machine (e.g., reduced signal level, low battery power) a warning to the operator shall be provided before the ability of the CCS to control a machine is lost.

When the ability of a CCS to control a machine has been lost for a time that is determined from a risk assessment of the application, an automatic stop of the machine shall be initiated.

NOTE In some cases, for example, in order to avoid this automatic stop generating an unexpected hazardous condition, it can be necessary for the machine to go to a predetermined state before stopping.

Restoration of the ability of a CCS to control a machine shall not restart the machine. Restart shall require a deliberate action, for example manual actuation of a start button.

9.2.4.3 Control limitation

Measures shall be taken (e.g. coded transmission) to prevent the machine from responding to signals other than those from the intended cableless operator control station(s).

Cableless operator control station(s) shall only control the intended machine(s) and shall affect only the intended machine functions.

1 Under consideration.

9.2.4.4 Use of multiple cableless operator control stations

When more than one cableless operator control station is used to control a machine, then:

- only one cableless operator control station shall be enabled at a time except as necessary for the operation of the machine;
- transfer of control from one cableless operator control station to another shall require a deliberate manual action at the control station that has control;
- during machine operation, transfer of control shall only be possible when both cableless operator control stations are set to the same mode of machine operation and/or function(s) of the machine;
- transfer of control shall not change the selected mode of machine operation and/or function(s) of the machine;
- each cableless operator control station that has control of the machine shall be provided with an indication that it has control (by for example, the provision of an indicating light, a visual display indication).

NOTE Indications at other locations can be necessary as determined by the risk assessment.

9.2.4.5 Portable cableless operator control stations

Portable cableless operator control stations shall be provided with means (for example key operated switch, access code) to prevent unauthorized use.

Each machine under cableless control should have an indication when it is under cableless control.

When a portable cableless operator control station can be connected to one or more of several machines, means shall be provided on the portable cableless operator control station to select which machine(s) is to be connected. Selecting a machine to be connected shall not initiate control commands.

9.2.4.6 Deliberate disabling of cableless operator control stations

Where a cableless operator control station is disabled when under control, the associated machine shall meet the requirements for loss of ability of a CCS to control a machine in 9.2.4.2.

Where it is necessary to disable a cableless operator control station without interrupting machine operation, means shall be provided (for example on the cableless operator control station) to transfer control to another fixed or portable control station.

9.2.4.7 Emergency stop devices on portable cableless operator control stations

Emergency stop devices on portable cableless operator control stations shall not be the sole means of initiating the emergency stop function of a machine.

Confusion between active and inactive emergency stop devices shall be avoided by appropriate design and information for use. See also ISO 13850.

9.2.4.8 Emergency stop reset

Restarting of cableless control after power loss, disabling and re-enabling, loss of communication, or failure of parts of the CCS shall not result in a reset of an emergency stop condition.

The instructions for use shall state that the reset of an emergency stop condition initiated by a portable cableless operator control station shall only be performed when it can be seen that the reason for initiation has been cleared.

Depending on the risk assessment, in addition to the resetting of the emergency stop actuator on the portable cableless operator control station, one or more supplementary fixed reset devices should be provided.

9.3 Protective interlocks

9.3.1 Reclosing or resetting of an interlocking safeguard

The reclosing or resetting of an interlocking safeguard shall not initiate hazardous machine operation.

NOTE Requirements for interlocking guards with a start function (control guards) are specified in 6.3.3.2.5 of ISO 12100:2010.

9.3.2 Exceeding operating limits

Where an operating limit (for example speed, pressure, position) can be exceeded leading to a hazardous situation, means shall be provided to detect when a predetermined limit(s) is exceeded and initiate an appropriate control action.

9.3.3 Operation of auxiliary functions

The correct operation of auxiliary functions shall be checked by appropriate devices (for example pressure sensors).

Where the non-operation of a motor or device for an auxiliary function (for example lubrication, supply of coolant, swarf removal) can cause a hazardous situation, or cause damage to the machine or to the work in progress, appropriate interlocking shall be provided.

9.3.4 Interlocks between different operations and for contrary motions

All contactors, relays, and other control devices that control elements of the machine and that can cause a hazardous situation when actuated at the same time (for example those which initiate contrary motion), shall be interlocked against incorrect operation.

Reversing contactors (for example those controlling the direction of rotation of a motor) shall be interlocked in such a way that in normal service no short-circuit can occur when switching.

Where, for safety or for continuous operation, certain functions on the machine are required to be interrelated, proper co-ordination shall be ensured by suitable interlocks. For a group of machines working together in a co-ordinated manner and having more than one controller, provision shall be made to co-ordinate the operations of the controllers as necessary.

Where a failure of a mechanical brake actuator can result in the brake being applied when the associated machine actuator is energized and a hazardous situation can result, interlocks shall be provided to switch off the machine actuator.

9.3.5 Reverse current braking

Where braking of a motor is accomplished by current reversal, measures shall be provided to prevent the motor starting in the opposite direction at the end of braking where that reversal can cause a hazardous situation or damage to the machine or to the work in progress. For this purpose, a device operating exclusively as a function of time is not permitted.

Control circuits shall be so arranged that rotation of a motor shaft, for example by applying a manual force or any other force causing the shaft to rotate after it has stopped, shall not result in a hazardous situation.

9.3.6 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), the control or operating mode selector shall simultaneously:

- disable all other operating (control) modes;
- permit operation only by the use of a hold-to-run device or by a similar control device positioned so as to permit sight of the hazardous elements;
- permit operation of the hazardous elements only in reduced risk conditions (e.g. reduced speed, reduced power / force, step-by-step operation, e.g. with a limited movement control device);
- prevent any operation of hazardous functions by voluntary or involuntary action on the machine's sensors.

If these four conditions cannot be fulfilled simultaneously, the control or operating mode selector shall activate other protective measures designed and constructed to ensure a safe intervention zone. In addition, the operator shall be able to control operation of the parts he is working on from the adjustment point.

9.4 Control functions in the event of failure

9.4.1 General requirements

Where failures or disturbances in the electrical equipment can cause a hazardous situation or damage to the machine or to the work in progress, appropriate measures shall be taken to minimize the probability of the occurrence of such failures or disturbances. The required measures and the extent to which they are implemented, either individually or in combination, depend on the level of risk associated with the respective application (see 4.1).

Examples of such measures that can be appropriate include but are not limited to:

- protective interlocking of the electrical circuit;
- use of proven circuit techniques and components (see 9.4.2.2);
- provision of partial or complete redundancy (see 9.4.2.3) or diversity (see 9.4.2.4);
- provision for functional tests (see 9.4.2.5).

The electrical control system(s) shall have an appropriate performance that has been determined from the risk assessment of the machine.

The requirements for safety-related control functions of IEC 62061 and/or ISO 13849-1, ISO 13849-2 shall apply.

Where functions performed by the electrical control system(s) have safety implications but application of IEC 62061 leads to a required safety integrity less than that required by SIL 1, compliance with the requirements of this part of IEC 60204 can lead to an adequate performance of the electrical control system(s).

Where memory retention is achieved for example, by battery power, measures shall be taken to prevent hazardous situations arising from failure, undervoltage or removal of the battery.

Means shall be provided to prevent unauthorized or inadvertent memory alteration by, for example, requiring the use of a key, access code or tool.

9.4.2 Measures to minimize risk in the event of failure

9.4.2.1 General

Measures to minimize risk in the event of failure include but are not limited to:

- use of proven circuit techniques and components;
- provisions of partial or complete redundancy;
- provision of diversity;
- provision for functional tests.

9.4.2.2 Use of proven circuit techniques and components

These measures include but are not limited to:

- bonding of control circuits to the protective bonding circuit for functional purposes (see 9.4.3.1.1 and Figure 4);
- connection of control devices in accordance with 9.4.3.1.1;
- stopping by de-energizing;
- the switching of all control circuit conductors (for example both sides of a coil) of the device being controlled;
- switching devices having direct opening action (see IEC 60947-5-1);
- monitoring by:
  - use of mechanically linked contacts (see IEC 60947-5-1);
  - use of mirror contacts (see IEC 60947-4-1);
- circuit design to reduce the possibility of failures causing undesirable operations.

9.4.2.3 Provisions of partial or complete redundancy

By providing partial or complete redundancy, it is possible to minimize the probability that one single failure in the electrical circuit can result in a hazardous situation. Redundancy can be effective in normal operation (on-line redundancy) or designed as special circuits that take over the protective function (off-line redundancy) only where the operating function fails.

Where off-line redundancy which is not active during normal operation is provided, suitable measures shall be taken to ensure that those control circuits are available when required.

9.4.2.4 Provision of diversity

The use of control circuits having different principles of operation, or using different types of components or devices can reduce the probability of hazards resulting from faults and/or failures. Examples include:

– the use of a combination of normally open and normally closed contacts;

– the use of different types of control devices in the circuit(s);

– the combination of electromechanical and electronic equipment in redundant configurations.

The combination of electrical and non-electrical systems (for example mechanical, hydraulic, pneumatic) may perform the redundant function and provide the diversity.

9.4.2.5 Provision for functional tests

Functional tests may be carried out automatically by the control system, or manually by inspection or tests at start-up and at predetermined intervals, or a combination as appropriate (see also 17.2 and 18.6).

9.4.3 Protection against malfunction of control circuits

9.4.3.1 Insulation faults

9.4.3.1.1 General

Measures shall be provided to reduce the probability that insulation faults on any control circuit can cause malfunction such as unintentional starting, potentially hazardous motions, or prevent stopping of the machine.

The measures to meet the requirements include but are not limited to the following methods:

– method a) Earthed control circuits fed by transformers;

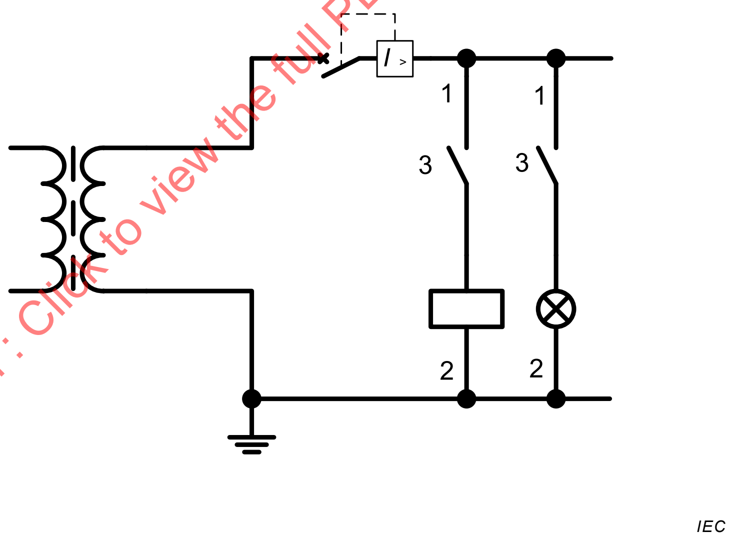
– method b) Non-earthed control circuits fed by transformers;

– method c) Control circuits fed by transformer with an earthed centre-tap winding;

– method d) Control circuits not fed by a transformer.

9.4.3.1.2 Method a) – Earthed control circuits fed by transformers

The common conductor shall be connected to the protective bonding circuit at the point of supply. All contacts, solid state elements, etc., which are intended to operate an electromagnetic or other device (for example, a relay, indicator light) are to be inserted between the switched conductor of the control circuit supply and one terminal of the coil or device. The other terminal of the coil or device is connected directly to the common conductor of the control circuit supply without any switching elements (see Figure 7).



1	Switched conductors
2	Common conductors
3	Control switches

Figure 7 – Method a) Earthed control circuit fed by a transformer

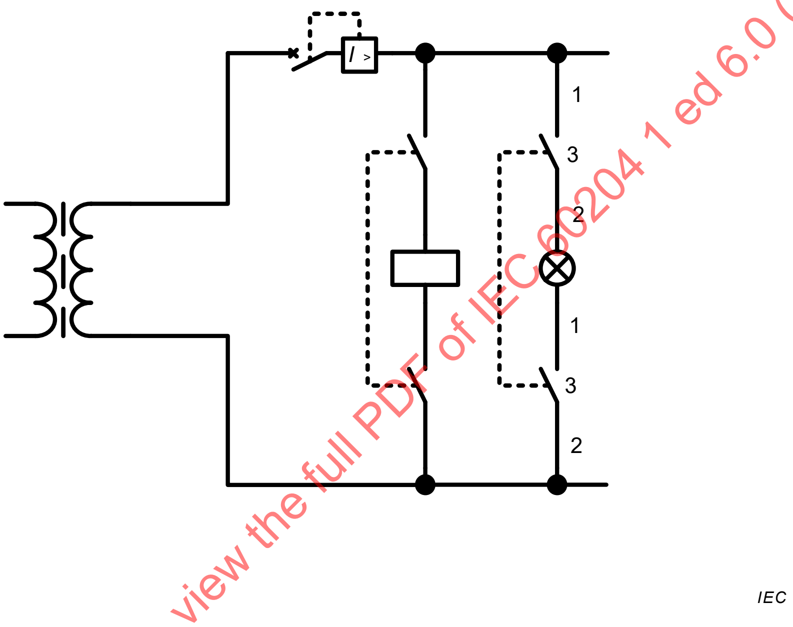
NOTE Method a) can be used also for DC control circuits. In this case the transformer shown in Figure 7 is substituted by a DC power supply unit.

Exception: Contacts of protective devices may be connected between the common conductor and the coils, provided that the connection is very short (for example in the same enclosure) so that an earth fault is unlikely (for example overload relays directly fitted to contactors).

9.4.3.1.3 Method b) – Non-earthed control circuits fed by transformers

Control circuits fed from a control transformer that is not connected to the protective bonding circuit shall either:

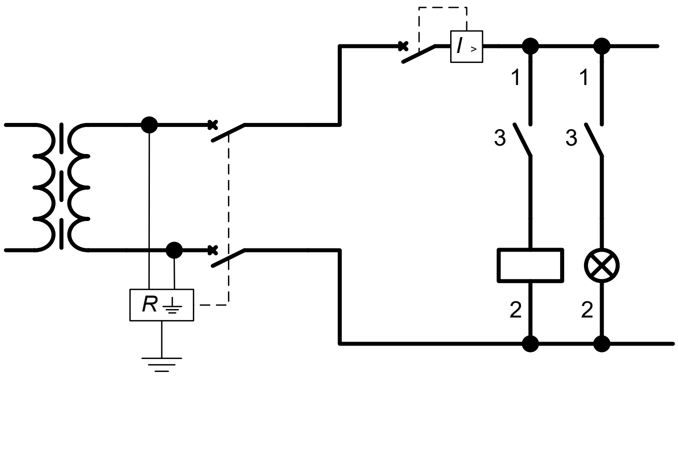
1) have 2-pole control switches that operate on both conductors, see Figure 8; or
2) be provided with a device, for example an insulation monitoring device, that interrupts the circuit automatically in the event of an earth fault, see Figure 9; or
3) where an interruption as per item 2 above would increase the risk, for example when continued operation is required during the first fault to earth, it can be sufficient to provide an insulation monitoring device (e.g. in accordance with IEC 61557-8) that will initiate an acoustic and optical signal at the machine, see Figure 10. Requirements for the procedure to be performed by the machine user in response to this alarm shall be described in the information for use.



1	Switched conductors
2	Common conductors
3	Control switches

Figure 8 – Method b1) Non-earthed control circuit fed by transformer

NOTE 1 Method b1) can be used also for DC control circuits. In this case the transformer shown in Figure 8 is substituted by a DC power supply.

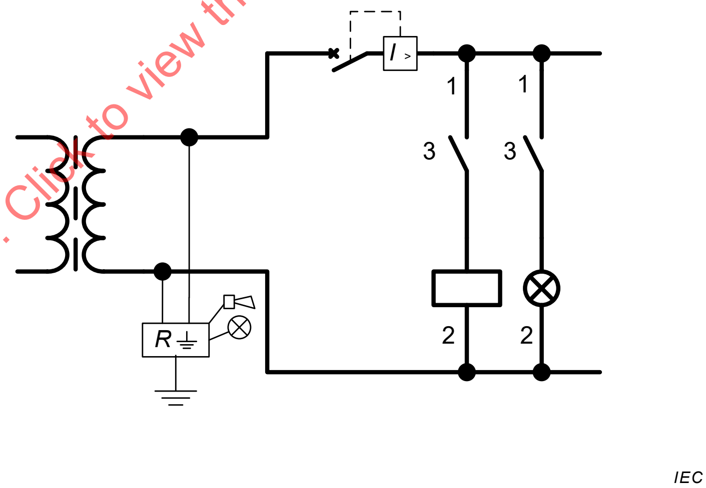


1	Switched conductors
2	Common conductors
3	Control switches

Figure 9 – Method b2) Non-earthed control circuit fed by transformer

NOTE 2 Method b2) can be used also for DC control circuits. In this case the transformer shown in Figure 9 is substituted by a DC power supply.

NOTE 3 Figure 9 does not show the overcurrent protective devices in the measurement circuits for protection of the insulation monitoring device.



1	Switched conductors
2	Common conductors
3	Control switches

Figure 10 – Method b3) Non-earthed control circuit fed by transformer

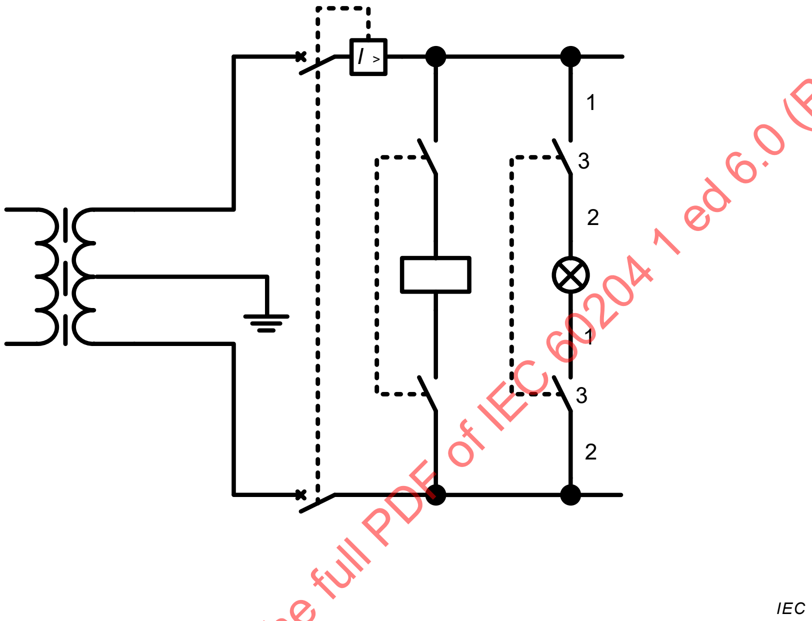
NOTE 4 Method b3) can be used also for DC control circuits. In this case the transformer shown in Figure 10 is substituted by a DC power supply. When a transformer and rectifier combination is used, the insulation monitoring device is connected to the protective bonding circuit in the DC part of the control circuit, so after the rectifier.

NOTE 5 Figure 10 does not show the overcurrent protective devices in the measurement circuits for protection of the insulation monitoring device.

9.4.3.1.4 Method c) – Control circuits fed by transformer with an earthed centre-tap winding

Control circuits fed from a control transformer with its centre-tap winding connected to the protective bonding circuit shall have overcurrent protective devices that break both the conductors.

The control switches shall be 2-pole types that operate on both conductors.



1	Switched conductors
2	Common conductors
3	Control switches

Figure 11 – Method c) Control circuits fed by transformer with an earthed centre-tap winding

9.4.3.1.5 Method d) – Control circuits not fed by a transformer

Control circuits that are not fed by a control transformer or switch mode power supply units fitted with transformers having separate windings in accordance with IEC 61558-2-16 are only allowed for machines with a maximum of one motor starter and/or maximum of two control devices, in accordance with 9.1.1.

Depending on the earthing of the supply system the possible cases are:

1) directly connected to an earthed supply system (TN- or TT-system) and:
   a) being powered between a line conductor and the neutral conductor, see Figure 12; or
   b) being powered between two line conductors, see Figure 13; or
2) directly connected to a supply system that is not earthed or is earthed through a high impedance (IT-system) and:
   a) being powered between a line conductor and the neutral conductor, see Figure 14; or
   b) being powered between two line conductors, see Figure 15.

Method d1b) requires multi-pole control switches that switch all live conductors in order to avoid an unintentional start in case of an earth fault in the control circuit.

Method d2) requires that a device shall be provided that interrupts the circuit automatically in the event of an earth fault.

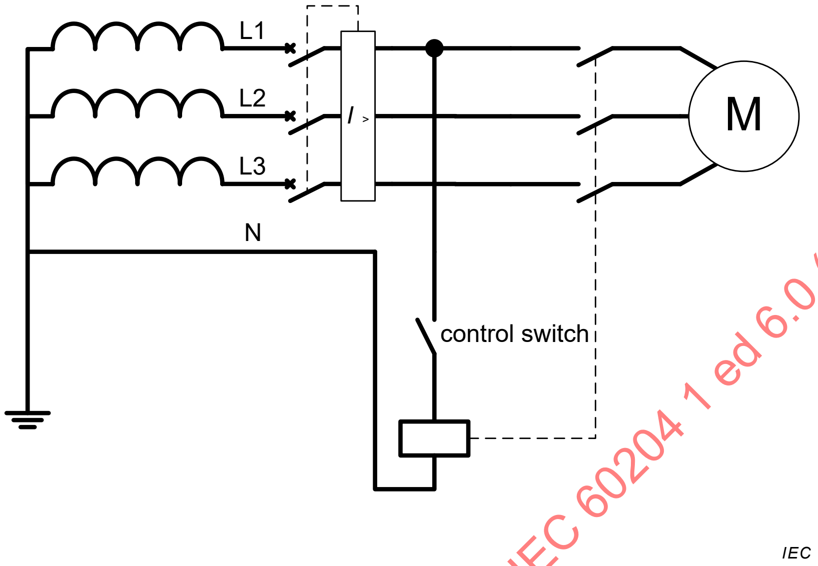


Figure 12 – Method d1a) Control circuit without transformer connected between a phase and the neutral of an earthed supply system

NOTE 1 Figure 12 shows the case where the supply system is a TN system. The control circuit is the same in the case of a TT system.

NOTE 2 Figure 12 does not show any protective devices for the power circuit and control circuit, provisions for which are stated in 6.3 and 7.2.

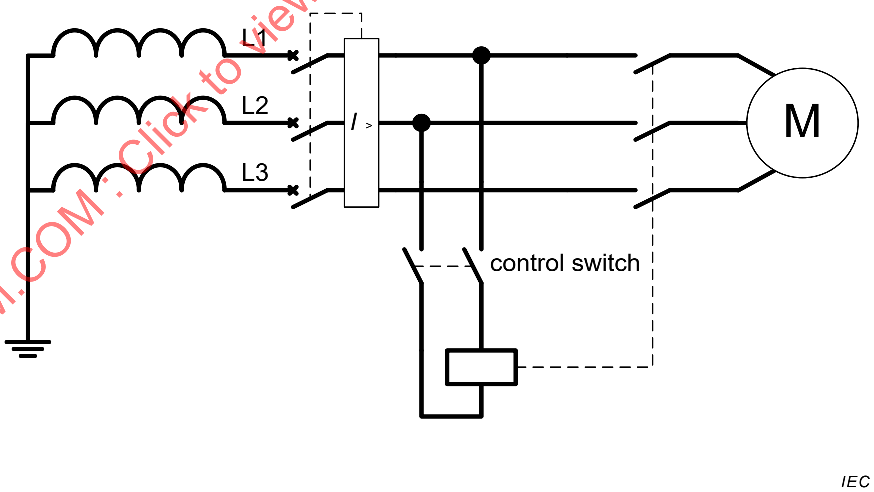


Figure 13 – Method d1b) Control circuit without transformer connected between two phases of an earthed supply system

NOTE 3 Figure 13 shows the case where the supply system is a TN system. The control circuit is the same in case of a TT system.

NOTE 4 Figure 13 does not show any necessary protective devices for power circuit and control circuit, provisions for which are stated in 6.3 and 7.2.

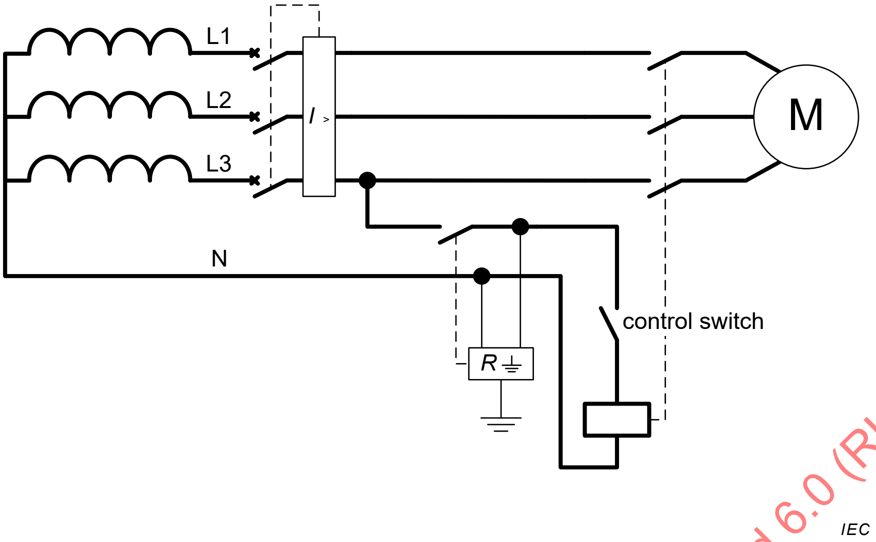


Figure 14 – Method d2a) Control circuit without transformer connected between phase and neutral of a non-earthed supply system

NOTE 5 Figure 14 does not show any necessary protective devices for the power circuit and control circuit, provisions for which are stated in 6.3 and 7.2.

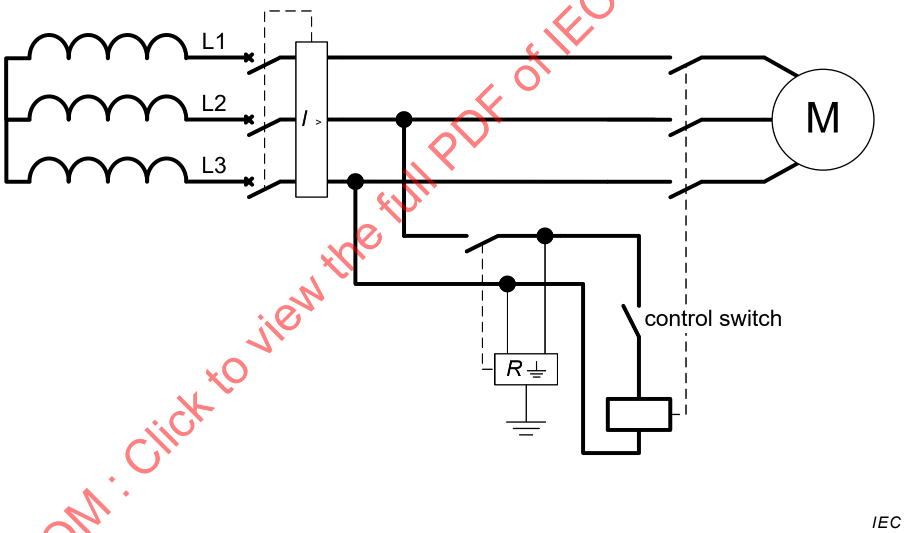


Figure 15 – Method d2b) control circuit without transformer connected between two phases of a non-earthed supply system

NOTE 6 Figure 15 does not show any necessary protective devices for power circuit and control circuit, provisions for which are stated in 6.3 and 7.2.

9.4.3.2 Voltage interruptions

See also 7.5.

Where the control system uses a memory device(s), proper functioning in the event of power failure shall be ensured (for example by using a non-volatile memory) to prevent any loss of memory that can result in a hazardous situation.

9.4.3.3 Loss of circuit continuity

Where the loss of continuity of control circuits depending upon sliding contacts can result in a hazardous situation, appropriate measures shall be taken (for example by duplication of the sliding contacts).

10 Operator interface and machine-mounted control devices

10.1 General

10.1.1 General requirements

Control devices for operator interface shall, as far as is practicable, be selected, mounted, and identified or coded in accordance with IEC 61310 series.

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 machine operations, and of sensors (for example position sensors) that can initiate machine operation. Further information can be found in IEC 60447.

Ergonomic principles shall be taken into account in the location of operator interface devices.

10.1.2 Location and mounting

As far as is practicable, machine-mounted control devices shall be:

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

The actuators of hand-operated control devices shall be selected and 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;
- the operator is not placed in a hazardous situation when operating them.

The actuators of foot-operated control devices shall be selected and installed so that:

- they are within easy reach of the normal working position of the operator;
- the operator is not placed in a hazardous situation when operating them.

10.1.3 Protection

The degree of protection (IP rating in accordance with IEC 60529) together with other appropriate measures shall provide protection against:

- the effects of liquids, vapours, or gases found in the physical environment or used on the machine;
- the ingress of contaminants (for example swarf, dust, particulate matter).

In addition, the operator interface control devices shall have a minimum degree of protection against contact with live parts of IPXXD in accordance with IEC 60529.

10.1.4 Position sensors

Position sensors (for example position switches, proximity switches) shall be so arranged that they will not be damaged in the event of overtravel.

Position sensors in circuits with safety-related control functions (for example, to maintain the safe condition of the machine or prevent hazardous situations arising at the machine) shall have direct opening action (see IEC 60947-5-1) or shall provide similar reliability (see 9.4.2).

10.1.5 Portable and pendant control stations

Portable and pendant operator control stations and their control devices shall be so selected and arranged as to minimize the possibility of machine operations caused by inadvertent actuation, shocks and vibrations (for example if the operator control station is dropped or strikes an obstruction) (see also 4.4.8).

10.2 Actuators

10.2.1 Colours

Actuators (see 3.1.1) shall be colour-coded as follows.

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 switching off actuators (including supply disconnecting devices where it is foreseen that they are for use in an emergency). If a background exists immediately around the actuator, then this background shall be coloured YELLOW. The combination of a RED actuator with a YELLOW background shall only be used for emergency operation devices.

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 actuators that alternately act as START/ON and STOP/OFF actuators. The colours RED, YELLOW, or GREEN shall not be used.

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

The colour YELLOW is reserved for use in abnormal conditions, for example, in the event of an abnormal condition of the process, or to interrupt an automatic cycle.

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 actuators.

10.2.2 Markings

In addition to the functional identification as described in 16.3, recommended symbols to be placed near to or preferably directly on certain actuators are given in Table 2 or 3.

Table 2 – Symbols for actuators (Power)

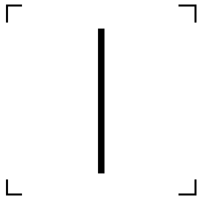
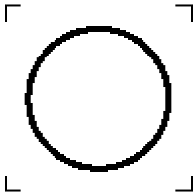
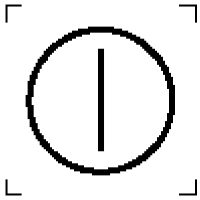
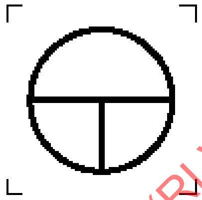
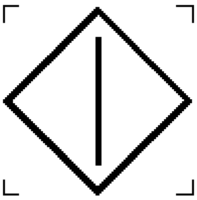
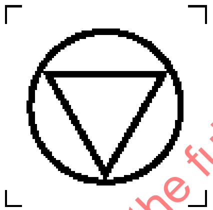
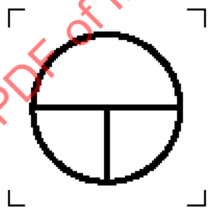
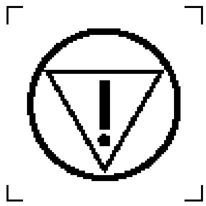
Power			
ON	OFF	ON/OFF (push on-push off)	ON (hold-to-run)
IEC 60417-5007 (2002-10)	IEC 60417-5008 (2002-10)	IEC 60417-5010 (2002-10)	IEC 60417-5011 (2002-10)
			

Table 3 – Symbols for actuators (Machine operation)

Machine operation			
START	STOP	HOLD-TO-RUN	EMERGENCY STOP
IEC 60417-5104 (2006-08)	IEC 60417-5110A (2004-06)	IEC 60417-5011 (2002-10)	IEC 60417-5638 (2002-10)
			

10.3 Indicator lights and displays

10.3.1 General

Indicator lights and displays serve to give the following types of information:

– indication: to attract the operator's 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 and displays shall be selected and installed in such a manner as to be visible from the normal position of the operator (see also IEC 61310-1).

Circuits used for visual or audible devices used to warn persons of an impending hazardous event shall be fitted with facilities to check the operability of these devices.

10.3.2 Colours

Indicator lights should be colour-coded with respect to the condition (status) of the machine in accordance with Table 4.

Table 4 – Colours for indicator lights and their meanings with respect to the condition of the machine

Colour	Meaning	Explanation	Action by operator
RED	Emergency	Hazardous condition	Immediate action to deal with hazardous condition (for example switching off the machine supply, being alert to the hazardous condition and staying clear of the machine)
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

Indicating towers on machines should have the applicable colours in the following order from the top down; RED, YELLOW, BLUE, GREEN and WHITE.

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 flashing frequencies are 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, additional acoustic warnings should be considered.

10.4 Illuminated push-buttons

Illuminated push-button actuators shall be colour-coded in accordance with 10.2.1. Where there is difficulty in assigning an appropriate colour, WHITE shall be used.

The colour of active emergency stop actuators shall remain RED regardless of the state of the illumination.

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 machine elements (for example slides, spindles, carriers) shall be constructed and mounted so as to minimize inadvertent operation.

10.7 Emergency stop devices

10.7.1 Location of emergency stop devices

Devices for emergency stop shall be readily accessible.

Emergency stop devices shall be provided at each location where the initiation of an emergency stop can be required.

There can be circumstances where confusion can occur between active and inactive emergency stop devices caused by, for example, unplugging or otherwise disabling an operator control station. In such cases, means (for example, design and information for use) shall be provided to minimise confusion.

10.7.2 Types of emergency stop device

The types of device for emergency stop include, but are not limited to:

- a push-button device for actuation by the palm or the fist (e.g. mushroom head type);
- a pull-cord operated switch;
- a pedal-operated switch without a mechanical guard.

The devices shall be in accordance with IEC 60947-5-5.

10.7.3 Operation of the supply disconnecting device to effect emergency stop

Where a stop category 0 is suitable, the supply disconnecting device may serve the function of emergency stop where:

- it is readily accessible to the operator; and
- it is of the type described in 5.3.2 a), b), c), or d).

Where intended for emergency use, the supply disconnecting device shall meet the colour requirements of 10.2.1.

10.8 Emergency switching off devices

10.8.1 Location of emergency switching off devices

Emergency switching off devices shall be located as necessary for the given application. Normally, those devices will be located separate from operator control stations. Where confusion can occur between emergency stop and emergency switching off devices, means shall be provided to minimise confusion.

NOTE This can be achieved by, for example, the provision of a break-glass enclosure for the emergency switching off device.

10.8.2 Types of emergency switching off device

The types of device for initiation of emergency switching off include:

- a push-button operated switch with a palm or mushroom head type of actuator;
- a pull-cord operated switch.

The devices shall have direct opening action (see Annex K of IEC 60947-5-1:2003 and IEC 60947-5-1:2003/AMD1:2009).

10.8.3 Local operation of the supply disconnecting device to effect emergency switching off

Where the supply disconnecting device is to be locally operated for emergency switching off, it shall be readily accessible and shall meet the colour requirements of 10.2.1.

10.9 Enabling control device

The enabling control function is described in 9.2.3.9.

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:

– designed in accordance with ergonomic principles;
– 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 IEC 60947-5-8 specifies requirements for three-position enabling switches.

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 machine and its associated equipment.

11.2 Location and mounting

11.2.1 Accessibility and maintenance

All items of controlgear shall be placed and oriented so that they can be identified without moving them or the wiring. For items that require checking for correct operation or that are liable to need replacement, those actions should be possible without dismantling other equipment or parts of the machine (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. 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.

No devices except devices for operating, indicating, measuring, and cooling shall be mounted on doors or on access covers of enclosures that are expected to be removed.

Where control devices are connected through plug-in arrangements, their association shall be made clear by type (shape), marking or reference designation, singly or in combination (see 13.4.5).

Plug-in devices that are handled during normal operation shall be provided with non-interchangeable features where the lack of such a facility can result in malfunctioning.

Plug/socket combinations that are handled during normal operation shall be located and mounted so as to provide unobstructed access.

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;
– adequately insulated;
– sufficiently spaced.

11.2.2 Physical separation or grouping

Non-electrical parts and devices, not directly associated with the electrical equipment, shall not be located within enclosures containing controlgear. Devices such as solenoid valves should be separated from the other electrical equipment (for example in a separate compartment).

Control devices mounted in the same location and connected to the power circuits, or to both power and control circuits, should be grouped separately from those connected only to the control circuits.

Terminals shall be separated into groups for:

– power circuits;
– control circuits of the machine;
– other control circuits, fed from external sources (for example for interlocking).

The groups may be mounted adjacently, provided that each group can be readily identified (for example by markings, by use of different sizes, by use of barriers or by colours).

When arranging the location of devices (including interconnections), the clearances and creepage distances specified for them by the supplier shall be maintained, taking into account the external influences or conditions of the physical environment.

11.2.3 Heating effects

The temperature rise inside electrical equipment enclosures shall not exceed the ambient temperature specified by the component manufacturers.

NOTE 1 IEC TR 60890 can be used for the calculation of temperature rise inside enclosures.

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

NOTE 2 Information on the selection of insulating materials to resist thermal stresses is given in IEC 60216 and IEC 60085.

11.3 Degrees of protection

The protection of controlgear against ingress of solid foreign objects and of liquids shall be adequate taking into account the external influences under which the machine is intended to operate (i.e. the location and the physical environmental conditions) and shall be sufficient against dust, coolants, lubricants and swarf.

NOTE 1 The degrees of protection against ingress of water are covered by IEC 60529. Additional protective measures can be necessary against other liquids.

Enclosures of controlgear shall provide a degree of protection of at least IP22 (see IEC 60529).

Exception: an enclosure providing a minimum degree of protection IP22 is not required where:

a) an electrical operating area provides an appropriate degree of protection against ingress of solids and liquids, or:

b) removable collectors on conductor wire or conductor bar systems are used and the measures of 12.7.1 are applied.

NOTE 2 Some examples of applications, along with the degree of protection typically provided by their enclosures, are listed below:

– ventilated enclosure, containing only motor starter resistor and other large size equipment	IP10
– ventilated enclosure, containing other equipment	IP32
– enclosure used in general industry	IP32, IP43 and IP54
– enclosure used in locations that are cleaned with low-pressure water jets (hosing)	IP55
– enclosure providing protection against fine dust	IP65
– enclosure containing slip-ring assemblies	IP2X

Depending upon the conditions where installed, another degree of protection can be appropriate.

11.4 Enclosures, doors and openings

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

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

Windows of enclosures shall be of a material suitable to withstand expected mechanical stress and chemical attack.

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

The joints or gaskets of doors, lids, covers and enclosures shall withstand the chemical effects of the aggressive liquids, vapours, or gases used on the machine. The means provided to maintain the degree of protection of an enclosure on doors, lids and covers that require opening or removal for operation or maintenance shall:

- be securely attached to either the door/cover or the enclosure;
- not deteriorate due to removal or replacement of the door or the cover, and so impair the degree of protection.

Where openings in enclosures are provided (for example, for cable access), including those towards the floor or foundation or to other parts of the machine, means shall be provided to ensure the degree of protection specified for the equipment. Openings for cable entries shall be easy to re-open on site. A suitable opening may be provided in the base of enclosures within the machine so that moisture due to condensation can drain away.

There shall be no opening between enclosures containing electrical equipment and compartments containing coolant, lubricating or hydraulic fluids, or those into which oil, other liquids, or dust can penetrate. This requirement does not apply to electrical devices specifically designed to operate in oil (for example electromagnetic clutches) nor to electrical equipment in which coolants are used.

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

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
– 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
– 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 16.2.2 can be necessary.

11.5 Access to electrical equipment

Doors in gangways and for access to electrical operating areas shall:

– be at least 0,7 m wide and 2,0 m high;
– open outwards;
– have a means (for example panic bolts) to allow opening from the inside without the use of a key or tool.

NOTE Further information is given in IEC 60364-7-729.

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.

These requirements do not apply to the integral wiring of assemblies, subassemblies, and devices that are manufactured and tested in accordance with their relevant IEC standard (for example IEC 61800 series).

12.2 Conductors

Conductors should be of copper. Where aluminium conductors are used, the cross-sectional area shall be at least 16 mm^2.

To ensure adequate mechanical strength, the cross-sectional area of conductors should not be less than as shown in Table 5. However, conductors with smaller cross-sectional areas or other constructions than shown in Table 5 may be used in equipment provided adequate mechanical strength is achieved by other means and proper functioning is not impaired.

NOTE Classification of conductors is given in Table D.4.

Table 5 – Minimum cross-sectional areas of copper conductors

Location	Application	Type of conductor, cable				
		Single core		Multicore		
		Flexible Class 5 or 6	Solid (class 1) or stranded (class 2)	Two core, shielded	Two core not shielded	Three or more cores, shielded or not
Wiring outside (protecting) enclosures	Power circuits, fixed	1,0	1,5	0,75	0,75	0,75
	Power circuits, subjected to frequent movements	1,0	–	0,75	0,75	0,75
	Control circuits	1,0	1,0	0,2	0,5	0,2
	Data communication	–	–	–	–	0,08
Wiring inside enclosures a)	Power circuits (connections not moved)	0,75	0,75	0,75	0,75	0,75
	Control circuits	0,2	0,2	0,2	0,2	0,2
	Data communication	–	–	–	–	0,08

NOTE All cross-sections in mm^2.

a) Except special requirements of individual standards, see also 12.1.

Class 1 and class 2 conductors are primarily intended for use between rigid, non-moving parts where vibration is not considered to be likely to cause damage.

All conductors that are subject to frequent movement (for example one movement per hour of machine operation) should have flexible stranding of class 5 or class 6.

12.3 Insulation

Where the insulation of conductors and cables can constitute hazards due for example to the propagation of a fire or the emission of toxic or corrosive fumes, guidance from the cable supplier should be sought. It is important to give special attention to the integrity of a circuit having a safety-related function.

The insulation of cables and conductors used, shall be suitable for a test voltage:

– not less than 2 000 V AC for a duration of 5 min for operation at voltages higher than 50 V AC or 120 V DC, or
– not less than 500 V AC for a duration of 5 min for PELV circuits (see IEC 60364-4-41, class III equipment).

The mechanical strength and thickness of the insulation shall be such that the insulation cannot be damaged in operation or during laying, especially for cables pulled into ducts.

12.4 Current-carrying capacity in normal service

The current-carrying capacity depends on several factors, for example insulation material, number of conductors in a cable, design (sheath), methods of installation, grouping and ambient temperature.

NOTE 1 Detailed information and further guidance can be found in IEC 60364-5-52, in some national standards or given by the manufacturer.

One typical example of the current-carrying capacities for PVC insulated wiring between enclosures and individual items of equipment under steady-state conditions is given in Table 6.

NOTE 2 For specific applications where the correct cable dimensioning can depend on the relationship between the period of the duty cycle and the thermal time constant of the cable (for example starting against high-inertia load, intermittent duty), the cable manufacturer can provide information.

Table 6 – Examples of current-carrying capacity (I_Z) of PVC insulated copper conductors or cables under steady-state conditions in an ambient air temperature of +40 °C for different methods of installation

	Installation method (see D.2.2)			
	B1	**B2**	**C**	**E**
Cross-sectional area mm^2	**Current-carrying capacity I_z for three phase circuits** A			
0,75	8,6	8,5	9,8	10,4
1,0	10,3	10,1	11,7	12,4
1,5	13,5	13,1	15,2	16,1
2,5	18,3	17,4	21	22
4	24	23	28	30
6	31	30	36	37
10	44	40	50	52
16	59	54	66	70
25	77	70	84	88
35	96	86	104	110
50	117	103	125	133
70	149	130	160	171
95	180	156	194	207
120	208	179	225	240
	Control circuit pairs			
0,20	4,5	4,3	4,4	4,4
0,5	7,9	7,5	7,5	7,8
0,75	9,5	9,0	9,5	10

NOTE 1 The values of the current-carrying capacity of Table 6 are based on:

– one symmetrical three-phase circuit for cross-sectional areas 0,75 mm^2 and greater;

– one control circuit pair for cross-sectional areas between 0,2 mm^2 and 0,75 mm^2.

Where more loaded cables/pairs are installed, derating factors for the values of Table 6 can be found in Tables D.2 or D.3.

NOTE 2 For ambient temperatures other than 40 °C, correction factors for current-carrying capacities are provided in Table D.1.

NOTE 3 These values are not applicable to flexible cables wound on drums (see 12.6.3).

NOTE 4 Current-carrying capacities of other cables are provided in IEC 60364-5-52.

12.5 Conductor and cable voltage drop

The voltage drop from the point of supply to the load in any power circuit cable shall not exceed 5 % of the nominal voltage under normal operating conditions. In order to conform to this requirement, it can be necessary to use conductors having a larger cross-sectional area than that derived from Table 6.

In control circuits, the voltage drop shall not reduce the voltage at any device below the manufacturer's specification for that device, taking into account inrush currents.

See also 4.3.

The voltage drop in components, for example overcurrent protective devices and switching devices, should be considered.

12.6 Flexible cables

12.6.1 General

Flexible cables shall have Class 5 or Class 6 conductors.

NOTE 1 Class 6 conductors have smaller diameter strands and are more flexible than Class 5 conductors (see Table D.4).

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

– 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 2 Cables for such conditions are specified in some national standards.

NOTE 3 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.

12.6.2 Mechanical rating

The cable handling system of the machine shall be so designed to keep the tensile stress of the conductors as low as is practicable during machine operations. 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.

12.6.3 Current-carrying capacity of cables wound on drums

Cables to be wound on drums shall be selected with conductors having a cross-sectional area such that, when fully wound on the drum and carrying the normal service load, the maximum allowable conductor temperature is not exceeded.

For cables of circular cross-sectional area installed on drums, the maximum current-carrying capacity in free air should be derated in accordance with Table 7

NOTE The current-carrying capacity of cables in free air can be found in manufacturers' specifications or in relevant national standards.

Table 7 – Derating factors for cables wound on drums

Drum type	Number of layers of cable				
	Any number	**1**	**2**	**3**	**4**
Cylindrical ventilated	–	0,85	0,65	0,45	0,35
Radial ventilated	0,85	–	–	–	–
Radial non-ventilated	0,75	–	–	–	–

It is recommended that the use of derating factors be discussed with the cable and the cable drum manufacturers. This may result in other factors being used.

NOTE 1 A radial type drum is one where spiral layers of cable are accommodated between closely spaced flanges; if fitted with solid flanges, the drum is described as non-ventilated and if the flanges have suitable apertures, as ventilated.

NOTE 2 A ventilated cylinder drum is one where the layers of cable are accommodated between widely spaced flanges and the drum and end flanges have ventilating apertures.

12.7 Conductor wires, conductor bars and slip-ring assemblies

12.7.1 Basic protection

Conductor wires, conductor bars and slip-ring assemblies shall be installed or enclosed in such a way that, during normal access to the machine, basic protection is achieved by the application of one of the following protective measures:

– protection by partial insulation of live parts, or where this is not practicable;
– protection by enclosures or barriers of at least IP2X or IPXXB.

Horizontal top surfaces of barriers or enclosures that are readily accessible shall provide a degree of protection of at least IP4X or IPXXD.

Where the required degree of protection is not achieved, protection by placing live parts out of reach in combination with emergency switching off in accordance with 9.2.3.4.3 shall be applied.

Conductor wires and conductor bars shall be so placed and/or protected as to:

– prevent contact, especially for unprotected conductor wires and conductor bars, with conductive items such as the cords of pull-cord switches, strain-relief devices and drive chains;
– prevent damage from a swinging load.

See also 6.2.6.

12.7.2 Protective conductors

Where conductor wires, conductor bars and slip-ring assemblies are installed as part of the protective bonding circuit, they shall not carry current in normal operation. Therefore, the protective conductor (PE) and the neutral conductor (N) shall each use a separate conductor wire, conductor bar or slip-ring.

The continuity of protective conductors using sliding contacts shall be ensured by taking appropriate measures (for example, duplication of the current collector, continuity monitoring).

12.7.3 Protective conductor current collectors

Protective conductor current collectors shall have a shape or construction so that they are not interchangeable with the other current collectors. Such current collectors shall be of the sliding contact type.

12.7.4 Removable current collectors with a disconnector function

Removable current collectors having a disconnector function shall be so designed that the protective conductor circuit is interrupted only after the live conductors have been disconnected, and the continuity of the protective conductor circuit is re-established before any live conductor is reconnected (see also 8.2.3).

12.7.5 Clearances in air

Clearances between the respective conductors, and between adjacent systems, of conductor wires, conductor bars, slip-ring assemblies and their current collectors shall be suitable for at least a rated impulse voltage of an overvoltage category III in accordance with IEC 60664-1.

12.7.6 Creepage distances

Creepage distances between the respective conductors, between adjacent systems of conductor wires, conductor bars and slip-ring assemblies, and their current collectors shall be suitable for operation in the intended environment, for example open air, inside buildings, protected by enclosures.

In abnormally dusty, moist or corrosive environments, the following creepage distance requirements apply:

– unprotected conductor wires, conductor bars, and slip-ring assemblies shall be equipped with insulators with a minimum creepage distance of 60 mm;
– enclosed conductor wires, insulated multipole conductor bars and insulated individual conductor bars shall have a minimum creepage distance of 30 mm.

The manufacturer's recommendations shall be followed regarding special measures to prevent a gradual reduction in the insulation values due to unfavourable ambient conditions (for example deposits of conductive dust, chemical attack).

12.7.7 Conductor system sectioning

Where conductor wires or conductor bars are arranged so that they can be divided into isolated sections, suitable design measures shall be employed to prevent the energization of adjacent sections by the current collectors themselves.

12.7.8 Construction and installation of conductor wire, conductor bar systems and slip-ring assemblies

Conductor wires, conductor bars and slip-ring assemblies in power circuits shall be grouped separately from those in control circuits.

Conductor wires, conductor bars and slip-ring assemblies, including their current collectors, shall be capable of withstanding, without damage, the mechanical forces and thermal effects of short-circuit currents.

Removable covers for conductor wire and conductor bar systems laid underground or underfloor shall be so designed that they cannot be opened by one person without the aid of a tool.

Where conductor bars are installed in a common metal enclosure, the individual sections of the enclosure shall be bonded together and connected to the protective bonding circuit. Metal covers of conductor bars laid underground or underfloor shall also be bonded together and connected to the protective bonding circuit.

The protective bonding circuit shall include the covers or cover plates of metal enclosures or underfloor ducts. Where metal hinges form a part of the protective bonding circuit, their continuity shall be verified (see Clause 18).

Conductor bar ducts that can be subject to accumulation of liquid such as oil or water shall have drainage facilities.

13 Wiring practices

13.1 Connections and routing

13.1.1 General requirements

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 nature of the conductors being terminated.

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

Soldered connections shall only be permitted where terminals are provided that are suitable for soldering.

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

NOTE IEC 61666 provides rules that can be used for the designation of terminals within the electrical equipment.

Where an incorrect electrical connection (for example, arising from replacement of devices) is identified as a source of risk that needs to be reduced and it is not practicable to reduce the possibility of incorrect connection by design measures, the conductors and/or terminations shall be identified.

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

Means of retaining conductor strands 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.

Shielded conductors shall be so terminated as to prevent fraying of strands and to permit easy disconnection.

Identification tags shall be legible, permanent, and appropriate for the physical environment.

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

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 splices or joints for the purpose of 13.1.2.

Exception: Where it is impracticable to provide terminals in a junction box (for example on mobile machines, on machines having long flexible cables; cable connections exceeding a length which is not practical to be supplied by the cable manufacturer on one cable drum), splices or joints may be used.

Where it is necessary to connect and disconnect cables and cable assemblies, 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 or in the same plug/socket combination provided that the arrangement does not impair the proper functioning of the respective circuits and:

- where those circuits operate at different voltages, the conductors are separated by suitable barriers or;
- the conductors are insulated for the highest voltage to which any of the conductors can be subjected, for example line to line voltage for unearthed systems and phase to earth voltage for earthed systems.

13.1.4 AC circuits – Electromagnetic effects (prevention of eddy currents)

Conductors of AC circuits installed in ferromagnetic enclosures shall be arranged so that all conductors of each circuit, including the protective conductor of each circuit, are contained in the same enclosure. Where such conductors enter a ferrous enclosure, they shall be arranged such that the conductors are not individually surrounded by ferromagnetic material.

Single-core cables armoured with steel wire or steel tape should not be used for AC circuits.

NOTE 1 The steel wire or steel tape armour of a single-core cable is regarded as a ferromagnetic enclosure. For single-core wire armoured cables, the use of aluminium armour is recommended.

NOTE 2 Derived from IEC 60364-5-52.

13.1.5 Connection between pick-up and pick-up converter of an inductive power supply system

The cable between the pick-up and the pick-up converter shall be:

– as short as practicable;

– adequately protected against mechanical damage.

NOTE The output of the pick-up can be a current source, therefore damage to the cable can result in a high voltage hazard.

13.2 Identification of conductors

13.2.1 General requirements

Each conductor shall be identifiable at each termination in accordance with the technical documentation.

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).

NOTE 1 Annex B can be used for agreement between supplier and user regarding a preferred method of identification.

NOTE 2 IEC 62491 provides rules and guidelines for the labelling of cables and cores/conductors used in industrial installations, equipment and products.

13.2.2 Identification of the protective conductor / protective bonding conductor

The protective conductor / protective bonding conductor shall be readily distinguishable from other conductors by shape, location, marking, 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 protective conductors/protective bonding conductors.

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(s) can be easily identified by its shape, position, or construction (for example a braided conductor, uninsulated stranded conductor), or where the insulated conductor is not readily accessible or is part of a multicore cable, colour coding throughout its length is not necessary. However, where the conductor is not clearly visible throughout its length, the ends or accessible locations shall be clearly identified by the graphical symbol IEC 60417-5019:2006-08 (see Figure 16) or with the letters PE or by the bicolour combination GREEN-AND-YELLOW.

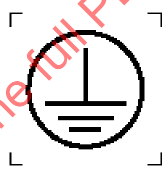


Figure 16 – Symbol IEC 60417-5019

Exception: Protective bonding conductors may be marked with the letters PB and/or the symbol IEC 60417-5021 (2002-10) (see Figure 17).

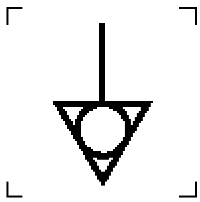


Figure 17 – Symbol IEC 60417-5021

13.2.3 Identification of the neutral conductor

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 6.2.2 of IEC 60445:2010). 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.

Where identification by colour is used, bare 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.

13.2.4 Identification by colour

Where colour-coding is used for identification of conductors (other than the protective conductor (see 13.2.2) and the neutral conductor (see 13.2.3)), the following colours may be used:

BLACK, BROWN, RED, ORANGE, YELLOW, GREEN, BLUE (including LIGHT BLUE), VIOLET, GREY, WHITE, PINK, TURQUOISE.

NOTE This list of colours is derived from IEC 60757.

It is recommended that, where colour is used for identification, 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 13.2.2).

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

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

- BLACK: AC and DC power circuits;
- RED: AC control circuits;
- BLUE: DC control circuits;
- ORANGE: excepted circuits in accordance with 5.3.5.

Exceptions to the above are permitted where insulation is not available in the colours recommended (for example in multiconductor cables).

13.3 Wiring inside enclosures

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 (see the IEC 60332 series).

It is recommended that electrical equipment mounted inside enclosures be designed and constructed in such a way as to permit modification of the wiring from the front of the 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 swingout panels shall be provided.

Connections to devices mounted on doors or to other movable parts shall be made using flexible conductors in accordance with 12.2 and 12.6 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).

Conductors and cables that do not run in ducts shall be adequately supported.

Terminal blocks or plug/socket combinations shall be used for control wiring that extends beyond the enclosure. For plug/socket combinations, see also 13.4.5 and 13.4.6.

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

13.4 Wiring outside enclosures

13.4.1 General requirements

The means of introduction of cables or ducts with their individual glands, bushings, etc., into an enclosure shall ensure that the degree of protection is not reduced (see 11.3).

Conductors of a circuit shall not be distributed over different multi-core cables, conduits, cable ducting systems or cable trunking systems. This is not required where a number of multi-core cables, forming one circuit, are installed in parallel. Where multi-core cables are installed in parallel, each cable shall contain one conductor of each phase and the neutral if any.

13.4.2 External ducts

Conductors and their connections external to the electrical equipment enclosure(s) shall be enclosed in suitable ducts (i.e. conduit or cable trunking systems) as described in 13.5 except for suitably protected cables that may be installed without ducts and with or without the use of cable trays or cable support means. Where devices such as position switches or proximity switches are supplied with a dedicated cable, their cable need not be enclosed in a duct when the cable is suitable for the purpose, sufficiently short, and so located or protected, that the risk of damage is minimized.

Fittings used with ducts or cables shall be suitable for the physical environment.

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

13.4.3 Connection to moving elements of the machine

The design of connections to moving parts shall take into account the foreseeable frequency of movement and shall be made using conductors in accordance with 12.2 and 12.6. Flexible cable and flexible conduit shall be so installed as to avoid excessive flexing and straining, particularly at the fittings.

Cables subject to movement shall be supported in such a way that there is no mechanical strain on the connection points nor any sharp flexing. When this is achieved by the provision of a loop, it shall have sufficient length to provide for a bending radius of the cable as specified by the cable manufacturer or if no such specification is given, at least 10 times the diameter of the cable.

Flexible cables of machines shall be so installed or protected as to minimize the possibility of external damage due to factors that include the following cable use or potential abuse:

– being run over by the machine itself;
– being run over by vehicles or other machines;
– coming into contact with the machine structure during movements;
– running in and out of cable baskets, or on or off cable drums;
– acceleration forces and wind forces on festoon systems or suspended cables;
– excessive rubbing by cable collector;
– exposure to excessive radiated heat.

The cable sheath shall be resistant to the normal wear that can be expected from movement and to the effects of environmental contaminants (for example oil, water, coolants, dust).

Where cables subject to movement are close to moving parts, precautions shall be taken to maintain a space of at least 25 mm between the moving parts and the cables. Where that distance is not practicable, fixed barriers shall be provided between the cables and the moving parts.

The cable handling system shall be so designed that lateral cable angles do not exceed 5°, avoiding torsion in the cable when:

– being wound on and off cable drums; and
– approaching and leaving cable guidance devices.

Measures shall be taken to ensure that at least two turns of flexible cables always remain on a drum.

Devices serving to guide and carry a flexible cable shall be so designed that the inner bending radius at all points where the cable is bent is not less than the values given in Table 8, unless otherwise agreed with the cable manufacturer, taking into account the permissible tension and the expected fatigue life.

Table 8 – Minimum permitted bending radii for the forced guiding of flexible cables

Application	Cable diameter or thickness of flat cable (d) mm		
	$d \le 8$	$8 < d \le 20$	$d > 20$
Cable drums	6 d	6 d	8 d
Guide rollers	6 d	8 d	8 d
Festoon systems	6 d	6 d	8 d
All others	6 d	6 d	8 d

The straight section between two bends shall be at least 20 times the diameter of the cable.

Where flexible conduit is adjacent to moving parts, the construction and supporting means shall prevent damage to the flexible conduit under all conditions of operation.

Flexible conduit shall not be used for connections subject to rapid or frequent movements except when specifically designed for that purpose.

13.4.4 Interconnection of devices on the machine

Where several machine-mounted devices (for example position sensors, push-buttons) are connected in series or in parallel, it is recommended that the connections between those devices be made through terminals forming intermediate test points. Such terminals shall be conveniently placed, adequately protected, and shown on the relevant diagrams.

13.4.5 Plug/socket combinations

Components or devices inside an enclosure, terminated by fixed plug/socket combinations (no flexible cable), or components connected to a bus system by a plug/socket combination, are not considered to be plug/socket combinations for the purpose of this 13.4.5.

After installation in accordance with item a) below, 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 IP2X or IPXXB. PELV circuits are excepted from this requirement.

Where the plug/socket contains a contact for the protective bonding circuit, it shall have a first make last break contact (see also 8.2.4).

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 connection and disconnection is possible only when the switching device is in the OFF position.

Plug/socket combinations that are rated at more than 16 A shall have a retaining means to prevent unintended or accidental disconnection.

Where an unintended or accidental disconnection of plug/socket combinations can cause a hazardous situation, they shall have a retaining means.

The installation of plug/socket combinations shall fulfil the following requirements as applicable:

a) 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.
b) Metallic housings of plug/socket combinations shall be connected to the protective bonding circuit.
c) Plug/socket combinations intended to carry power loads but not to be disconnected during load conditions shall have a retaining means to prevent unintended or accidental disconnection and shall be clearly marked that they are not intended to be disconnected under load.
d) Where more than one plug/socket combination is provided in the same electrical equipment, the associated combinations shall be clearly identifiable. It is recommended that mechanical coding be used to prevent incorrect insertion.
e) Plug/socket combinations used in control circuits shall fulfil the applicable requirements of IEC 61984.

Exception: In plug/socket combinations in accordance with IEC 60309-1, only those contacts shall be used for control circuits which are intended for those purposes. This exception does not apply to control circuits using high frequency signals superimposed on the power circuits.

13.4.6 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.

13.4.7 Additional conductors

Consideration should be given to providing additional conductors for maintenance or repair. When spare conductors are provided, they shall be connected to spare terminals or isolated in such a manner as to prevent contact with live parts.

13.5 Ducts, connection boxes and other boxes

13.5.1 General requirements

Ducts shall provide a degree of protection (see IEC 60529) suitable for the application.

All sharp edges, flash, burrs, rough surfaces, or threads with which the insulation of the conductors can come in contact shall be removed from ducts and fittings. Where necessary, additional protection consisting of a flame-retardant, oil-resistant insulating material shall be provided to protect conductor insulation.

Drain holes of 6 mm diameter are permitted in cable trunking systems, connection boxes, and other boxes used for wiring purposes that can be subject to accumulations of oil or moisture.

In order to prevent confusion of conduits with oil, air, or water piping, it is recommended that the conduits be either physically separated or suitably identified.

Ducts and cable trays shall be rigidly supported and positioned at a sufficient distance from moving parts and in such a manner so as to minimize the possibility of damage or wear. In areas where human passage is required, the ducts and cable trays shall be mounted at least 2 m above the working surface.

Cable trays that are partially covered should not be considered to be ducts or cable trunking systems (see 13.5.6), and the cables used shall be of a type suitable for installation on open cable trays.

It is recommended that the dimensions and arrangement of ducts be such as to facilitate the insertion of the conductors and cables.

13.5.2 Rigid metal conduit and fittings

Rigid metal conduit and fittings shall be of galvanized steel or of a corrosion-resistant material suitable for the conditions. The use of dissimilar metals in contact that can cause galvanic action should be avoided.

Conduits shall be securely held in place and supported at each end.

Fittings shall be compatible with the conduit and appropriate for the application. Fittings should be threaded unless structural difficulties prevent assembly. Where threadless fittings are used, the conduit shall be securely fastened to the equipment.

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

13.5.3 Flexible metal conduit and fittings

A flexible metal conduit shall consist of a flexible metal tubing or woven wire armour. It shall be suitable for the expected physical environment.

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

13.5.4 Flexible non-metallic conduit and fittings

Flexible non-metallic conduit shall be resistant to kinking and shall have physical characteristics similar to those of the sheath of multiconductor cables.

The conduit shall be suitable for use in the expected physical environment.

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

13.5.5 Cable trunking systems

Cable trunking systems external to enclosures shall be rigidly supported and clear of all moving parts of the machine and of sources of contamination.

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 the IEC 61084 series.

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. Cable trunking systems shall not have opened but unused knockouts.

13.5.6 Machine compartments and cable trunking systems

The use of compartments or cable trunking systems within the column or base of a machine to enclose conductors is permitted provided the compartments or cable trunking systems are isolated from coolant or oil reservoirs and are entirely enclosed. Conductors run in enclosed compartments and cable trunking systems shall be so secured and arranged that they are not subject to damage.

13.5.7 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 machine is intended to operate (see 11.3).

Those boxes shall not have opened but unused knockouts nor any other openings and shall be so constructed as to exclude materials such as dust, flyings, oil, and coolant.

13.5.8 Motor connection boxes

Motor connection boxes shall enclose only connections to the motor and motor-mounted devices (for example brakes, temperature sensors, plugging switches, tachometer generators).

14 Electric motors and associated equipment

14.1 General requirements

Electric motors should conform to the relevant parts of IEC 60034 series.

The protection requirements for motors and associated equipment are given in 7.2 for overcurrent protection, in 7.3 for protection of motors against overheating, and in 7.6 for overspeed protection.

As many controllers do not switch off the supply to a motor when it is at rest, care shall be taken to ensure compliance with the requirements of 5.3, 5.4, 5.5, 7.5, 7.6 and 9.4. Motor control equipment shall be located and mounted in accordance with Clause 11.

14.2 Motor enclosures

Enclosures for motors should be in accordance with IEC 60034-5.

The degree of protection shall be dependent on the application and the physical environment (see 4.4). All motors shall be adequately protected from mechanical damage.

14.3 Motor dimensions

As far as is practicable, the dimensions of motors shall 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 easily accessible for inspection, maintenance, adjustment and alignment, lubrication, and replacement. The motor mounting arrangement shall be such that all motor mounting means can be removed and all terminal boxes are accessible.

Motors shall be so mounted that proper cooling is ensured and the temperature rise remains within the limits of the insulation class (see IEC 60034-1).

Where practicable, motor compartments should be clean and dry, and when required, shall be ventilated directly to the exterior of the machine. The vents shall be such that ingress of swarf, dust, or water spray is at an acceptable level.

There shall be no opening between the motor compartment and any other compartment that does not meet the motor compartment requirements. Where a conduit or pipe is run into the motor compartment from another compartment not meeting the motor compartment requirements, any clearance around the conduit or pipe shall be sealed.

14.5 Criteria for motor selection

The characteristics of motors and associated equipment shall be selected in accordance with the anticipated service and physical environmental conditions (see 4.4). In this respect, the points that shall be considered include:

– type of motor;
– type of duty cycle (see IEC 60034-1);
– fixed speed or variable speed operation, (and the consequent variable influence of the ventilation);
– mechanical vibration;
– type of motor control;
– temperature rise and other effects of the frequency spectrum of the voltage and/or current feeding the motor (particularly when it is supplied from a converter);
– method of starting and the possible influence of the inrush current on the operation of other users of the same power supply, taking also into account possible special considerations stipulated by the supply authority;
– variation of counter-torque load with time and speed;
– influence of loads with large inertia;
– influence of constant torque or constant power operation;
– possible need of inductive reactors between motor and converter.

14.6 Protective devices for mechanical brakes

Operation of the overload and overcurrent protective devices for mechanical brake actuators shall initiate the simultaneous de-energization (release) of the associated machine actuators.

NOTE Associated machine actuators are those associated with the same motion, for example cable drums and long-travel drives.

15 Socket-outlets and lighting

15.1 Socket-outlets for accessories

Where the machine or its associated equipment is provided with socket-outlets that are intended to be used for accessory equipment (for example hand-held power tools, test equipment), the following apply:

– the socket-outlets should conform to IEC 60309-1. Where that is not practicable, they should be clearly marked with the voltage and current ratings;

– the continuity of the protective bonding circuit to the socket-outlet shall be ensured;

– all unearthed conductors connected to the socket-outlet shall be protected against overcurrent and, when required, against overload in accordance with 7.2 and 7.3 separately from the protection of other circuits;

– where the power supply to the socket-outlet is not disconnected by the supply disconnecting device for the machine or the section of the machine, the requirements of 5.3.5 apply;

– where fault protection is provided by automatic disconnection of supply, the disconnection time shall be in accordance with Table A.1 for TN systems or Table A.2 for TT systems;

– circuits supplying socket-outlets with a current rating not exceeding 20 A shall be provided with residual current protection (RCDs) with a rated operating current not exceeding 30 mA.

15.2 Local lighting of the machine and of the equipment

15.2.1 General

The ON/OFF switch shall not be incorporated in the lampholder or in the flexible connecting cord.

Stroboscopic effects from lights shall be avoided by the selection of appropriate luminaires.

Where fixed lighting is provided in an enclosure, electromagnetic compatibility should be taken into account using the principles outlined in 4.4.2.

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 7.2.6):

– 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);

– a circuit of the electrical equipment of the machine for lighting, 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;

– an externally supplied lighting circuit (for example factory lighting supply). This shall be permitted in control enclosures only, and for the machine work light(s) where their total power rating is not more than 3 kW;

– power supply units, for DC supply to LED light sources, fitted with isolating transformers (for example, in accordance with IEC 61558-2-6).

Exception: where fixed lighting is out of reach of operators during normal operations, the provisions of 15.2.2 do not apply.

15.2.3 Protection

Local lighting circuits shall be protected in accordance with 7.2.6.

15.2.4 Fittings

Adjustable lighting fittings shall be suitable for the physical environment.

The lampholders shall be:

– in accordance with the relevant IEC standard;
– constructed with an insulating material protecting the lamp cap so as to prevent unintentional contact.

Reflectors shall be supported by a bracket and not by the lampholder.

Exception: where fixed lighting is out of reach of operators during normal operation, the provisions of 15.2.4 do not apply.

16 Marking, warning signs and reference designations

16.1 General

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

16.2 Warning signs

16.2.1 Electric shock hazard

Enclosures that do not otherwise clearly show that they contain electrical equipment that can give rise to a risk of electric shock shall be marked with the graphical symbol ISO 7010-W012 (see Figure 18).

Figure 18 – Symbol ISO 7010-W012

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

The warning sign may be omitted (see also 6.2.2 b)) for:

– an enclosure equipped with a supply disconnecting device;
– an operator-machine interface or control station;
– a single device with its own enclosure (for example position sensor).

16.2.2 Hot surfaces hazard

Where the risk assessment shows the need to warn against the possibility of hazardous surface temperatures of the electrical equipment, the graphical symbol ISO 7010-W017 shall be used (see Figure 19).

Figure 19 – Symbol ISO 7010-W017

NOTE ISO 13732-1 gives guidance for the assessment of the risks of burns when humans might touch hot surfaces with their unprotected skin.

16.3 Functional identification

Control devices and visual indicators shall be clearly and durably marked with regard to their functions either on or adjacent to the item. It is recommended that such markings are made in accordance with IEC 60417 and ISO 7000.

16.4 Marking of enclosures of electrical equipment

The following information shall be legibly and durably marked in a way that is plainly visible after the equipment is installed on enclosures that receive incoming power supplies:

- name or trade mark of supplier;
- certification mark or other marking that can be required by local or regional legislation, when required;
- type designation or model, where applicable;
- serial number where applicable;
- main document number (see IEC 62023) where applicable;
- rated voltage, number of phases and frequency (if AC), and full-load current for each incoming supply.

It is recommended that this information is provided adjacent to the main incoming supply(ies).

16.5 Reference designations

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

17 Technical documentation

17.1 General

The information necessary for identification, transport, installation, use, maintenance, decommissioning and disposal of the electrical equipment shall be supplied.

NOTE 1 Documentation is sometimes supplied in paper form, since it cannot be assumed that the user has access to the means of reading instructions supplied in electronic form or made available on an Internet site. However, it is often useful for the documentation to be made available in electronic form and on the Internet as well as in paper form, since this enables the user to download the electronic file if he so wishes and to recover the documentation if the paper copy has been lost. This practice also facilitates the updating of the documentation when this is necessary.

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

Annex I should be considered as guidance for the preparation of information and documents.

17.2 Information related to the electrical equipment

The following shall be supplied:

a) where more than one document is provided, a main document for the electrical equipment as a whole, listing the complementary documents associated with the electrical equipment;

b) identification of the electrical equipment (see 16.4);

c) information on installation and mounting including:

- a description of the electrical equipment's installation and mounting, and its connection to the electrical supplies and where relevant other supplies;
- short-circuit current rating of the electrical equipment for each incoming power supply;
- rated voltage, number of phases and frequency (if AC.), type of distribution system (TT, TN, IT) and full-load current for each incoming supply;
- any additional electrical supply(ies) requirements (for example maximum supply source impedance, leakage current) for each incoming supply;
- space required for the removal or servicing of the electrical equipment;
- installation requirements where needed to ensure that the arrangements for cooling are not impaired;
- environmental limitations (for example lighting, vibration, EMC environment, atmospheric contaminants) where appropriate;
- functional limitations (for example peak starting currents and permitted voltage drop(s)) as applicable;
- precautions to be taken for the installation of the electrical equipment relevant to the electromagnetic compatibility;

d) an instruction for the connection of simultaneously accessible extraneous-conductive-parts in the vicinity of the machine (for example, within 2,5 metres) such as the following to the protective bonding circuit:

- metallic pipes;
- fences;
- ladders;
- handrails.

e) information on the functioning and operation, including as applicable:

- an overview of the structure of the electrical equipment (for example by structure diagram or overview diagram);
- procedures for programming or configuring, as necessary for the intended use;
- procedures for restarting after an unexpected stop;
- a sequence of operation;

f) information on maintenance of the electrical equipment, as appropriate, including:

- frequency and method of functional testing;
- instructions on the procedures for safe maintenance and where it is necessary to suspend a safety function and/or protective measure (see 9.3.6);
- guidance on the adjustment, repair, and frequency and method of preventive maintenance;

- details of the interconnections of the electrical components subject to replacement (for example by circuit diagrams and/or connection tables);
- information on required special devices or tools;
- information on spare parts;
- information on possible residual risks, indication of whether any particular training is required and specification of any necessary personal protective equipment;
- where applicable, instructions to restrict availability of key(s) or tool(s) to skilled or instructed persons only;
- settings (DIP-switches, programmable parameter values, etc);
- information for validation of safety related control functions after repair or modification, and for periodic testing where necessary;

g) information on handling, transportation and storage as appropriate (for example dimensions, weight, environmental conditions, possible ageing constraints);

h) information for proper disassembly and handling of components (for example for recycling or disposal).

18 Verification

18.1 General

The extent of verification will be given in the dedicated product standard for a particular machine. Where there is no dedicated product standard for the machine, the verifications shall always include the items a), b), c) and h) and may include one or more of the items d) to g):

a) verification that the electrical equipment complies with its technical documentation;

b) verification of continuity of the protective bonding circuit (Test 1 of 18.2.2);

c) in case of fault protection by automatic disconnection of supply, conditions for protection by automatic disconnection shall be verified according to 18.2;

d) insulation resistance test (see 18.3);

e) voltage test (see 18.4);

f) protection against residual voltage (see 18.5);

g) verification that the relevant requirements of 8.2.6 are met;

h) functional tests (see 18.6).

When these tests are performed, it is recommended that they follow the sequence listed above.

When the electrical equipment is modified, the requirements stated in 18.7 shall apply.

For verifications that include measurement, measuring equipment in accordance with the IEC 61557 series is recommended.

The results of the verification shall be documented.

18.2 Verification of conditions for protection by automatic disconnection of supply

18.2.1 General

The conditions for automatic disconnection of supply (see 6.3.3) shall be verified by tests.

Test 1 verifies the continuity of the protective bonding circuit.

Test 2 verifies the conditions for protection by automatic disconnection of the supply in TN systems.

For TN-systems, those test methods are described in 18.2.2 and 18.2.3; their application for different conditions of supply are specified in 18.2.4.

For TT systems, see Clause A.2.

For IT systems, see IEC 60364-6.

Where RCDs are used in the electrical equipment, their function shall be verified in accordance with the manufacturer's instructions. The test procedure and test interval shall be specified in the maintenance instructions.

18.2.2 Test 1 – Verification of the continuity of the protective bonding circuit

The resistance between the PE terminal (see 5.2 and Figure 4) and relevant points that are part of the protective bonding circuit shall be measured with a current between at least 0,2 A and approximately 10 A derived from an electrically separated supply source (for example SELV, see 414 of IEC 60364-4-41:2005) having a maximum no-load voltage of 24 V AC or DC.

The resistance measured shall be in the expected range according to the length, the cross sectional area and the material of the related protective conductors and protective bonding conductor(s).

Earthed PELV supplies can produce misleading results in this test and therefore shall not be used.

NOTE Larger currents used for the continuity test increases the accuracy of the test result, especially with low resistance values, i.e. larger cross sectional areas and/or lower conductor lengths.

18.2.3 Test 2 – Fault loop impedance verification and suitability of the associated overcurrent protective device

The connections of each power supply including the connection of the associated protective conductor to the PE terminal of the machine, shall be verified by inspection.

The conditions for the protection by automatic disconnection of supply in accordance with 6.3.3 and Annex A shall be verified by both:

a) verification of the fault loop impedance by:
   – calculation, or
   – measurement in accordance with A.1.4, and
b) confirmation that the setting and characteristics of the associated overcurrent protective device are in accordance with the requirements of Annex A, and where a power drive system (PDS) is used, confirmation that the setting and characteristics of the protective device(s) associated with a PDS are in accordance with the converter manufacturer's and protective device manufacturer's instructions.

18.2.4 Application of the test methods for TN-systems

When Test 2 of 18.2.3 is carried out by measurement, it shall always be preceded by Test 1 of 18.2.2.

NOTE A discontinuity of the protective bonding circuit can cause a hazardous situation for the tester or other persons, or damage to the electrical equipment during the loop impedance test.

The tests that are necessary for machines of different status are specified in Table 9.

Table 9 – Application of the test methods for TN-systems

Procedure	Machine status	Verification on site
A	Electrical equipment of machines, erected and connected on site, where the continuity of the protective bonding circuits has not been confirmed following erection and connection on site.	Test 1 (see 18.2.2) and test 2 (see 18.2.3) Exception: Test 2 is not required where: – test 1 is performed on the protective bonding conductors of the machine that are connected on site, and; – the connections of each incoming power supply and of the associated protective conductor (PE) to the PE-terminal of the machine, are verified by inspection and previous calculations of the fault loop impedance (or resistance) by the manufacturer of the electrical equipment are available, and: – the arrangement of the installations permits the verification of the length and cross-sectional area of the conductors used for the calculation, and; – it can be confirmed through calculation or measurement, or by information supplied by the customer, that the supply source impedance on site does not exceed the value specified by the manufacturer of the electrical equipment. See 17.2 c), fourth bullet).
B	Machine supplied with confirmation of the verification (see 18.1) of continuity of the protective bonding circuits by test 1 or with the results of a test 2 by measurement, having protective bonding circuits exceeding the cable length for which examples are given in Table 10. Case B1) supplied fully assembled and not dismantled for shipment, Case B2) supplied dismantled for shipment, where the continuity of protective conductors is ensured after dismantling, transportation and reassembly (for example by the use of plug/socket connections).	Test 2 (see 18.2.3) Exception: Where it can be confirmed through calculation or measurement, or by information supplied by the customer, that the supply source impedance on site does not exceed the value specified by the manufacturer of the electrical equipment, or that of the test supply during a test 2 by measurement, no test is required on site apart from verification of the connections: • in case B1) of each incoming power supply and of the associated protective conductor to the PE terminal of the machine; • in case B2) of each incoming power supply and of the associated protective conductor to the PE terminal of the machine and of all connections of the protective conductor(s) that were disconnected for shipment.
C	Machine having protective bonding circuits not exceeding the cable length for which examples are given in Table 10, supplied with confirmation of the verification (see 18.1) of continuity of the protective bonding circuits by test 1. Case C1) supplied fully assembled and not dismantled for shipment. Case C2) supplied dismantled for shipment, where the continuity of protective conductors is ensured after dismantling, transportation and reassembly (for example by the use of plug/socket combination(s)).	For case C1 or C2, no test is required on site. For a machine not connected to the power supply by a plug/socket combination, the correct connection of the external protective conductor to the PE-terminal of the machine shall be verified by visual inspection. In case C2), the installation documents (see 17.2) shall require that all connections of the protective conductor(s) that were disconnected for shipment are verified, for example by visual inspection.

Table 10 – Examples of maximum cable lengths from protective devices to their loads for TN-systems

1 Maximum source impedance of the supply to the protective device	2 Minimum cross-sectional area	3 Maximum nominal rating or setting of the protective device I_N	4 Fuse discon-nect time 5 s	5 Fuse discon-nect time 0,4 s	6 Miniature circuit-breaker char.B $I_a = 5 \times I_N$	7 Miniature circuit-breaker char.C $I_a = 10 \times I_N$	8 Miniature circuit-breaker char.D $I_a = 20 \times I_N$	9 Adjusta-ble circuit-breaker $I_a = 8 \times I_N$
mΩ	mm^2	A	**Maximum cable length in m from each protective device to its load**					
500	1,5	16	97	53	76	30	7	31
500	2,5	20	115	57	94	34	3	36
500	4,0	25	135	66	114	35		38
400	6,0	32	145	59	133	40		42
300	10	50	125	41	132	33		37
200	16	63	175	73	179	55		61
200	25 (line)/16 (PE)	80	133					38
100	35 (line)/16 (PE)	100	136					73
100	50 (line)/25 (PE)	125	141					66
100	70 (line)/35 (PE)	160	138					46
50	95 (line)/50 (PE)	200	152					98
50	120 (line)/70 (PE)	250	157					79

The values of the maximum cable length in Table 10 are based on the following assumptions:

- PVC cable with copper conductors, conductor temperature under short-circuit conditions 160 °C (see Table D.5);
- cables with line conductors up to 16 mm^2 provide a protective conductor of equal cross sectional area to that of the line conductors;
- cables above 16 mm^2 provide a reduced size protective conductor as shown;
- 3-phase system, nominal voltage of the power supply 400 V (U_0 = 230 V);
- column 3 values are correlated with Table 6 (see 12.4).
- disconnection time for circuit-breakers is ≤ 0,4 s (columns 6 – 9)

A deviation from these assumptions can require a complete calculation or measurement of the fault loop impedance. Further information is available from IEC 60228 and IEC TR 61200-53.

18.3 Insulation resistance tests

When insulation resistance tests are performed, the insulation resistance measured at 500 V DC between the power circuit conductors and the protective bonding circuit shall be not less than 1 MΩ. 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.

If the electrical equipment of the machine contains surge protection devices which are likely to operate during the test, it is permitted to either:

– disconnect these devices, or
– reduce the test voltage to a value lower than the voltage protection level of the surge protection devices, but not lower than the peak value of the upper limit of the supply (phase to neutral) voltage.

18.4 Voltage tests

When voltage tests are performed, test equipment in accordance with IEC 61180-2 should be used.

The test voltage shall be at a nominal frequency of 50 Hz or 60 Hz.

The maximum test voltage shall have a value of twice the rated supply voltage of the equipment or 1 000 V, whichever is the greater. The maximum test voltage shall be applied between the power circuit conductors and the protective bonding circuit for at least 1 s. The requirements are satisfied if no disruptive discharge occurs.

Components and devices that are not rated to withstand the test voltage and surge protection devices which are likely to operate during the test shall be disconnected during testing.

Components and devices that have been voltage tested in accordance with their product standards may be disconnected during testing.

18.5 Protection against residual voltages

Where appropriate, tests shall be performed to ensure compliance with 6.2.4.

18.6 Functional tests

The functions of electrical equipment shall be tested.

18.7 Retesting

Where a portion of the machine or its associated equipment is changed or modified, the need for re-verification and testing of the electrical equipment shall be considered.

Particular attention should be given to the possible adverse effects that retesting can have on the equipment (for example overstressing of insulation, disconnection/reconnection of devices).

Annex A
(normative)

Fault protection by automatic disconnection of supply

A.1 Fault protection for machines supplied from TN-systems

A.1.1 General

The provisions in the Annex A are derived from IEC 60364-4-41:2005, and IEC 60364-6:2006.

Fault protection shall be provided by an overcurrent protective device that automatically disconnects the supply to the circuit or equipment in the event of a fault between a live part and an exposed conductive part or a protective conductor in the circuit or equipment, within a sufficiently short disconnecting time. A disconnecting time not exceeding 5 s is considered sufficiently short for machines that are neither hand-held nor portable.

Where this disconnecting time cannot be assured, supplementary protective bonding shall be provided in accordance with A.1.3 that can prevent a prospective touch voltage from exceeding 50 V AC or 120 V ripple-free DC between simultaneously accessible conductive parts.

NOTE The use of supplementary protective bonding does not preclude the need to disconnect the supply for other reasons, for example protection against fire, thermal stresses in equipment, etc.

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 a machine 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

System	50 V < U_0 ≤ 120 V s		120 V < U_0 ≤ 230 V s		230 V < U_0 ≤ 400 V s		U_0 > 400 V s	
	AC	DC	AC	DC	AC	DC	AC	DC
TN	0,8	NOTE 1	0,4	5	0,2	0,4	0,1	0,1

U_0 is the nominal AC or DC line to earth voltage.

NOTE 1 Disconnection may be required for reasons other than protection against electric shock.

NOTE 2 For voltages which are within the tolerance band stated in IEC 60038, the disconnecting time appropriate to the nominal voltage applies.

NOTE 3 For intermediate values of voltage, the next higher value in the above table is to be used.

A.1.2 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 line 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 general condition fulfils this requirement:

$$Z_s \times I_a \leq U_0$$

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 AC 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 in the following equation:

$$Z_{s\,(n)} \leq \frac{2}{3} \times \frac{U_0}{I_a}$$

where Z_s(n) is the measured or calculated value of Z_s under normal operating conditions.

Where the value of the fault loop impedance exceeds $2U_0/3I_a$, a more precise assessment can be made in accordance with the procedure described in C.61.3.6.2 of IEC 60364-6:2006.

A.1.3 Condition for protection by reducing the touch voltage below 50 V

Where the requirements of A.1.2 cannot be assured, supplementary protective bonding can be selected as the means of ensuring that touch voltages will not exceed 50 V. This is achieved when the impedance of the protective bonding circuit (Z_{PE}) does not exceed:

$$Z_{PE} \leq \frac{50}{U_0} \times Z_S$$

where Z_{PE} is the impedance of the protective bonding circuit between the equipment anywhere in the installation and the PE terminal of the machine (see 5.2 and Figure 4) or between simultaneously accessible exposed conductive parts and/or extraneous-conductive-parts.

Confirmation of this condition can be achieved by using the method of Test 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:

$$R_{PE} \leq \frac{50}{I_{a(5s)}}$$

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 4) and the equipment anywhere on the machine, or between simultaneously accessible exposed conductive parts and/or extraneous-conductive-parts.

NOTE 1 Supplementary protective bonding is considered as an addition to fault protection.

NOTE 2 Supplementary protective bonding may involve the entire installation, a part of the installation, an item of apparatus, or a location.

A.1.4 Verification of conditions for protection by automatic disconnection of the supply

A.1.4.1 General

The effectiveness of the measures for fault protection by automatic disconnection of supply in accordance with A.1.2 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). See Figure A.1.

Exception: Verification of the continuity of the protective conductors may replace the measurement where the calculations of the fault loop impedance are available and when the arrangement of the installations permits the verification of the length and cross-sectional area of the conductors.

Where a power drive system (PDS) is used, the disconnection time for fault protection shall meet the relevant requirements of this Annex A at the incoming supply terminals of the basic drive module (BDM) of the PDS. See Figure A.2.

A.1.4.2 Measurement of the fault loop impedance

Where measurement of the fault loop impedance is performed, it is recommended that the measuring equipment comply 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 machine 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 line conductors not used in the test may be opened, for example, by removing fuses.

The measured value of the fault loop impedance shall be in accordance with A.1.2.

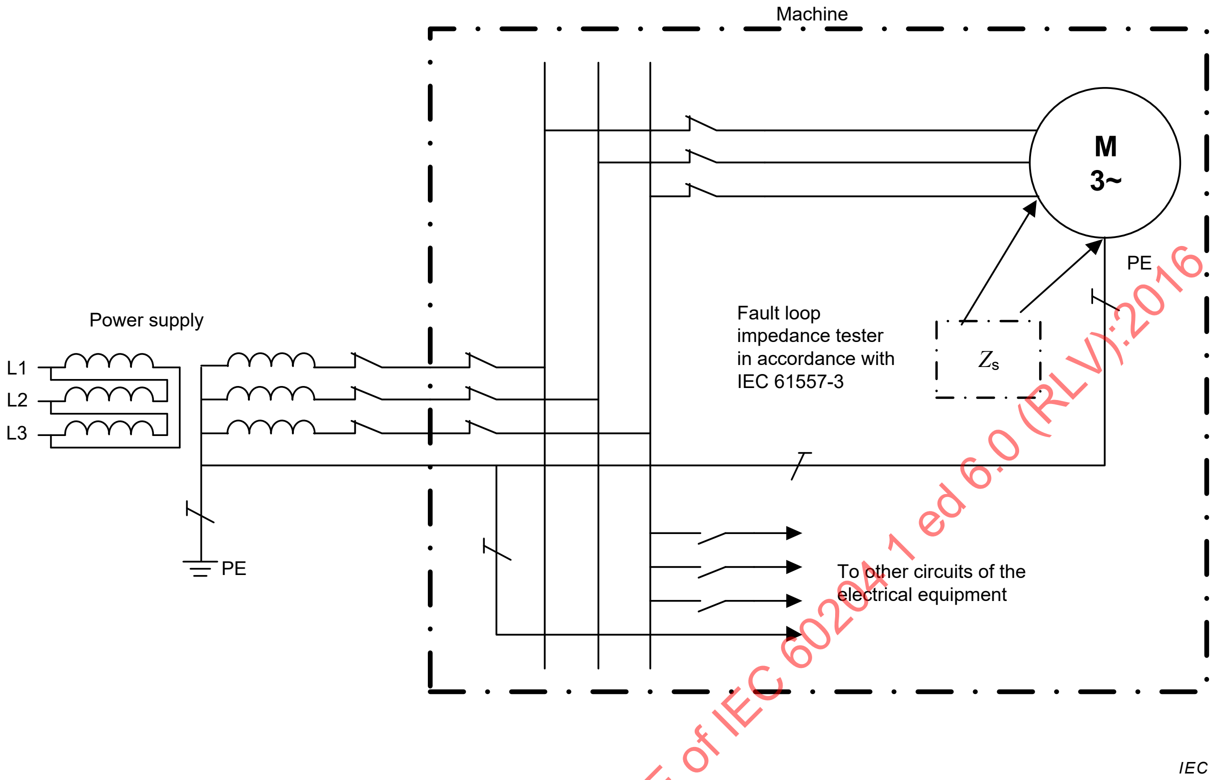


Figure A.1 – Typical arrangement for fault loop impedance (Z_s) measurement in TN systems

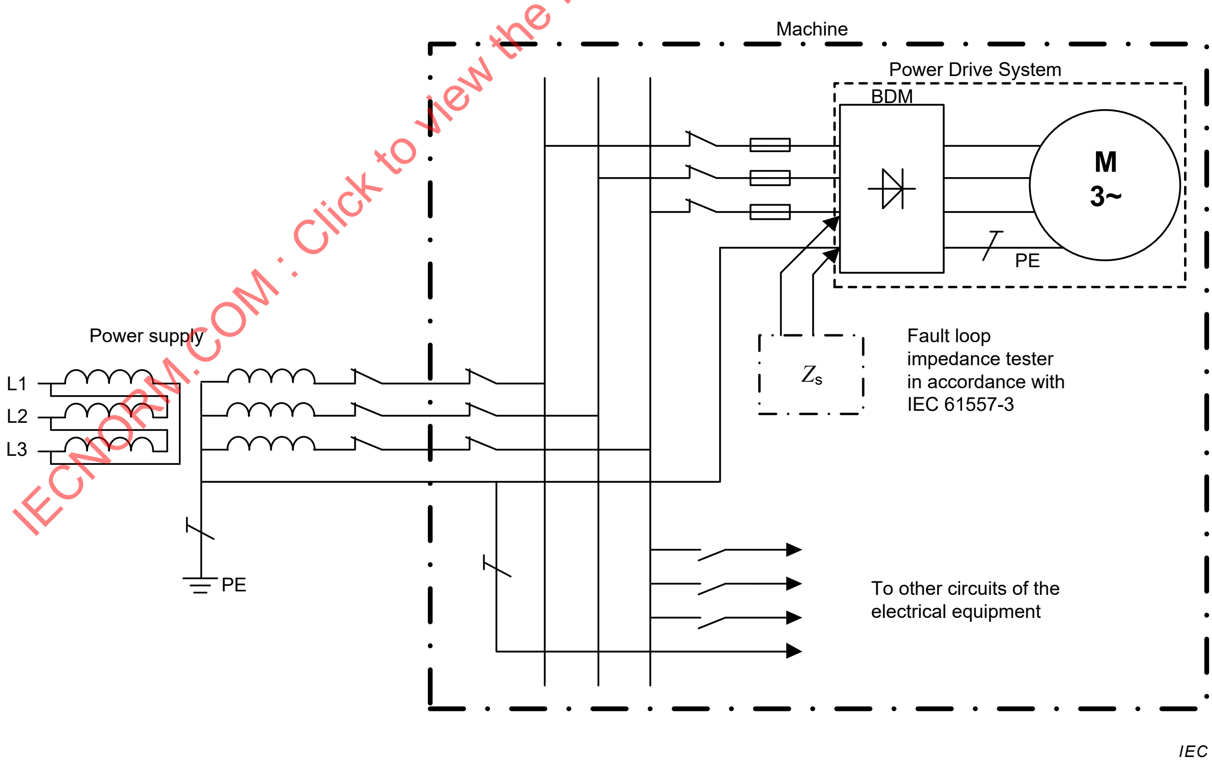


Figure A.2 – Typical arrangement for fault loop impedance (Z_s) measurement for power drive system circuits in TN systems

A.2 Fault protection for machines supplied from TT-systems

A.2.1 Connection to earth

All exposed-conductive-parts and all extraneous-conductive-parts shall be bonded to the protective bonding circuit.

Exception: see 8.2.5.

In addition to the requirements of 5.2, provision for additional earthing of machine elements and/or the PE conductor of the electrical equipment may be provided.

NOTE In a TT system, the neutral point or the mid-point of the power supply system is earthed, or where a neutral point or mid-point is not available or not accessible, a line conductor is earthed (derived from IEC 60364-4-41:2005, 411.5.1).

A.2.2 Fault protection for TT systems

A.2.2.1 General

Generally in TT systems, RCDs shall be used for fault protection. Alternatively, overcurrent protective devices may be used for fault protection provided a suitably low value of Z_s is permanently and reliably assured. Z_s is the impedance of the fault loop.

NOTE In some countries the use of overcurrent protective devices is not permitted as the means of fault protection in TT systems.

Where automatic disconnection of supply is used as a measure for fault protection, the electrical equipment designer may either:

a) use in the design calculations a value of earth electrode resistance or earth fault loop impedance measured in accordance with IEC 60364-6 or declared by the intended user of the equipment (see Annex B); or
b) for series-manufactured machines, specify a value of the earth electrode resistance or earth fault loop impedance suitable for the intended installations;

and shall state in the installation instructions the value of earth electrode resistance or earth fault loop impedance used for the design of the electrical equipment, specifying that this is the maximum value to which the machine can be connected.

Where a power drive system (PDS) is used, the disconnection time for fault protection shall meet the relevant requirements of this Annex A at the incoming supply terminals of the basic drive module (BDM) of the PDS. See Figure A.4.

A.2.2.2 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) disconnection time as required by Table A.2, and
b) $R_A \times I_{\Delta n} \leq 50$ V

where:

R_A is the sum of the resistances of the earth electrode and the protective conductor for each exposed conductive-part,

$I_{\Delta n}$ is the rated residual operating current of the RCD.

Exception: a disconnection time not exceeding 1 s is permitted for distribution circuits and for circuits not covered by Table A.2.

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, information is given in 535.3 of IEC 60364-5-53:2001.

NOTE 3 The disconnection times in accordance with Table A.2 relate to prospective residual fault currents significantly higher than the rated residual operating current of the RCD (typically 5 $I_{\Delta n}$).

NOTE 4 The definition of R_A is extracted from IEC 60364-4-41. In this part of IEC 60204, the term “earth electrode” in the definition of R_A is considered to mean the “earth-return path” as defined by IEC 60050-195:1998, 195-02-30.

A.2.2.3 Protection by overcurrent protective devices

Where an overcurrent protective device is used the following condition shall be fulfilled:

$$Z_s \times I_a \leq U_o$$

where:

Z_s is the impedance of the fault loop comprising:

the source,

the line conductor up to the point of the fault,

the protective conductor of each exposed-conductive-part,

the earthing conductor,

the earth electrode of the installation and the earth electrode of the source;

I_a is the current causing the automatic operation of the disconnecting device within the time specified in Table A.2.

Exception: a disconnection time not exceeding 1 s is permitted for circuits not covered by Table A.2.

U_o is the nominal AC or DC line to earth voltage.

The maximum disconnection times stated in Table A.2 shall be applied to circuits not exceeding 32 A. Maximum disconnection times shall not exceed 1 s for circuits 32 A or greater.

Table A.2 – Maximum disconnecting time for TT-systems

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	
	AC	DC	AC	DC	AC	DC	AC	DC
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 all extraneous-conductive-parts will be connected to the protective bonding circuit, the maximum disconnection times specified in Table A.1 may be used.

U_o is the nominal AC or DC line to earth voltage.

NOTE Disconnection can be required for reasons other than protection against electric shock.

A.2.3 Verification of protection by automatic disconnection of supply using a residual current protective device

Fault protection in a TT system by automatic disconnection of supply using a residual current protective device shall be verified by the following:

- inspection of the rated residual current for tripping value, and the disconnecting time value of the residual current protective device, and

- 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.

A.2.4 Measurement of the fault loop impedance (Z_s)

Where measurement of the fault loop impedance is performed the measuring equipment should comply 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.

The measurement shall be performed with the electrical equipment connected to a supply of between 99 % and 101 % the nominal frequency of the supply at the intended installation.

NOTE 1 Figure A.3 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 line conductors not used in the test may be opened, for example, by removing fuses.

NOTE 2 Figure A.4 illustrates a typical arrangement for measuring the fault loop impedance when a power drive system is used.

The measured value of the fault loop impedance shall be in accordance with A.2.2.3.

NOTE 3 Information on the verification of performance of a residual current protective device and measurement of earth fault loop impedance can be found in IEC 60364-6.

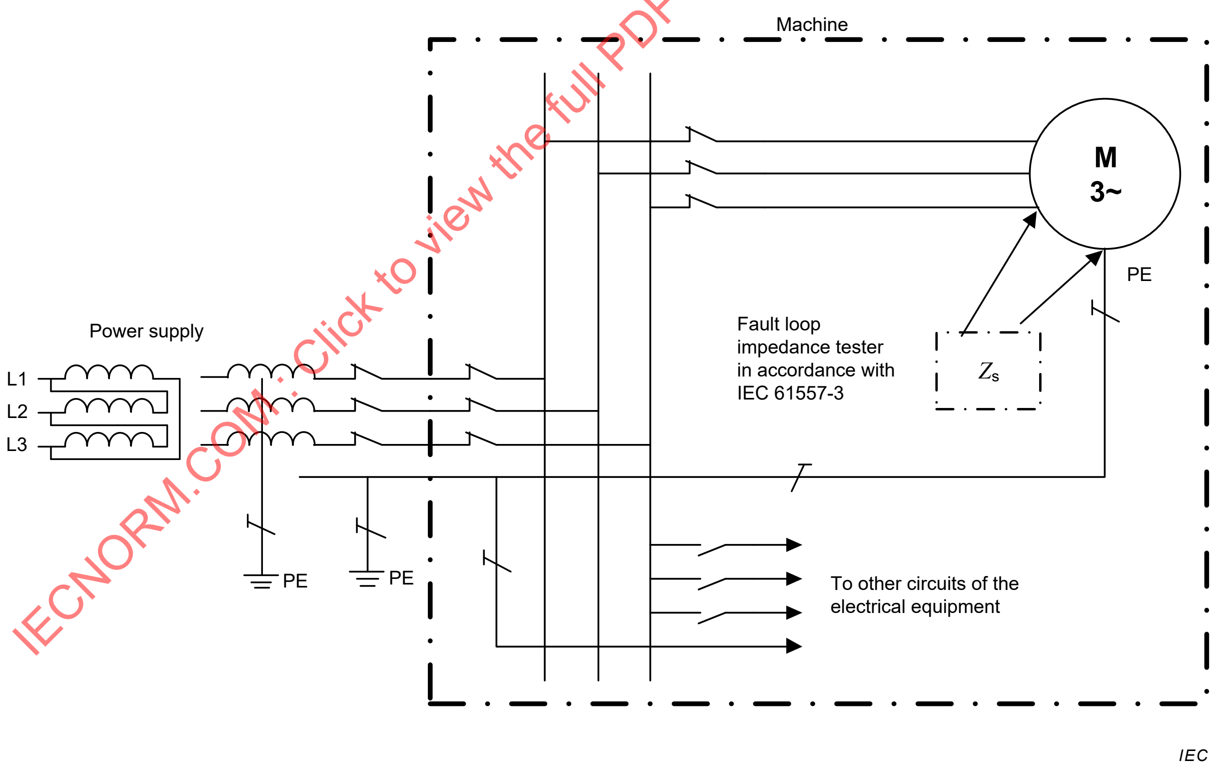


Figure A.3 – Typical arrangement for fault loop impedance (Z_s) measurement in TT systems

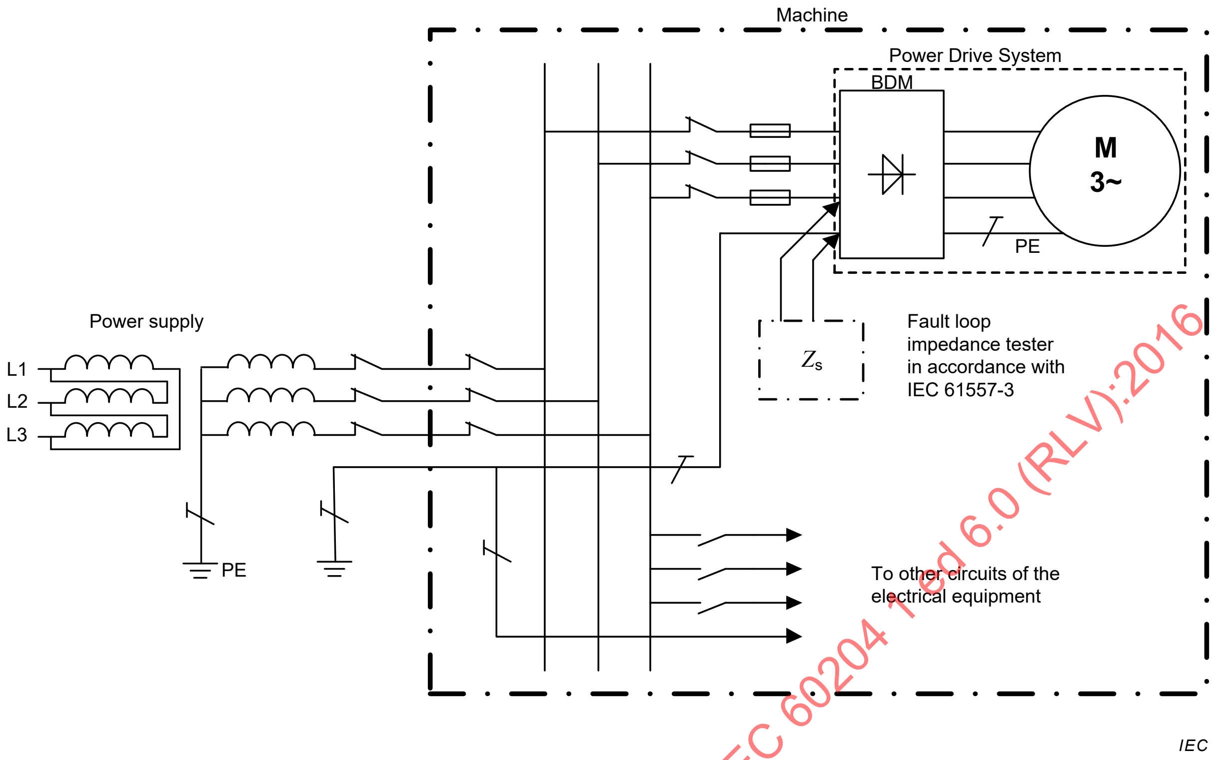


Figure A.4 – Typical arrangement for fault loop impedance (Z_s) measurement for power drive system circuits in TT systems

Annex B
(informative)

Enquiry form for the electrical equipment of machines

The use of this enquiry form can facilitate an exchange of information between the user and supplier on basic conditions and additional user requirements to enable suitable design, application and utilization of the electrical equipment of the machine (see 4.1) particularly when the conditions on site can deviate from those generally expected.

Annex B can also serve as an internal checklist for serial manufactured machines.

Name of manufacturer/supplier				
Name of end user				
Tender/order number			Date	
Type of machine	Type designation		Serial number	
1. Special conditions (see Clause 1)				
a) Is the machine to be used in the open air?	Yes/No		If yes, specification	
b) Will the machine use, process or produce explosive or flammable material?	Yes/No		If yes, specification	
c) Is the machine for use in potentially explosive or flammable atmospheres?	Yes/No		If yes, specification	
d) Can the machine present special hazards when producing or consuming certain materials?	Yes/No		If yes, specification	
e) Is the machine for use in mines?	Yes/No		If yes, specification	
2. Electrical supplies and related conditions (see 4.3)				
a) Anticipated voltage fluctuations (if more than ±10 %)				
b) Anticipated frequency fluctuations (if more than ±2 %)	Continuous		Short time	
c) Indicate possible future changes in electrical equipment that will require an increase in the electrical supply requirements				
d) Specify voltage interruptions in supply if longer than specified in Clause 4 where electrical equipment has to maintain operation under such conditions				
3. Physical environment and operating conditions (see 4.4)				
a) Electromagnetic environment (see 4.4.2)	Residential, commercial or light industrial environment		Industrial environment	
Special EMC conditions or requirements				
b) Ambient temperature range				
c) Humidity range				
d) Altitude				
e) Special environmental conditions (for example corrosive atmospheres, dust, wet environments)				
f) Radiation				
g) Vibration, shock				

h) Special installation and operation requirements (for example flame-retardant cables and conductors)				
i) Transportation and storage (for example, temperatures outside the range specified in 4.5)				
k) restrictions related to size, weight or point load				
4. Incoming electrical supplies				
Specify for each source of supply:				
a) Nominal voltage (V)	AC		DC	
	If AC, number of phases		Frequency (Hz)	
Value of the supply source impedance (Ω) at the point of connection to the electrical equipment				
Prospective short-circuit current (kA r.m.s.) at the point of connection to the electrical equipment (see also item 2)				
b) Type of distribution system (see IEC 60364-1)	TN (system with one point directly earthed, with a protective conductor (PE) directly connected to that point); specify if the earthed point is the neutral point (centre of the star) or another point		TT (system with one point directly earthed but the protective conductor (PE) of the machine not connected to that earth point of the system)	
	IT (system that is not directly earthed)			
In the case of IT systems, is insulation monitoring/fault location to be provided by the supplier of the electrical equipment?	Yes		No	
c) Is the electrical equipment to be connected to a neutral (N) supply conductor? (See 5.1)	Yes		No	
Maximum current (A) allowed				
d) Supply disconnecting device				
Is disconnection of the neutral (N) conductor required?	Yes		No	
Is a removable link for disconnecting the neutral (N) required?	Yes		No	
Type of supply disconnecting device to be provided				
e) Cross sectional area and material of external protective (PE) conductor				
f) Is an RCD provided in the installation?	Yes/No		If yes, type and rated residual operating current	
5. Protection against electric shock (see Clause 6)				
a) For which of the following classes of persons is access to the interior of enclosures required during normal operation of the equipment?	Electrically skilled persons		Electrically instructed persons	
b) Are locks with removable keys to be provided for securing the doors? (see 6.2.2)	Yes		No	
Type of locking device				
Basic lock unit (except key cylinder) to be supplied and installed by				
Key cylinder to be supplied and installed by				

6. Protection of equipment (see Clause 7)				
a) Will the user or the supplier of the electrical equipment provide supply conductors and the overcurrent protection for the supply conductors? (see 7.2.2)				
Type and rating of overcurrent protective devices				
b) Largest (kW) three-phase AC motor that may be started direct-on-line				
c) May the number of motor overload detection devices be reduced? (see 7.3.2)	Yes		No	
d) Is overvoltage protection to be provided?	Yes/No		If yes, specification	
7. Operation				
For cableless control systems, specify the time delay before automatic machine shutdown is initiated in the absence of a valid signal.				
8. Operator interface and machine-mounted control devices (see Clause 10)				
Special colour preferences (for example to align with existing machinery):	Start		Stop	
	Other			
9. Controlgear				
Degree of protection of enclosures (see 11.3) or special conditions:				
10. Wiring practices (see Clause 13)				
Is there a specific method of identification to be used for the conductors? (see 13.2.1)	Yes		No	
Type				
11. Accessories and lighting (see Clause 15)				
a) Is a particular type of socket-outlet required?	Yes		No	
If yes, which type?				
b) Where the machine is equipped with local lighting:	Highest permissible voltage (V)		If lighting circuit voltage is not obtained directly from the power supply, state preferred voltage	
12. Marking, warnings and reference designations (see Clause 16)				
a) Functional identification (see 16.3)				
Specifications:				
b) Inscriptions/special markings	On electrical equipment?		In which language?	
c) Specific local regulations that must be complied with	Yes		No	
If yes, which one?				
13. Technical documentation (see Clause 17)				
a) Technical documentation (see 17.1)	On what media/		In which language?	
	File format?			
b) Instructions for use (see 17.1)	On what media?		In which language?	
	File format?			

c) Size, location and purpose of ducts, open cable trays or cable supports to be provided by the user				
d) Indicate if special limitations on the size or weight affect the transport of a particular machine or controlgear assemblies to the installation site:	Maximum dimensions		Maximum weight	
e) In the case of specially built machines, is a certificate of operating tests with the loaded machine to be supplied?	Yes		No	
f) In the case of other machines, is a certificate of operating type tests on a loaded prototype machine to be supplied?	Yes		No	

Annex C
(informative)

Examples of machines covered by this part of IEC 60204

The following list shows examples of machines whose electrical equipment should conform to this part of IEC 60204. The list is not intended to be exhaustive but is consistent with the definition of machinery (3.1.40). This part of IEC 60204 need not be applied to machines that are household and similar domestic appliances within the scope of the IEC 60335 series of standards.

Metalworking machinery

- metal cutting machines
- metal forming machines

Plastics and rubber machinery

- injection moulding machines
- extrusion machines
- blow moulding machines
- thermoset moulding machines
- size reduction machines

Wood machinery

- woodworking machines
- laminating machines
- sawmill machines

Assembly machines

Material handling machines

- robots
- conveyors
- transfer machines
- storage and retrieval machines

Textile machines

Refrigeration and air-conditioning machines

Food machinery

- dough breaks
- mixing machines
- pie and tart machines
- meat processing machines

Printing, paper and board machinery

- printing machines
- finishing machines, guillotines, folders
- reeling and slitting machines
- folder box gluing machines
- paper and board making machines

Inspecting/testing machinery

- co-ordinate measuring machines
- in-process gauging machines

Compressors

Packaging machinery

- palletizers/depalletizers
- wrapping and shrink-wrapping machines

Laundry machines

Heating and ventilating machines

Leather/imitation leather goods and footwear machinery

- cutting and punching machines
- roughing, scouring, buffing, trimming and brushing machines
- footwear moulding machines
- lasting machines

Hoisting machinery (see IEC 60204-32)

- cranes
- hoists

Machinery for transportation of persons

- escalators
- ropeways for transportation of persons, for example chairlifts, ski lifts
- passenger lifts

Power-operated doors

Leisure machinery

- fairground and amusement rides

Pumps

Agriculture and forestry machines

Construction and building materials machinery

- tunnelling machines
- concrete batching machines
- brick-making machines
- stone, ceramic and glass-making machines

Transportable machinery

- wood working machines
- metal working machines

Mobile machinery

- lifting platforms
- fork lift trucks
- construction machines

Machines for hot metal processing

Tanning machinery

- multi-roller machines
- bandknife machines
- hydraulic tanning machines

Mining and quarrying machines

Annex D
(informative)

Current-carrying capacity and overcurrent protection of conductors and cables in the electrical equipment of machines

D.1 General

The purpose of this Annex A is to provide additional information on the selection of conductor sizes where the conditions given for Table 6 (see Clause 12) have to be modified (see notes to Table 6).

D.2 General operating conditions

D.2.1 Ambient air temperature

The current carrying capacity for PVC insulated conductors given in Table 6 is related to an ambient air temperature of +40 °C. For other ambient air temperatures, the correction factors are given in Table D.1.

The correction factors for rubber insulated cables are given by the manufacturer.

Table D.1 – Correction factors

Ambient air temperature °C	Correction factor
40	1,00
45	0,91
50	0,82
55	0,71
60	0,58

NOTE The correction factors are derived from IEC 60364-5-52.

The maximum temperature under normal conditions for PVC 70 °C.

D.2.2 Methods of installation

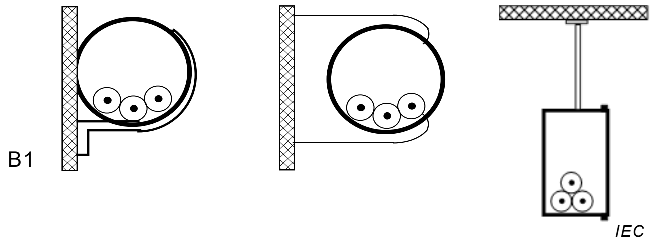
In machines, the methods of conductor and cable installation between enclosures and individual items of the equipment shown in Figure D.1 are assumed to be typical (the letters used are in accordance with IEC 60364-5-52):

– Method B1: using conduits (3.1.9) and cable trunking systems (3.1.6) for holding and protecting conductors or single core cables;

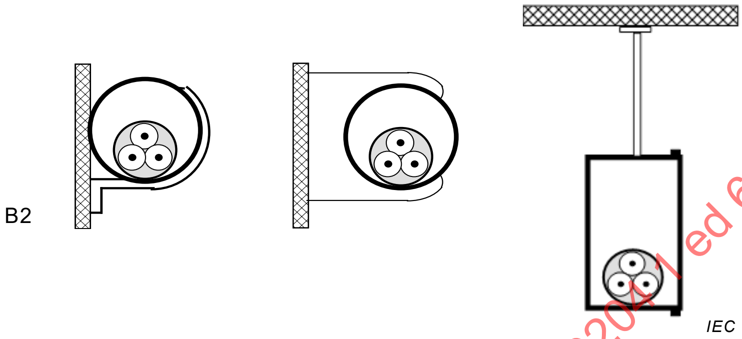
– Method B2: same as B1 but used for multicore cables;

– Method C: multicore cables installed in free air, horizontal or vertical without gap between cables on walls;

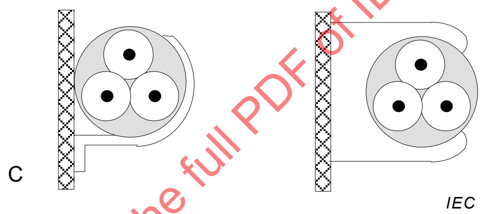
– Method E: multicore cables in free air, horizontal or vertical laid on open cable trays (3.1.5).



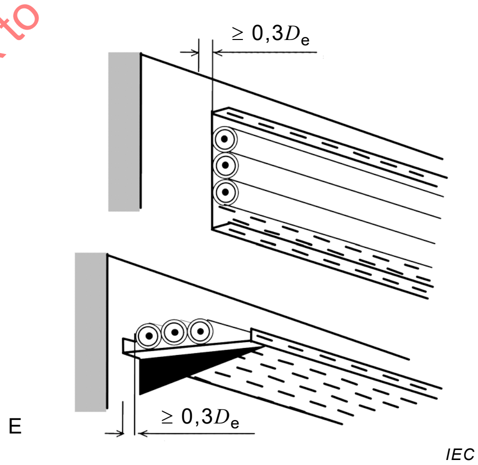
a) Conductors/single core cables in conduit and cable trunking systems



b) Cables in conduit and cable trunking systems



c) Cables on walls



d) Cables on open cable trays

Figure D.1 – Methods of conductor and cable installation independent of number of conductors/cables

D.2.3 Grouping

Where more loaded conductors in cables or conductor pairs are installed, derate the values of I_z, given in Table 6 or by the manufacturer in accordance with Tables D.2 or D.3.

NOTE Circuits with I_b < 30 % of I_z need not be derated.

Table D.2 – Derating factors for I_z for grouping

Methods of installation (see Figure D.1) (see Note 3)	Number of loaded circuits/cables			
	2	4	6	9
B1 (conductors or single core cables) and B2 (multicore cables)	0,80	0,65	0,57	0,50
C single layer with no gap between cables	0,85	0,75	0,72	0,70
E single layer on one perforated tray without gap between cables	0,88	0,77	0,73	0,72
E as before but with 2 to 3 trays, with a vertical spacing between each tray of 300 mm (see Note 4)	0,86	0,76	0,71	0,66
Control circuit pairs ≤ 0,5mm² independent of methods of installation	0,76	0,57	0,48	0,40

NOTE 1 These factors are applicable to

– cables, all equally loaded, the circuit itself symmetrically loaded;

– groups of circuits of insulated conductors or cables having the same allowable maximum operating temperature.

NOTE 2 The same factors are applied to

– groups of two or three single-core cables;

– multicore cables.

NOTE 3 Factors derived from IEC 60364-5-52:2009.

NOTE 4 A perforated cable tray is a tray where the holes occupy more than 30 % of the area of the base. (Derived from IEC 60364-5-52:2009).

Table D.3 – Derating factors for I_z for multicore cables up to 10 mm²

Number of loaded conductors or pairs	Conductors (≥ 1 mm²) (see Note 3)	Pairs (0,25 mm² to 0,75 mm²)
1	–	1,0
3	1,0	0,5
5	0,75	0,39
7	0,65	0,34
10	0,55	0,29
24	0,40	0,21

NOTE 1 Applicable to multicore cables with equally loaded conductors/pairs.

NOTE 2 For grouping of multicore cables, see derating factors of Table D.2.

NOTE 3 Factors derived from IEC 60364-5-52:2009.

D.2.4 Classification of conductors

Table D.4 – Classification of conductors

Class	Description	Use/application
1	Solid copper or aluminium conductors	Fixed installations
2	Stranded copper or aluminium conductors	
5	Flexible stranded copper conductors	Machine installations with presence of vibration; connection to moving parts
6	Flexible stranded copper conductors conductors that are more flexible than class 5	For frequent movements
NOTE Derived from IEC 60228.		

D.3 Co-ordination between conductors and protective devices providing overload protection

Figure D.2 illustrates the relationship between the parameters of conductors and the parameters of protective devices providing overload protection.

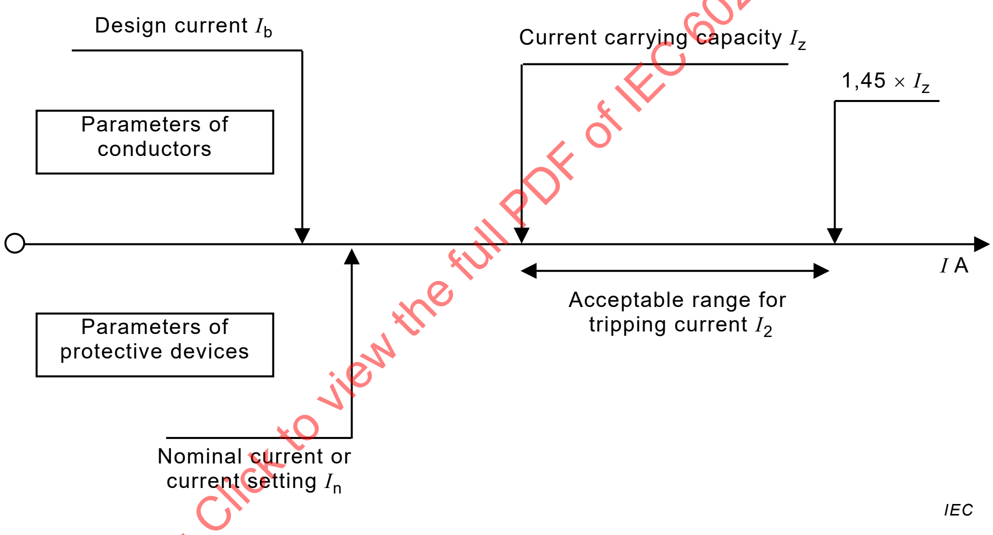


Figure D.2 – Parameters of conductors and protective devices

Correct protection of a cable requires that the operating characteristics of a protective device (for example overcurrent protective device, motor overload protective device) protecting the cable against overload satisfy the two following conditions:

$$I_b \leq I_n \leq I_z$$

$$I_2 \leq 1{,}45 \times I_z$$

where

I_b is the current for which the circuit is designed;

I_z is the effective current-carrying capacity, in amperes, of the cable for continuous service according to Table 6 for the particular installation conditions:

- temperature, derating of I_z see Table D.1;
- grouping, derating of I_z see Table D.2;
- multicore cables, derating of I_z see Table D.3.

I_n is the nominal current of the protective device;

NOTE 1 For adjustable protective devices, the nominal current I_n is the current setting selected.

I_2 is the minimum current ensuring effective operation of the protective device within a specified time (for example 1 h for protective devices up to 63 A).

The current I_2 ensuring effective operation of the protective device is given in the product standard or may be provided by the manufacturer.

NOTE 2 For motor circuit conductors, overload protection for conductor(s) can be provided by the overload protection for the motor(s) whereas the short-circuit protection is provided by short-circuit protective devices.

Where a device that provides both overload and short-circuit protection is used in accordance with Clause D.3 for conductor overload protection, it does not ensure complete protection in all cases (for example overload with currents less than I_2), nor will it necessarily result in an economical solution. Therefore, such a device can be unsuitable where overloads with currents less than I_2 are likely to occur.

D.4 Overcurrent protection of conductors

All conductors are required to be protected against overcurrent (see 7.2) by protective devices inserted in all live conductors so that any short-circuit current flowing in the cable is interrupted before the conductor has reached the maximum allowable temperature.

NOTE Information on neutral conductors can be found in 7.2.3, third paragraph.

Table D.5 – Maximum allowable conductor temperatures under normal and short-circuit conditions

Type of insulation	Maximum temperature under normal conditions °C	Ultimate short-time conductor temperature under short-circuit conditions [a)] °C
Polyvinyl chloride (PVC)	70	160
Rubber	60	200
Cross-linked polyethylene (XLPE)	90	250
Ethylene propylene compound (EPR)	90	250
Silicone rubber (SiR)	180	350
NOTE For ultimate short-time conductor temperatures greater than 200 °C, neither tinned nor bare copper conductors are suitable. Silver-plated or nickel-plated copper conductors are suitable for use above 200 °C.		
a) These values are based on the assumption of adiabatic behaviour for a period of not more than 5 s.		

In practice, the requirements of 7.2 are fulfilled when the protective device at a current I causes the interruption of the circuit within a time that in no case exceeds the time t where $t < 5$ s.

The value of the time t in seconds can be calculated using the following formula:

$$t = (k \times S/I)^2$$

where:

S is the cross-sectional area in square millimetres;

I is the effective short-circuit current in amperes expressed for AC as the r.m.s. value;

k is the factor shown for copper conductors when insulated with the following material:

PVC 115

Rubber	141
SiR	132
XLPE	143
EPR	143

D.5 Effect of harmonic currents on balanced three-phase systems

In case of circuits feeding single phase loads with load current including harmonics, the neutral conductor of the circuit might be additionally loaded and a reduction of the current carrying capacity of that cable might be necessary. For reference see IEC 60364-5-52:2009, Annex E.

Annex E
(informative)

Explanation of emergency operation functions

NOTE The concepts below are included here to give the reader an understanding of these terms even though in this part of IEC 60204 only two of them are used.

- **Emergency operation**

  Emergency operation includes separately or in combination:

  – emergency stop;

  – emergency start;

  – emergency switching off;

  – emergency switching on.

- **Emergency stop**

  An emergency operation intended to stop a process or a movement that has become hazardous.

- **Emergency start**

  An emergency operation intended to start a process or a movement to remove or to avoid a hazardous situation.

- **Emergency switching off**

  An emergency operation intended to switch off the supply of electrical energy to all or a part of an installation where a risk of electric shock or another risk of electrical origin is involved.

- **Emergency switching on**

  An emergency operation intended to switch on the supply of electrical energy to a part of an installation that is intended to be used for emergency situations.

Annex F
(informative)

Guide for the use of this part of IEC 60204

This part of IEC 60204 gives a large number of general requirements that may or may not be applicable to the electrical equipment of a particular machine. A simple reference without any qualification to the complete standard IEC 60204-1 is therefore not sufficient. Choices need to be made to cover all requirements of this part of IEC 60204. A technical committee preparing a product family or a dedicated product standard (type C in ISO and CEN), and the supplier of a machine for which no product family or dedicated product standard exists, should use this part of IEC 60204:

a) by reference; and

b) by selection of the most appropriate option(s) from the requirements given in the relevant clauses; and

c) by modification of certain clauses, as necessary, where the particular requirements for the equipment of the machine are adequately covered by other relevant standards,

providing the options selected and the modifications made do not adversely affect the level of protection required for that machine according to the risk assessment.

When applying the three principles a), b) and c) listed above, it is recommended that:

– reference be made to the relevant clauses and subclauses of this standard:
  - that are complied with, indicating where relevant the applicable option;
  - that have been modified or extended for the specific machine or equipment requirements; and
– reference be made directly to the relevant standard, for those requirements for the electrical equipment that are adequately covered by that standard.

Specific expertise can be necessary to:

– perform the necessary risk assessment of the machine;
– read and understand all of the requirements of this part of IEC 60204;
– choose the applicable requirements from this part of IEC 60204 where alternatives are given;
– identify alternative or additional particular requirements that differ from or are not included in the requirements of this part of IEC 60204, and that are determined by the machine and its use; and
– specify precisely those particular requirements.

Figure 1 of this part of IEC 60204 is a block diagram of a typical machine and can be used as the starting point of this task. It indicates the Clauses and Subclauses dealing with particular requirements/equipment. However, this part of IEC 60204 is a complex document and Table F.1 can help identify the application options for a particular machine and gives reference to other relevant standards.

Table F.1 – Application options

Subject	Clause or Subclause	i)	ii)	iii)	iv)
Scope	1		X		
General requirements	4	X	X	X	ISO 12100
Selection of equipment	4.2.2		X	X	IEC 61439 series
Supply disconnecting (isolating) device	5.3	X			
Excepted circuits	5.3.5	X		X	ISO 12100
Prevention of unexpected start-up, isolation	5.4, 5.5 and 5.6	X	X	X	ISO 14118
Protection against electric shock	6	X			IEC 60364-4-41
Emergency operations	9.2.3.4	X		X	ISO 13850
Two-hand control	9.2.3.8	X	X		ISO 13851
Cableless control	9.2.4	X	X	X	IEC 62745
Control functions in the event of failure	9.4	X	X	X	ISO 12100 ISO 13849 (all parts) IEC 62061
Position sensors	10.1.4	X	X	X	ISO 14119
Colours and markings of operator interface devices	10.2, 10.3 and 10.4	X	X		IEC 60073 IEC 61310 (all parts)
Emergency stop	9.2.3.4.2	X			ISO 13850
Emergency stop devices	10.7	X	X		IEC 60947-5-5
Emergency switching off devices	10.8	X	X		IEC 60364-5-53
Controlgear – protection against ingress of contaminants, etc.	10.1.3 and 11.3	X	X	X	IEC 60529
Identification of conductors	13.2	X	X		IEC 62491
Verification	18	X	X	X	IEC 60364-6
Additional user requirements	Annex B		X	X	
Fault protection in TN systems	Annex A (A.1)	X			IEC 60364-4-41 IEC 60364-6
Fault protection in TT systems	Annex A (A.2)	X			IEC 60364-4-41 IEC 60364-6

Clauses and Subclauses of this part of IEC 60204 where action should be considered (shown by X) with respect to:

i) selection from the measures given;

ii) additional requirements;

iii) different requirements;

iv) examples of other standards that can be relevant.

Annex G
(informative)

Comparison of typical conductor cross-sectional areas

Table G.1 provides a comparison of the conductor cross-sectional areas of the American Wire Gauge (AWG) with square millimetres, square inches, and circular mils.

Table G.1 – Comparison of conductor sizes

Wire size	**Gauge No**	**Cross-sectional area**		**DC resistance of copper at 20 °C**	**Circular mils**
mm²	(AWG)	mm²	inches²	Ohms per km	
0,2		0,196	0,000 304	91,62	387
	24	0,205	0,000 317	87,60	404
0,3		0,283	0,000 438	63,46	558
	22	0,324	0,000 504	55,44	640
0,5		0,500	0,000 775	36,70	987
	20	0,519	0,000 802	34,45	1 020
0,75		0,750	0,001 162	24,80	1 480
	18	0,823	0,001 272	20,95	1 620
1,0		1,000	0,001 550	18,20	1 973
	16	1,31	0,002 026	13,19	2 580
1,5		1,500	0,002 325	12,20	2 960
	14	2,08	0,003 228	8,442	4 110
2,5		2,500	0,003 875	7,56	4 934
	12	3,31	0,005 129	5,315	6 530
4		4,000	0,006 200	4,700	7 894
	10	5,26	0,008 152	3,335	10 380
6		6,000	0,009 300	3,110	11 841
	8	8,37	0,012 967	2,093	16 510
10		10,000	0,001 550	1,840	19 735
	6	13,3	0,020 610	1,320	26 240
16		16,000	0,024 800	1,160	31 576
	4	21,1	0,032 780	0,829 5	41 740
25		25,000	0,038 800	0,734 0	49 338
	2	33,6	0,052 100	0,521 1	66 360
35		35,000	0,054 200	0,529 0	69 073
	1	42,4	0,065 700	0,413 9	83 690
50		47,000	0,072 800	0,391 0	92 756

The resistance for temperatures other than 20°C can be found using the formula:

$$R = R1\ [1 + 0{,}003\ 93\ (t - 20)]$$

where:

$R1$ is the resistance at 20 °C;

R is the resistance at a temperature t°C.

Annex H
(informative)

Measures to reduce the effects of electromagnetic influences

H.1 Definitions

For the purposes of Annex H only, the following terms and definitions apply.

H.1.1 apparatus

finished device or combination thereof made commercially available as a single functional unit, intended for the end user and liable to generate electromagnetic disturbance, or the performance of which is liable to be affected by such disturbance

H.1.2 fixed installation

particular combination of several types of apparatus and, where applicable, other devices, which are assembled, installed and intended to be used permanently at a predefined location

H.2 General

This Annex H provides recommendations to improve electromagnetic immunity and reduce emission of electromagnetic disturbances.

For EMC purposes, electrical equipment for machinery is deemed to be either apparatus or fixed installations. Where electrical safety and electromagnetic compatibility result in different requirements, electrical safety always has the higher priority.

Electromagnetic Interference (EMI) can disturb or damage process monitoring, control and automation systems. Currents due to lightning, switching operations, short-circuits and other electromagnetic phenomena can cause overvoltages and electromagnetic interference.

These effects can occur for example:

- where large conductive loops exist,
- where different electrical wiring systems are installed in common routes, e.g. power supply, communication, control or signal cables.

Cables carrying large currents with a high rate of change of current (di/dt) can induce overvoltages in other cables, which can influence or damage the connected electrical equipment.

H.3 Mitigation of electromagnetic interference (EMI)

H.3.1 General

Consideration should be given, in the design of the electrical equipment to the measures described below for reducing the electromagnetic influences on electrical equipment.

Only electrical equipment which meets the requirements of the appropriate EMC standards, or the EMC requirements of the relevant product standard, should be used.

H.3.2 Measures to reduce EMI

The following measures reduce electromagnetic interference:

a) The installation of surge protection devices and/or filters for equipment sensitive to electromagnetic influences is recommended to improve electromagnetic compatibility with regard to conducted electromagnetic phenomena;

b) Conductive sheaths (e.g. armouring, screens) of cables should be bonded to the protective bonding circuit;

c) Inductive loops should be avoided by selection of common routes for power, signal and data circuits wiring while maintaining circuit separation in accordance with Clause H.4;

d) Power cables should be kept separate from signal or data cables;

e) Where it is necessary for power and signal or data cables to cross each other they should be crossed at right-angles;

f) Use of cables with concentric conductors to reduce currents induced into the protective conductor;

g) Use of symmetrical multicore cables (e.g. screened cables containing separate protective conductors) for the electrical connections between motors and converters;

h) Use of signal and data cables according to the EMC requirements of the manufacturer's instructions;

i) Where screened signal or data cables are used, care should be taken to reduce current flowing through the screens of signal cables, or data cables, which are earthed. It can be necessary to install a by-pass conductor; see Figure H.1;

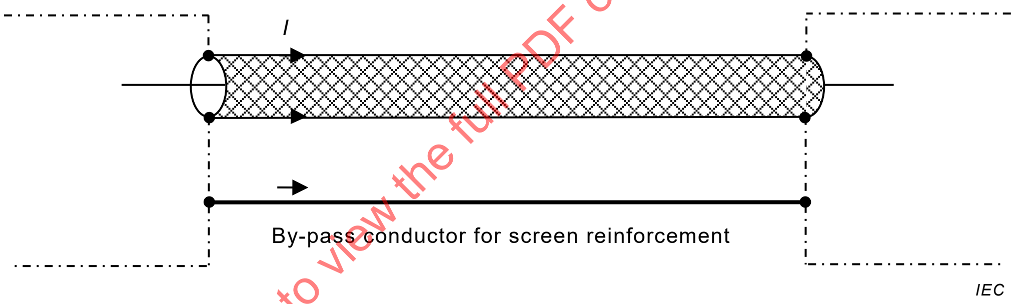


Figure H.1 – By-pass conductor for screen reinforcement

NOTE A good equipotential bonding of the components of the machine reduces the need for by-pass conductors.

j) Equipotential bonding connections should have an impedance as low as practicable by being as short as practicable and where applicable braided to conduct higher frequencies;

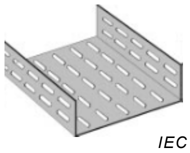
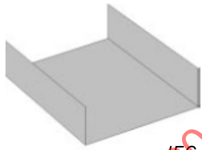
k) If electronic equipment requires a reference voltage at about earth potential in order to function correctly; this reference voltage is provided by the functional earthing conductor. For equipment operating at high frequencies, the connections shall be kept as short as practicable.

H.4 Separation and segregation of cables

Power cables and data cables which share the same route should be installed according to the requirements of this Annex H.

Where no other information is available, then the cable separation distance between the power and data cables should be in accordance with Table H.1 and Figure H.2.

Table H.1 – Minimum separation distances using metallic containment as illustrated in Figure H.2

Separation without metallic containment	$\boxed{A}$ **Mesh metallic containment** 	$\boxed{B}$ **Perforated metallic containment** 	$\boxed{C}$ **Solid metallic containment** 
≥ 200 mm	≥ 150 mm	≥ 100 mm	0 mm

$\boxed{A}$ Screening performance (DC-100 MHz) equivalent to welded mesh steel basket of mesh size 50 mm × 100 mm (excluding ladders). This screening performance is also achieved with steel tray even if the wall thickness is less than 1 mm and/or the evenly distributed perforated area is greater than 20 %.

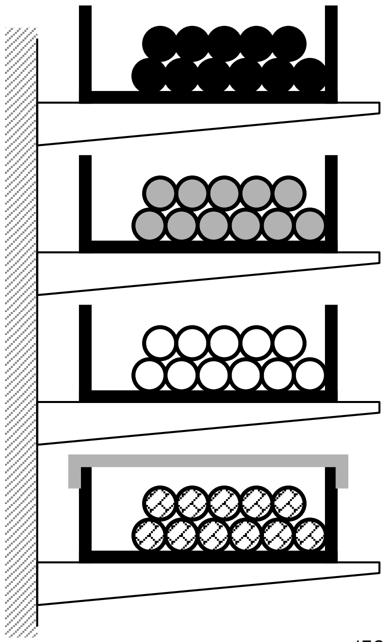
$\boxed{B}$ Screening performance (DC-100 MHz) equivalent to steel tray of at least 1 mm wall thickness and no more than 20 % evenly distributed perforated area. This screening performance is also achieved with screened power cables.

No part of the cable within the metallic containment should be less than 10 mm below the top of the metallic containment.

$\boxed{C}$ Screening performance (DC-100 MHz) equivalent to a steel conduit of at least 1 mm wall thickness. Separation specified is in addition to that provided by any divider/screen.

The minimum separation requirement specified in Table H.1 applies to the horizontal or vertical separation between adjacent cable trays or cable trunking systems. Where data cables and power supply cables are required to cross and required minimum separation cannot be maintained then the angle of their crossing should be maintained at 90 degrees on either side of the crossing for a distance no less than the applicable minimum separation requirement.

Figures H.2 and H.3 show examples of separation and segregation.



For distances see Table H.1.

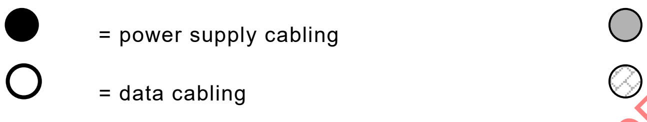
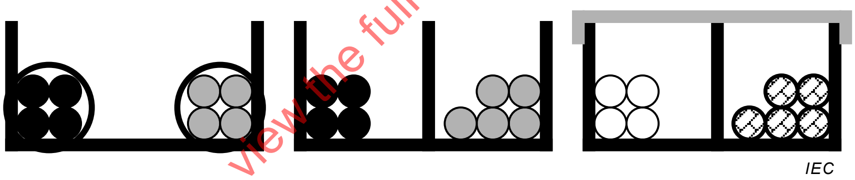


Figure H.2 – Examples of vertical separation and segregation



For distances see Table H.1.

Figure H.3 – Examples of horizontal separation and segregation

Usable space within the cable tray or cable trunking system should allow for an agreed quantity of additional cables to be installed (see Annex B). The cable bundle height should be lower than the side-walls of the cable tray or cable trunking system, as shown in Figure H.4 below. The overlapping lid of cable trunking systems improves the electromagnetic compatibility performance.

For a U-shape cable tray, the magnetic field decreases near the two corners. For this reason, deep side-walls are preferred.

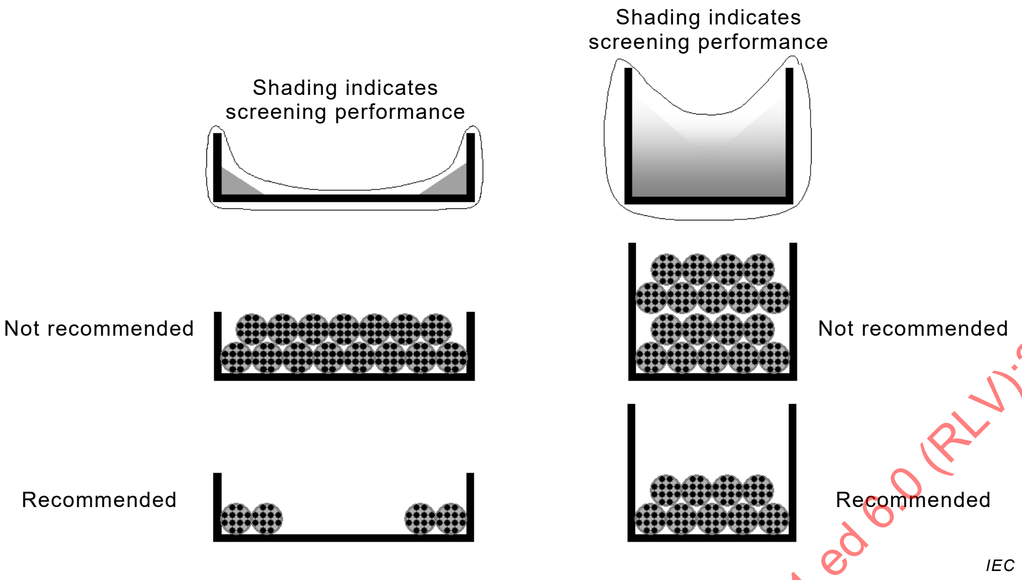


Figure H.4 – Cable arrangements in metal cable trays

Metal cable trays or cable trunking systems which are intended to provide electromagnetic compatibility shall always be connected to the local equipotential bonding system at both ends. For long distances, for example greater than 50 m, additional connections to the equipotential bonding system are recommended. All connections to the equipotential bonding system should have low impedance.

Where metal cable trays or cable trunking systems are constructed from several elements, care should be taken to ensure continuity by effective bonding between adjacent elements.

The shape of the metallic section should achieve continuity of shielding throughout its length. All interconnections should have low impedance; see Figure H.5.

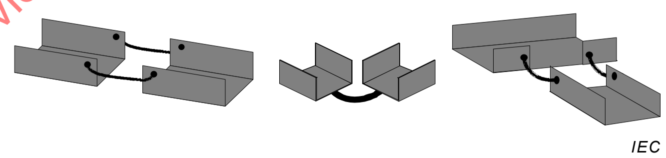
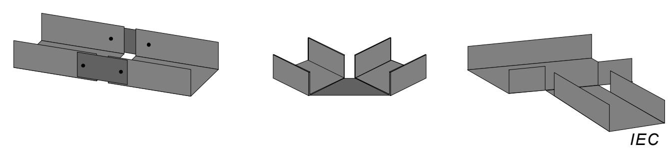
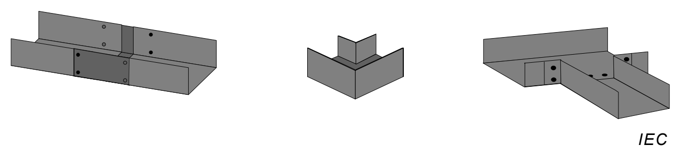
a	Non-conformant	
b	Conformant	
c	Recommended	

Figure H.5 – Connections between metal cable trays or cable trunking systems

Where metallic covers for metallic cable trunking systems are used, a cover over the full length is preferred. If that is not possible, the covers should be connected to the cable tray at least at both ends by short connections less than 10 cm, e.g. braided or mesh straps.

Figure H.6 shows a metal cable tray crossing a wall at which a fire barrier is to be installed. Where metal cable trays are required to be interrupted to pass through building structures, a low impedance interconnection should be provided between the two metallic sections. Regulations with respect to fire barriers take precedence over EMC considerations.

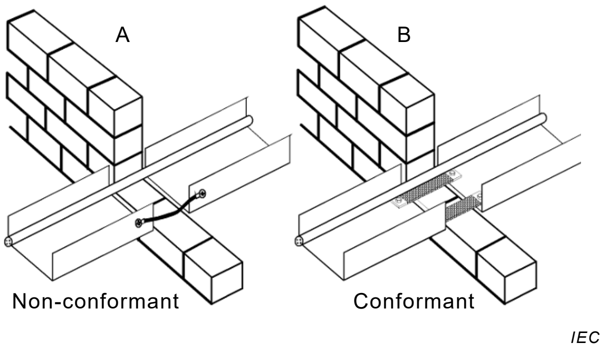


Figure H.6 – Interruption of metal cable trays at fire barriers

H.5 Power supply of a machine by parallel sources

Where a machine is supplied with power by parallel sources, see IEC 60364-1.

H.6 Supply impedance where a Power Drive System (PDS) is used

Connection of a PDS to too high a supply source impedance can lead to conducted emission problems.

Annex I
(informative)

Documentation / Information

A list of available standards applicable to documentation and information is provided in Table I.1.

Brief definitions of a set of internationally standardized document kinds are given in the publicly available database IEC 61355 DB (http://std.iec.ch/iec61355).

Table I.1 – Documentation / Information that can be applicable

Type of information for the electrical equipment	Recommended standard
Structuring principles	IEC 81346-1: *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules*
Structuring of documents	IEC 62023: *Structuring of technical information and documentation* (see note)
Parts list	IEC 62027: *Preparation of object lists, including parts lists*
List of documents	IEC 62027: *Preparation of object lists, including parts lists*
Specification of the properties of the electrical equipment	IEC PAS 62569-1: *Generic specification of information on products – Part 1: Principles and methods*
Instructions for handling, transportation and storage	IEC 82079-1: *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*
Instructions for installation, erection, assembling on site, dismantling, etc.	IEC 82079-1: *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*
Instructions for use	IEC 82079-1: *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*
Instructions for service and maintenance	IEC 82079-1: *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*
Reference designations	IEC 81346-1: *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules* and IEC 81346-2: *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 2: Classification of objects and codes for classes*
Terminal designations	IEC 61666: *Industrial systems, installations and equipment and industrial products – Identification of terminals within a system*
Designations of cables and cores	IEC 62491: *Industrial systems, installations and equipment and industrial products – Labelling of cables and cores*
Circuit diagrams	IEC 61082-1: *Preparation of documents used in electrotechnology – Part 1: Rules*
Layout of equipment and overall dimensions	IEC 61082-1: *Preparation of documents used in electrotechnology – Part 1: Rules*
Interconnection diagram, terminal list, cable list, cable tray layout	IEC 61082-1: *Preparation of documents used in electrotechnology – Part 1: Rules*
Spare parts list for a specified period	IEC 62027: *Preparation of object lists, including parts lists*
List of parameters (e.g. of converters)	(No standard exists)

Type of information for the electrical equipment	**Recommended standard**
List of tools	IEC 82079: *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*
Identification systems	IEC 62507-1: *Identification systems enabling unambiguous information interchange – Requirements – Part 1: Principles and methods*
NOTE For simple equipment IEC 62023 allows all information to be contained within one single document.	

Bibliography

IEC 60034-5, *Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification*

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

IEC 60038:2009, *IEC standard voltages*

IEC 60050, *International Electrotechnical Vocabulary* (available at <http://www.electropedia.org>)

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

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60204-11:2000, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV*

IEC 60204-31:2013, *Safety of machinery – Electrical equipment of machines – Part 31: Particular safety and EMC requirements for sewing machines, units and systems*

IEC 60204-32:2008, *Safety of machinery – Electrical equipment of machines – Part 32: Requirements for hoisting machines*

IEC 60204-33:2009, *Safety of machinery – Electrical equipment of machines – Part 33: Requirements for semiconductor fabrication equipment*

IEC 60216 (all parts), *Electrical insulating materials – Thermal endurance properties*

IEC 60228:2004, *Conductors of insulated cables*

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*

IEC 60287 (all parts), *Electric cables – Calculation of the current rating*

IEC 60320-1, *Appliance couplers for household and similar general purposes –Part 1: General requirements*

IEC 60332 (all parts), *Tests on electric and optical fibre cables under fire conditions*

IEC 60335 (all parts), *Household and similar electrical appliances – Safety*

IEC 60364 (all parts), *Low-voltage electrical installations*

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

IEC TR 60755, *General requirements for residual current operated protective devices*

IEC 60757:1983, *Code for designation of colours*

IEC TR 60890, *A method of temperature-rise verification of low-voltage switchgear and controlgear assemblies by calculation*

IEC 60909-0:2001, *Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents*

IEC TR 60909-1:2002, *Short-circuit currents in three-phase a.c. systems – Part 1: Factors for the calculation of short-circuit currents according to IEC 60909-0*

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-4-1, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

IEC 60947-5-2:2007, *Low-voltage switchgear and controlgear – Part 5-2: Control circuit devices and switching elements – Proximity switches*

IEC 60947-5-8, *Low-voltage switchgear and controlgear – Part 5-8: Control circuit devices and switching elements – Three-position enabling switches*

IEC 60947-7-1:2009, *Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

IEC 61000-5-2:1997, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling*

IEC 61000-6-1:2005, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards: Immunity for residential, commercial and light-industrial environments*

IEC 61000-6-2:2005, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

IEC 61000-6-3:2006, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

IEC 61000-6-4:1997, *Electromagnetic compatibility (EMC) – Part 6: Generic standards – Section 4: Emission standard for industrial environments*

IEC 61082-1:2014, *Preparation of documents used in electrotechnology – Part 1: Rules*

IEC 61084 (all parts), *Cable trunking and ducting systems for electrical installations*

IEC 61175, *Industrial systems, installations and equipment and industrial products – Designation of signals*

IEC 61180 (all parts), *High-voltage test techniques for low-voltage equipment*

IEC TR 61200-53:1994, *Electrical installation guide – Part 53: Selection and erection of electrical equipment – Switchgear and controlgear*

IEC 61355, *Collection of standardized and established document kinds* (available at http://std.iec.ch/iec61355)

IEC 61496-1:2004, *Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests*

IEC 61506, *Industrial-process measurement and control – Documentation of application software*

IEC 61557 (all parts), *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1500 V d.c. – Equipment for testing, measuring or monitoring of protective measures*

IEC 61558-2-2, *Safety of power transformers, power supplies, reactors and similar products – Part 2-2: Particular requirements and tests for control transformers and power supplies incorporating control transformers*

IEC 61558-2-16, *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V – Part 2-16: Particular requirements and tests for switch mode power supply units and transformers for switch mode power supply units*

IEC 61643-12:2008, *Low-voltage surge protective devices – Part 12: Surge protective devices connected to low-voltage power distribution systems – Selection and application principles*

IEC 61666, *Industrial systems, installations and equipment and industrial products – Identification of terminals within a system*

IEC 61800 (all parts), *Adjustable speed electrical power drive systems*

IEC TR 61912-1:2007, *Low-voltage switchgear and controlgear – Overcurrent protective devices – Part 1: Application of short-circuit ratings*

IEC 62020, *Electrical accessories – Residual current monitors for household and similar uses (RCMs)*

IEC 62027:2011, *Preparation of object lists, including parts lists*

IEC 62305-1:2010, *Protection against lightning – Part 1: General principles*

IEC 62305-4:2010, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

IEC 62491, *Industrial systems, installations and equipment and industrial products – Labelling of cables and cores*

IEC 62507-1, *Identification systems enabling unambiguous information interchange – Requirements – Part 1: Principles and methods*

IEC 62745[2], *Safety of machinery – Requirements for the interfacing of cableless controllers to machinery*

IEC PAS 62569-1, *Generic specification of information on products – Part 1: Principles and methods*

IEC 81346-1:2009, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules*

IEC 81346-2:2009, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 2: Classification of objects and codes for classes*

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2 Under consideration.

IEC 82079-1:2012, *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*

IEC Guide 106:1996, *Guide for specifying environmental conditions for equipment performance rating*

ISO 3864-1:2011, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

ISO 7000:2014, *Graphical symbols for use on equipment – Registered symbols*

ISO 12100:2010, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO 13732-1, *Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces – Part 1:Hot surfaces*

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

ISO 14118:2000, *Safety of machinery – Prevention of unexpected start-up*

ISO 14122-1:2001, *Safety of machinery – Permanent means of access to machinery – Part 1: Choice of fixed means of access between two levels*
ISO 14122-1:2001/AMD1:2010

ISO 14122-2:2001, *Safety of machinery – Permanent means of access to machinery – Part 2: Working platforms and walkways*
ISO 14122-2:2001/AMD1:2010

ISO 14122-3:2001, *Safety of machinery – Permanent means of access to machinery – Part 3: Stairs, stepladders and guard-rails*
ISO 14122-3:2001/AMD1:2010

CENELEC HD 516 S2, *Guide to use of low-voltage harmonized cables*

EN 50160:2010, *Voltage characteristics of electricity supplied by public electricity networks*
EN 50160:2010/AMD1:2015

UL 508A,*UL Standard for Safety for Industrial Control Panels*, second Edition, 2013 revised 2014.

NFPA 79, *Electrical Standard for Industrial Machinery*, 2015 edition.

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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SÉCURITÉ DES MACHINES – ÉQUIPEMENT ÉLECTRIQUE DES MACHINES –

Partie 1: Exigences générales

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La Norme internationale IEC 60204-1 a été établie par le comité d'études 44 de l'IEC: Sécurité des machines – Aspects électrotechniques.

Cette sixième édition annule et remplace la cinquième édition parue en 2005. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) exigences supplémentaires pour traiter des applications impliquant des systèmes d'entraînements électriques de puissance (PDS);
b) exigences révisées concernant la compatibilité électromagnétique (CEM);
c) clarification des exigences de protection contre les surintensités;

d) exigences pour la détermination des caractéristiques du courant de court-circuit de l'équipement électrique;

e) révision des exigences de liaisons de protection et la terminologie;

f) réorganisation et révision à l'Article 9, notamment les exigences relatives à la suppression sûre du couple du PDS, à l'arrêt d'urgence, et à la protection du circuit de commande;

g) révision des symboles pour les organes de commande des appareils de commande;

h) révision des exigences sur la documentation technique;

i) mise à jour générale des conditions nationales particulières, des normes et des références bibliographiques.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
44/765/FDIS	44/771/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60204, publiées sous le titre général *Sécurité des machines – Équipement électrique des machines*, peut être consultée sur le site web de l'IEC.

Les différentes pratiques suivantes, à caractère moins permanent, existent dans les pays indiqués ci-après:

4.3.1 Les caractéristiques de la tension fournie par les réseaux de distribution publics en Europe sont données dans l'EN 50160:2010.

5.1: Exception non admise (États-Unis).

5.1: Les schémas TN-C ne sont pas autorisés dans les installations à basse tension dans les bâtiments (Norvège).

5.2: Les bornes pour le raccordement des conducteurs de mise à la terre pour des raisons de protection peuvent être identifiées par la couleur verte, les lettres “G” ou “GR”, “GRD” ou “GND”, ou les mots “ground” ou "grounding" ou le symbole graphique IEC 60417-5019:2006-08 ou toute combinaison (États-Unis).

6.3.3 b), 13.4.5 b), 18.2.1: Les schémas TT de puissance ne sont pas admis (États-Unis).

6.3.3, 18.2, Annexe A: Les schémas TN ne sont pas utilisés. Les schémas TT sont la norme nationale (Japon).

6.3.3 b): L'utilisation de dispositifs différentiels résiduels avec un courant de fonctionnement résiduel assigné de 1 A au maximum est obligatoire dans les schémas TT, ces dispositifs servant de moyen de protection en cas de défaut par une coupure automatique de l'alimentation (Italie).

7.2.3 La coupure du conducteur neutre est obligatoire dans un schéma TN-S (France et Norvège).

7.2.3 Troisième alinéa: la distribution d'un conducteur neutre dans un schéma IT n'est pas admise (États-Unis et Norvège).

7.10: Pour l’évaluation des caractéristiques assignées en court-circuit, les exigences du document UL 508A Supplement SB, peuvent être utilisées (États-Unis).

8.2.2 Voir IEC 60364-5-54:2011, Annexe E, Liste des notes concernant certains pays.

9.1.2 La tension nominale maximale d'un circuit de commande en courant alternatif est de 120 V (États-Unis).

12.2: Seuls les conducteurs à âme câblée sont admis sur les machines, sauf pour les conducteurs massifs de section 0,2 mm^2 dans les enveloppes (États-Unis).

12.2: Le conducteur de circuit de puissance le plus faible admis sur les machines est de 0,82 mm^2 (AWG 18) pour des conducteurs multifilaires ou dans les enveloppes (États-Unis).

Tableau 5: La section est spécifiée dans la NFPA 79 en dimensions américaines (AWG) (États-Unis). Voir Annexe G.

13.2.2 Pour le conducteur de protection, la couleur VERTE (avec ou sans bandes JAUNES) est utilisée comme équivalent à la combinaison bicolore VERT-et-JAUNE (États-Unis et Canada).

13.2.3 La couleur BLANC ou GRIS est utilisée pour repérer les conducteurs neutres mis à la terre au lieu de la couleur BLEU (États-Unis et Canada).

15.2.2 Premier alinéa: Valeur maximale entre conducteurs 150 V (États-Unis).

15.2.2 Deuxième alinéa, 5ème tiret: Le courant assigné à pleine charge des circuits d'éclairage ne dépasse pas 15 A (États-Unis).

16.4: Exigences de marquage de plaque signalétique (États-Unis).

A.2.2.2: La valeur maximale admissible de R_A est réglementée (par exemple, lorsque $U_o \geq 300$ V, R_A doit être inférieure à 10 Ω, lorsque $U_o < 300$ V, R_A doit être inférieure à 100 Ω, U_o est la tension phase-terre alternative nominale en volts (V) (Japon).

A.2.2.2: La valeur maximale admissible de R_A est 83 Ω (Pays-Bas).

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives à la publication recherchée. A cette date, la publication sera

- reconduite,
- supprimée,
- remplacée par une édition révisée, ou
- amendée.

IMPORTANT – Le logo *"colour inside"* qui se trouve sur la page de couverture de cette publication indique qu'elle contient des couleurs qui sont considérées comme utiles à une bonne compréhension de son contenu. Les utilisateurs devraient, par conséquent, imprimer cette publication en utilisant une imprimante couleur.

INTRODUCTION

La présente partie de l'IEC 60204 fournit les exigences et recommandations relatives à l'équipement électrique des machines en vue d'améliorer:

– la sécurité des personnes et des biens;
– la cohérence de réponse des commandes;
– la facilité de fonctionnement et de la maintenance.

Des préconisations complémentaires sur l'utilisation de la présente partie de l'IEC 60204 sont données dans l'Annexe F.

La Figure 1 est fournie en tant qu'aide pour la compréhension des relations entre les différents éléments d'une machine et ses équipements associés. La Figure 1 est un schéma d'ensemble d'une machine type et de ses équipements associés représentant les divers éléments de l'équipement électrique explicités dans la présente partie de l'IEC 60204. Les chiffres entre parenthèses ( ) renvoient aux Articles et Paragraphes de la présente partie de l'IEC 60204. La Figure 1 part du principe que la totalité des éléments pris ensemble y compris les moyens de protection, outillages/auxiliaires, logiciels et la documentation constituent la machine et que celle-ci ou plusieurs machines fonctionnant ensemble avec habituellement au moins un niveau de supervision constituent une cellule ou un système de production.

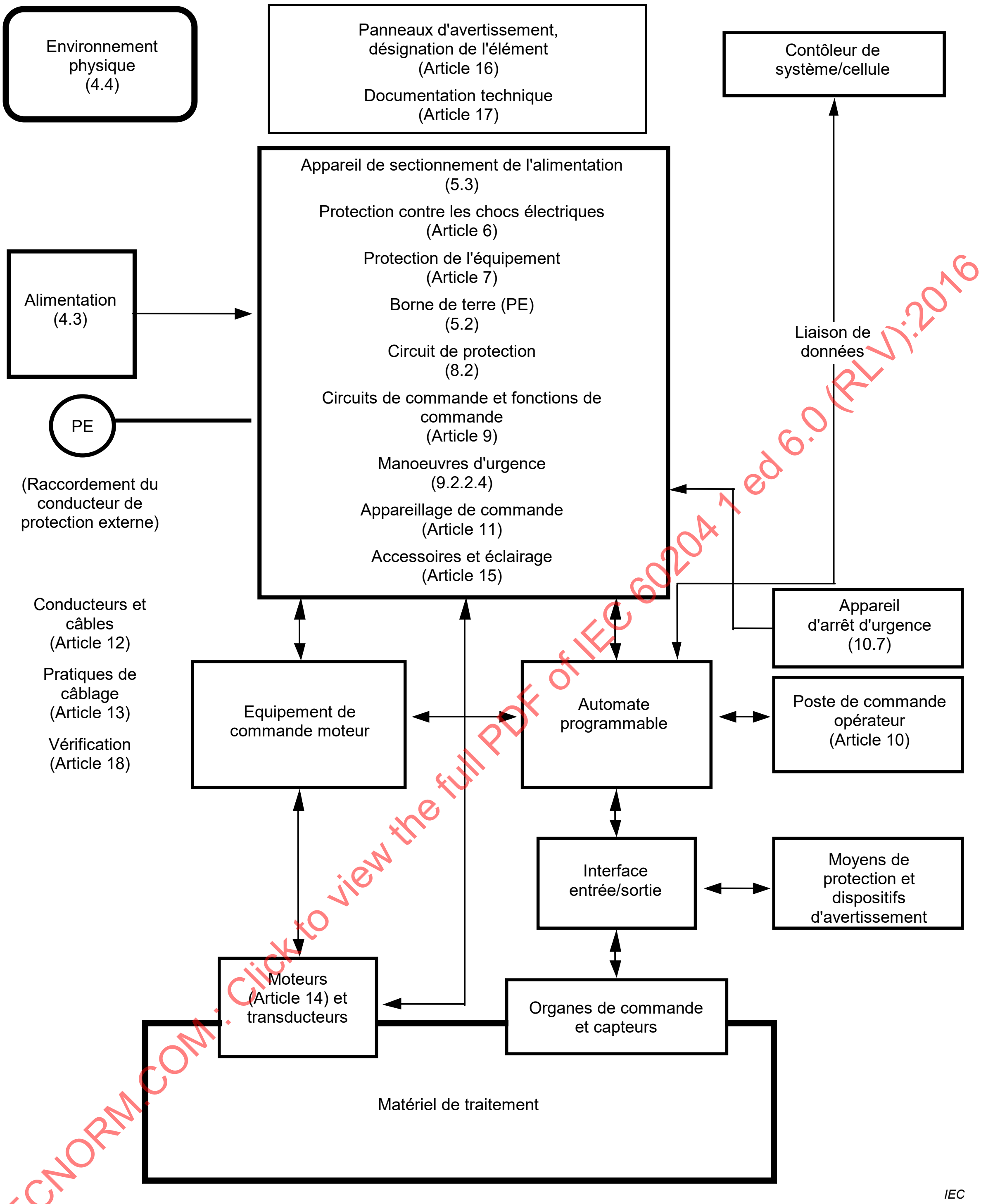


Figure 1 – Schéma d'ensemble d'une machine type

SÉCURITÉ DES MACHINES – ÉQUIPEMENT ÉLECTRIQUE DES MACHINES –

Partie 1: Exigences générales

1 Domaine d'application

La présente partie de l'IEC 60204 s'applique aux équipements et systèmes électriques, électroniques et électroniques programmables des machines non portables à la main en fonctionnement y compris un groupe de machines fonctionnant ensemble d'une manière coordonnée.

NOTE 1 La présente partie de l'IEC 60204 est une norme d'application et n'est pas destinée à limiter ou inhiber les progrès technologiques.

NOTE 2 Dans la présente partie de l'IEC 60204, le terme *électrique* signifie électrique, électronique et électronique programmable (c'est-à-dire qu'un *équipement électrique* signifie un équipement électrique, électronique et électronique programmable).

NOTE 3 Dans le cadre de la présente partie de l'IEC 60204, le terme *personne* s'applique à n'importe quel individu et indique les personnes désignées et averties par l'utilisateur ou son ou ses agents pour l'utilisation ou la maintenance de la machine concernée.

L'équipement couvert par la présente partie de l'IEC 60204 commence au point de connexion de l'alimentation à l'équipement électrique de la machine (voir 5.1).

NOTE 4 Les exigences concernant l'installation de l'alimentation électrique sont données dans la série IEC 60364.

La présente partie de l'IEC 60204 est applicable à l'équipement électrique ou aux parties de l'équipement électrique qui fonctionnent sous des tensions d'alimentation nominales ne dépassant pas 1 000 V en courant alternatif ou 1 500 V en courant continu et pour des fréquences nominales d'alimentation ne dépassant pas 200 Hz.

NOTE 5 Les informations sur l'équipement électrique ou les parties de l'équipement électrique qui fonctionnent sous des tensions d'alimentation nominales plus élevées peuvent être consultées dans l'IEC 60204-11.

La présente partie de l'IEC 60204 ne couvre pas toutes les exigences (par exemple, la protection, le verrouillage ou la commande) qui sont nécessaires ou exigées par d'autres normes ou réglementations destinées à protéger les personnes contre des dangers autres que les dangers électriques. Chaque type de machine répond à des exigences propres à prendre en compte pour assurer la sécurité appropriée.

La présente partie de l'IEC 60204 inclut spécifiquement, sans toutefois s'y limiter, l'équipement électrique des machines telles que définies en 3.1.40.

NOTE 6 L'Annexe C donne une liste d'exemples de machines dont l'équipement électrique peut être couvert par la présente partie de l'IEC 60204.

La présente partie de l'IEC 60204 ne spécifie pas les exigences complémentaires et particulières qui peuvent s'appliquer à l'équipement électrique des machines qui, par exemple:

– sont destinées à être utilisées à l'air libre (c'est-à-dire à l'extérieur de bâtiments ou d'autres structures de protection);
– utilisent, traitent ou produisent des matériaux potentiellement explosifs (par exemple de la peinture ou de la sciure);

– sont destinées à être utilisées dans des atmosphères explosibles ou potentiellement inflammables;
– présentent des risques particuliers lors de la fabrication ou de l'utilisation de certains matériaux;
– sont destinées à être utilisées dans les mines;
– sont des machines, unités ou systèmes de couture (couverts par l'IEC 60204-31);
– sont des appareils de levage (couverts par l'IEC 60204-32).
– sont des équipements de fabrication des semi-conducteurs (couverts par l'IEC 60204-33).

Les circuits de puissance, dans lesquels l'énergie électrique est utilisée directement comme outil de travail, sont exclus de la présente partie de l'IEC 60204.

2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60034-1, *Machines électriques tournantes – Partie 1: Caractéristiques assignées et caractéristiques de fonctionnement*

IEC 60072 (toutes les parties), *Dimensions et séries de puissances des machines électriques tournantes*

IEC 60309-1, *Prises de courant pour usages industriels – Partie 1: Règles générales*

IEC 60364-1, *Installations électriques à basse tension – Partie 1: Principes fondamentaux, détermination des caractéristiques générales, définitions*

IEC 60364-4-41:2005, *Installations électriques à basse tension – Partie 4-41: Protection pour assurer la sécurité – Protection contre les chocs électriques*

IEC 60364-4-43:2008, *Installations électriques à basse tension – Partie 4-43: Protection pour assurer la sécurité – Protection contre les surintensités*

IEC 60364-5-52:2009, *Installations électriques à basse tension – Partie 5-52: Choix et mise en œuvre des matériels électriques – Canalisations*

IEC 60364-5-53:2001, *Installations électriques des bâtiments – Partie 5-53: Choix et mise en œuvre des matériels électriques – Sectionnement, coupure et commande*
IEC 60364-5-53:2001/AMD1:2002

IEC 60364-5-54:2011, *Installations électriques basse-tension – Partie 5-54: Choix et mise en œuvre des matériels électriques – Installations de mise à la terre et conducteurs de protection*

IEC 60417, *Symboles graphiques utilisables sur le matériel.* Disponible à l'adresse: http://www.graphical-symbols.info/equipment

IEC 60445:2010, *Principes fondamentaux et de sécurité pour les interfaces homme-machines, le marquage et l'identification – Identification des bornes de matériels, des extrémités de conducteurs et des conducteurs*

IEC 60529, *Degrés de protection procurés par les enveloppes (Code IP)*

IEC 60664-1, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 1: Principes, exigences et essais*

IEC 60947-2, *Appareillage à basse tension – Partie 2: Disjoncteurs*

IEC 60947-3, *Appareillage à basse tension – Partie 3: Interrupteurs, sectionneurs, interrupteurs-sectionneurs et combinés-fusibles*

IEC 60947-5-1:2003, *Appareillage à basse tension – Partie 5-1: Appareils et éléments de commutation pour circuits de commande – Appareils électromécaniques pour circuits de commande*
IEC 60947-5-1:2003/AMD1:2009

IEC 60947-5-5, *Appareillage à basse tension – Partie 5-5: Appareils et éléments de commutation pour circuits de commande – Appareil d'arrêt d'urgence électrique à accrochage mécanique*

IEC 60947-6-2, *Appareillage à basse tension – Partie 6-2: Matériels à fonctions multiples – Appareils (ou matériel) de connexion de commande de protection (ACP)*

IEC 61140, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

IEC 61310 (toutes les parties), *Sécurité des machines – Indication, marquage, manœuvre*

IEC 61439-1, *Ensembles d'appareillage à basse tension – Partie 1: Règles générales*

IEC 61558-1:2005, *Sécurité des transformateurs, alimentations, bobines d'inductance et produits analogues – Partie 1: Exigences générales et essais*
IEC 61558-1:2005/AMD1:2009

IEC 61558-2-6, *Sécurité des transformateurs, bobines d'inductance, blocs d'alimentation et produits analogues pour des tensions d'alimentation jusqu'à 1 100 V – Partie 2-6: Règles particulières et essais pour les transformateurs de sécurité et les blocs d'alimentation incorporant des transformateurs de sécurité*

IEC 61984, *Connecteurs – Exigences de sécurité et essais*

IEC 62023, *Structuration des informations et de la documentation techniques*

IEC 62061, *Sécurité des machines – Sécurité fonctionnelle des systèmes de commande électriques, électroniques et électroniques programmables relatifs à la sécurité*

ISO 7010:2011, *Symboles graphiques – Couleurs de sécurité et signaux de sécurité – Signaux de sécurité enregistrés*

ISO 13849-1, *Sécurité des machines – Parties des systèmes de commande relatives à la sécurité – Partie 1: Principes généraux de conception*

ISO 13849-2, *Sécurité des machines – Parties des systèmes de commande relatives à la sécurité – Partie 2: Validation*

ISO 13850:2006, *Sécurité des machines – Fonction d'arrêt d'urgence – Principes de conception*

3 Termes, définitions et abréviations

3.1 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

3.1.1
organe de commande
partie d'un appareil sur laquelle une action externe doit être appliquée

Note 1 à l'article: L'organe de commande peut prendre la forme d'une poignée, d'un bouton, d'un bouton-poussoir, d'une roulette, d'un plongeur, etc.

Note 2 à l'article: Certains organes n'exigent pas d'effort extérieur, mais seulement une action, par exemple les écrans tactiles.

Note 3 à l'article: Voir aussi 3.1.39.

3.1.2
température ambiante
température de l'air ou du milieu à l'emplacement où le matériel doit être utilisé

3.1.3
barrière
élément assurant la protection contre les contacts avec les parties actives dans toute direction habituelle d'accès

3.1.4
protection principale
protection contre les chocs électriques en l'absence de défaut

Note 1 à l'article: Appelée précédemment "protection contre les contacts directs".

[SOURCE: IEC 60050-195:1998, 195-06-01, modifié – La note a été ajoutée.]

3.1.5
chemin de câbles
tablette
support de câbles constitué d'une base continue avec des rebords, mais ne comportant pas de couvercle

Note 1 à l'article: Un chemin de câbles peut être perforé ou non perforé.

[SOURCE: IEC 60050-826:2004, 826-15-08]

3.1.6
système de goulottes
ensemble d'enveloppes fermées, munies d'un fond avec un couvercle amovible et destiné à la protection complète des conducteurs isolés ou des câbles

3.1.7
concomitant
agissant ou fonctionnant ensemble (mais pas nécessairement en synchronisme)

3.1.8
fil conducteur
barre conductrice
fil conducteur ou barre conductrice d'un réseau d'alimentation avec collecteur de courant coulissant

3.1.9
conduit
élément d'un système de canalisation fermé, de section droite circulaire ou non, destiné aux conducteurs et/ou câbles isolés dans les installations électriques

Note 1 à l’article: Il convient que les conduits soient suffisamment fermés de manière que les conducteurs et/ou les câbles isolés puissent être uniquement tirés et non insérés latéralement.

[SOURCE: IEC 60050-442:1998, 442-02-03, modifié – La définition a été modifiée et la note a été ajoutée.]

3.1.10
circuit de commande, <d’une machine>
circuit utilisé pour la commande, y compris la surveillance, d'une machine et de l'équipement électrique

3.1.11
appareil de commande
appareil raccordé au circuit de commande et servant à commander le fonctionnement de la machine

EXEMPLE Capteur de position, auxiliaire manuel de commande, relais, contacteur ou électrodistributeur.

3.1.12
poste de commande
poste de commande opérateur
ensemble constitué par un ou plusieurs organes de commande (voir 3.1.1) fixés sur le même panneau ou situés dans la même enveloppe

Note 1 à l’article: Un poste de commande peut aussi contenir des appareils associés, par exemple: potentiomètres, lampes de signalisation, appareils de mesure, dispositifs d'affichage, etc.

[SOURCE: IEC 60050-441:1984, 441-12-08, modifié – Le second terme privilégié a été ajouté, le mot "auxiliaires" a été remplacé par "organes" dans la définition et la note a été ajoutée.]

3.1.13
appareillage de commande
appareils de connexion et leur combinaison avec des appareils de commande, de mesure, de protection et de réglage qui leur sont associés, ainsi que les ensembles de tels appareils avec les connexions, les accessoires, les enveloppes et les supports correspondants, destinés en principe à la commande des appareils utilisateurs d'énergie électrique

[SOURCE: IEC 60050-441:1984, 441-11-03]

3.1.14
arrêt contrôlé
arrêt du mouvement d'une machine en maintenant la puissance aux organes de commande durant la procédure d'arrêt

3.1.15
contact direct
contact de personnes ou d'animaux domestiques ou d'élevage avec des parties actives

Note 1 à l’article: Voir 3.1.4.

[SOURCE: IEC 60050-826:2004,826-12-03, modifié – La note a été ajoutée.]

3.1.16
manœuvre positive d'ouverture, <d'un élément de contact >
accomplissement de la séparation des contacts résultant directement d'un mouvement de l'organe de commande et effectué au moyen de pièces non élastiques (par exemple, sans l'intermédiaire de ressorts)

[SOURCE: IEC 60947-5-1:2003, K.2.2]

3.1.17
canalisation
canal fermé destiné expressément au support et à la protection de conducteurs, de câbles et de barres électriques

Note 1 à l'article: Les conduits (voir 3.1.9), les systèmes de goulottes (voir 3.1.6) et les canaux enterrés sont des types de canalisations.

3.1.18
terre
terre locale
partie de la Terre en contact électrique avec une prise de terre, et dont le potentiel électrique n'est pas nécessairement égal à zéro

[SOURCE: IEC 60050-195:1998,195-01-03]

3.1.19
zone de service électrique
local ou emplacement pour équipements électriques dont l'accès est destiné à être restreint aux personnes qualifiées ou averties, par ouverture d'une porte ou retrait d'une barrière, sans l'aide d'une clé ou d'un outil et qui est clairement marqué à l'aide de panneaux de mise en garde appropriés

3.1.20
équipement électronique
partie d'un équipement électrique comprenant des circuits dépendants pour son fonctionnement de dispositifs et composants électroniques

3.1.21
appareil d'arrêt d'urgence
appareil pour circuit de commande manœuvré manuellement et utilisé pour provoquer un arrêt d'urgence

Note 1 à l'article: Voir 9.2.3.4.2.

[SOURCE: ISO 13850:2006, 3.2, modifié – La note a été ajoutée.]

3.1.22
appareil de coupure d'urgence
appareil de commande manœuvré manuellement et destiné à couper l'alimentation électrique ou à déclencher la coupure de l'alimentation électrique de tout ou partie d'une installation s'il y a risque de choc électrique ou tout autre risque d'origine électrique

Note 1 à l'article: Voir 9.2.3.4.3.

3.1.23
zone fermée de service électrique
local ou emplacement pour équipements électriques dont l'accès est destiné à être restreint aux personnes qualifiées ou averties par l'utilisation d'une clé ou d'un outil permettant d'ouvrir une porte ou de retirer une barrière, et qui est clairement marqué à l'aide de panneaux de mise en garde appropriés

3.1.24
enveloppe
élément procurant la protection des équipements contre certaines influences externes et, dans toutes les directions, la protection principale comme protection contre les contacts directs

Note 1 à l’article: La définition existante issue du VEI nécessite les explications suivantes dans le cadre du domaine d'application de la présente partie de l'IEC 60204:

a) Les enveloppes assurent la protection de personnes ou d'animaux domestiques ou d'élevage contre l'accès aux parties dangereuses.

b) Les barrières, les formes des ouvertures, ou tout autre moyen approprié pour prévenir ou limiter la pénétration des calibres d'essai spécifiés, soit fixés sur l'enveloppe, soit formés par l'appareillage sous enveloppe, sont considérés comme faisant partie de l'enveloppe, sauf s'ils peuvent être démontés sans l'aide d'une clé ou d'un outil.

c) Une enveloppe peut être:

– une armoire ou un coffret, monté sur la machine, ou séparé de la machine;

– un compartiment, constitué par un espace fermé dans la structure de la machine.

[SOURCE: IEC 60050-195:1998, 195-02-35, modifié – La définition a été modifiée.]

3.1.25
équipement électrique
éléments utilisés dans le cadre d'une installation électrique par les machines ou des parties de machines, par exemple, matériel, accessoires, dispositifs, composants, appareils, fixations, instruments et analogues

3.1.26
liaison équipotentielle
mise en œuvre de liaisons électriques entre parties conductrices pour réaliser l'équipotentialité

[SOURCE: IEC 60050-195:1998, 195-01-10]

3.1.27
partie conductrice accessible
masse, <dans une installation électrique>
partie conductrice d'un matériel électrique, susceptible d'être touchée, et qui n'est pas normalement sous tension, mais qui peut le devenir dans des conditions de défaut

[SOURCE: IEC 60050-826:2004, 826-12-10, modifié – La définition a été modifiée.]

3.1.28
élément conducteur étranger
partie conductrice ne faisant pas partie de l'installation électrique et susceptible d'introduire un potentiel électrique, généralement celui d’une terre locale

[SOURCE: IEC 60050-195:1998,195-06-11]

3.1.29
défaillance
cessation de l'aptitude d'un dispositif à accomplir une fonction requise

Note 1 à l’article: Après défaillance, le dispositif présente un défaut.

Note 2 à l’article: "Une "défaillance" est un passage d'un état à un autre, par opposition à une "panne", qui est un état.

Note 3 à l’article: La notion de défaillance, telle qu'elle est définie, ne s'applique pas à un dispositif constitué seulement de logiciel.

Note 4 à l'article: En pratique, les termes panne et défaillance sont souvent utilisés comme synonymes.

[SOURCE: IEC 60050-191:1990,191-04-01]

3.1.30
panne
dérangement, <en télécommunication>
état d'une entité inapte à accomplir une fonction requise, non comprise l'inaptitude due à la maintenance préventive ou à d'autres actions programmées, ou due à un manque de moyens extérieurs

Note 1 à l'article: Une panne est souvent la conséquence d'une défaillance de l'entité elle-même, mais elle peut exister sans défaillance préalable.

Note 2 à l'article: En anglais, le terme "fault" et sa définition sont identiques à ceux donnés dans l'IEC 60050-191:1990, 191-05-01. Dans le domaine des machines, le terme français "défaut" et le terme allemand "Fehler" sont utilisés en lieu et place des termes "panne" et "Fehlzustand" qui accompagnent cette définition.

3.1.31
protection en cas de défaut
protection contre les chocs électriques dans des conditions de premier défaut

Note 1 à l'article: Appelée précédemment "protection contre les contacts indirects".

[SOURCE: IEC 60050-195:1998,195-06-02, modifié – La note a été ajoutée.]

3.1.32
liaison fonctionnelle
liaison équipotentielle nécessaire pour le fonctionnement correct de l'équipement électrique

3.1.33
danger
source potentielle de blessures physiques ou d'atteinte à la santé

Note 1 à l'article: Le terme "danger" peut être qualifié de manière à définir son origine (par exemple, danger mécanique, danger électrique) ou la nature du dommage potentiel (par exemple, danger de choc électrique, danger de coupure, danger d'intoxication, danger d'incendie).

Note 2 à l'article: Le danger envisagé dans cette définition:

– ou bien est présent en permanence pendant l'utilisation normale de la machine (par exemple, déplacement d'éléments mobiles dangereux, arc électrique pendant une phase de soudage, mauvaise posture, émission de bruit, température élevée);
– ou bien peut apparaître de manière inattendue (par exemple, explosion, danger d'écrasement résultant d'une mise en marche intempestive/inattendue, projection résultant d'une rupture, chute résultant d'une accélération ou d'une décélération).

[SOURCE: ISO 12100:2010, 3.6, modifié – Le terme "phénomène dangereux" a été remplacé par "danger" dans la définition elle-même et dans les notes et la Note 3 a été supprimée.]

3.1.34
contact indirect
contact de personnes ou d'animaux avec des parties conductrices accessibles mises sous tension à la suite d'un défaut

Note 1 à l'article: Voir 3.1.31.

[SOURCE: IEC 60050-826:2004, 826-12-04, modifié – La définition a été modifiée.]

3.1.35
système d'alimentation par induction
système de transfert de puissance par induction comportant un dispositif convertisseur et un dispositif conducteur, le long desquels un ou plusieurs détecteurs ou convertisseurs

détecteurs associés peuvent se déplacer, sans aucun contact galvanique ou mécanique, afin de transférer l'énergie électrique, par exemple à une machine mobile

Note 1 à l'article: Le dispositif conducteur et le détecteur sont analogues respectivement au primaire et au secondaire d'un transformateur.

3.1.36
personne avertie, <en électricité>
personne suffisamment informée ou surveillée par une personne qualifiée en électricité pour lui permettre de percevoir les risques et d'éviter les dangers que peut présenter l'électricité

[SOURCE: IEC 60050-826:2004, 826-18-02, modifié – “une personne qualifiée en électricité” a été utilisée pour remplacer “des personnes qualifiées en électricité”]

3.1.37
verrouillage
configuration de dispositifs qui interagissent pour:

- prévenir les situations dangereuses, ou
- prévenir tout dommage aux équipements ou matériaux, ou
- prévenir des manœuvres spécifiées, ou
- assurer des manœuvres correctes

3.1.38
partie active
tout conducteur ou partie conductrice destiné(e) à être sous tension en service normal, incluant un conducteur neutre, mais, par convention, excluant un conducteur PEN

3.1.39
actionneur
mécanisme de puissance utilisé pour animer une machine (par exemple, moteur, solénoïde, vérin pneumatique ou hydraulique)

3.1.40
machines
machine
ensemble de pièces ou de composants liés entre eux, dont au moins un est mobile, auxquels sont associés les actionneurs et les circuits de commande et de puissance appropriés, réunis de façon solidaire en vue d'une application définie, notamment pour la transformation, le traitement, le déplacement ou le conditionnement d'un matériau

Note 1 à l'article: Le terme "machines" désigne aussi un ensemble de machines qui, afin de concourir à un même résultat, sont disposées et commandées de manière à être solidaires dans leur fonctionnement.

Note 2 à l'article: Le terme "composant" est employé ici au sens général et il ne fait pas seulement référence aux composants électriques.

[SOURCE: ISO 12100:2010, 3.1, modifié – La définition a été modifiée et la Note 2 renvoyant à une Annexe a été supprimée et remplacée par la présente Note 2 à l'article.]

3.1.41
marquage
signes ou inscriptions utilisés en premier lieu pour les besoins d'identification des équipements, des composants et/ou des appareils

3.1.42
conducteur (de) neutre
N
conducteur relié électriquement au point neutre et pouvant contribuer à la distribution de l'énergie électrique

[SOURCE: IEC 60050-195:1998, 195-02-06]

3.1.43
obstacle
élément empêchant un contact direct fortuit avec des parties actives, mais ne s'opposant pas à un contact direct par une action délibérée

[SOURCE: IEC 60050-195:1998, 195-06-16, modifié – Les mots “de protection (électrique)” ont été supprimés dans le terme.]

3.1.44
surintensité
courant supérieur à la valeur assignée

Note 1 à l'article: Pour des conducteurs, la valeur assignée est considérée comme étant égale au courant admissible.

[SOURCE: IEC 60050-826:2004, 826-11-14, modifié – La définition a été modifiée.]

3.1.45
surcharge d'un circuit
relation temps/courant dans un circuit supérieure à la pleine charge assignée du circuit lorsque ce dernier n'est pas en défaut

Note 1 à l'article: Il convient de ne pas utiliser le terme ''surcharge'' comme un synonyme de ''surintensité''.

3.1.46
ensemble fiche-prise
composant et composant adapté d'accouplement, appropriés pour terminer les conducteurs, destinés à la connexion ou à la déconnexion de deux ou plusieurs conducteurs

Note 1 à l'article: Les ensembles fiche-prise comprennent par exemple:

– les prises mobiles qui satisfont aux exigences de l'IEC 61984;
– une fiche et un socle de prise de courant, un prolongateur ou un connecteur conformément à l'IEC 60309-1;
– une fiche et un socle de prise de courant conformément à l'IEC 60884-1 ou un connecteur conformément à l'IEC 60320-1.

3.1.47
circuit de puissance
circuit qui transmet l'énergie aux éléments d'équipement utilisés pour le travail effectué par la machine et aux transformateurs qui alimentent les circuits de commande

3.1.48
courant de court-circuit présumé
***I*cp**
valeur efficace du courant qui circule lorsque les conducteurs d'alimentation de l'équipement électrique sont court-circuités par un conducteur d'impédance négligeable placé aussi près que la pratique le permet des bornes d'alimentation de l'équipement électrique

[SOURCE: IEC 61439-1:2011, 3.8.7, modifié – “l'ensemble” a été remplacé par “l'équipement électrique”]

3.1.49
liaison de protection
liaison équipotentielle destinée à la protection contre les chocs électriques

Note 1 à l'article: Les mesures destinées à protéger contre les chocs électriques peuvent aussi réduire le risque de brûlure ou d'incendie.

Note 2 à l'article: La liaison de protection peut être réalisée à l'aide de conducteurs de protection et de conducteurs de liaison de protection et par le branchement du conducteur des parties conductrices de la machine et de ses équipements électriques.

3.1.50
circuit de protection
ensemble des conducteurs de protection et des parties conductrices raccordés ensemble afin d'assurer la protection contre les chocs électriques en cas de défaut d'isolement

3.1.51
conducteur de protection
conducteur fournissant un chemin de courant de défaut primaire depuis les parties conductrices accessibles de l'équipement électrique jusqu'à une borne de mise à la terre (PE) de protection

3.1.52
redondance
utilisation de plusieurs dispositifs ou systèmes, ou d'éléments d'un dispositif ou système, visant à garantir que si l'un d'eux est défaillant dans l'exécution de sa fonction, un autre est disponible pour exécuter ladite fonction

3.1.53
désignation de référence
code distinctif servant à identifier un élément dans la documentation et sur le matériel

3.1.54
risque
combinaison de la probabilité d'un dommage (c'est-à-dire une blessure physique ou une atteinte à la santé) et de la gravité de ce dommage

[SOURCE: ISO 12100:2010, 3.12, modifié – Le texte entre parenthèses a été ajouté.]

3.1.55
moyen de protection
protecteur ou dispositif de protection mis en place comme mesure de sécurité pour protéger les personnes contre un danger

[SOURCE: ISO 12100:2010, 3.26, modifié – Les mots "mis en place comme mesure de sécurité pour protéger les personnes contre un danger" ont été ajoutés.]

3.1.56
protection
mesure de protection
mesure de prévention faisant appel à des moyens de protection pour préserver les personnes des phénomènes dangereux qui ne peuvent raisonnablement être éliminés, ou des risques qui ne peuvent être suffisamment réduits, par l'application de mesures de prévention intrinsèque

[SOURCE: ISO 12100:2010, 3.21]

3.1.57
fonction de sécurité
fonction d'une machine dont la défaillance peut provoquer un accroissement immédiat du (des) risque(s)

[SOURCE: ISO 12100:2010, 3.30; IEC 62061:2005, 3.2.15]

3.1.58
plancher de service
niveau sur lequel se trouvent les personnes intervenant pour le fonctionnement ou la maintenance de l'équipement électrique

3.1.59
courant de court-circuit
surintensité résultant d'un court-circuit dû à un défaut ou à un branchement incorrect dans un circuit électrique

[SOURCE: IEC 60050-441:1984, 441-11-07]

3.1.60
courant de court-circuit assigné
valeur du courant de court-circuit présumé à laquelle l'équipement électrique peut résister pendant la durée totale de fonctionnement (temps de coupure) du dispositif de protection contre les courts-circuits (DPCC) dans des conditions spécifiées

[SOURCE: IEC 61439-1:2011, 3.8.10.4, modifié – Le mot anglais «rated» a été supprimé du terme et la référence aux "ensembles" a été supprimée de la définition.]

3.1.61
personne qualifiée
personne qualifiée en électricité
personne ayant la formation, les connaissances techniques et l'expérience appropriées pour lui permettre de percevoir les risques et d'éviter les dangers associés à l'électricité

[SOURCE: IEC 60050-826:2004, 826-18-01, modifié – Les parenthèses ont été supprimées et les mots "les connaissances techniques" ont été ajoutés.]

3.1.62
fournisseur
entité (par exemple un fabricant, un maître d'œuvre, un installateur, un intégrateur) qui fournit l'appareillage ou les services associés à la machine

Note 1 à l'article: L'organisation d'usagers peut aussi agir en tant que son propre fournisseur.

3.1.63
appareil de connexion
appareil destiné à établir et/ou à interrompre le courant dans un ou plusieurs circuits électriques

Note 1 à l'article: Un appareil de connexion peut réaliser une de ces actions ou les deux.

[SOURCE: IEC 60050-441:1984, 441-14-01]

3.1.64
arrêt non contrôlé
arrêt du mouvement d'une machine par suppression de la puissance électrique aux actionneurs

Note 1 à l'article: Cette définition ne nécessite pas que les autres appareils d'arrêt soient dans un état particulier, par exemple les freins mécaniques ou hydrauliques.

3.1.65
utilisateur
entité qui utilise la machine et son équipement électrique associé

3.2 Abréviations

AWG	American Wire Gauge (Calibre américain des fils)
AC	Alternating current (courant alternatif)
MEP	Module d'entraînement principal
CCS	Cableless Control System (Système de commande sans fil)
DC	Direct current (courant continu)
CEM	Compatibilité électromagnétique
EMI	Electro-Magnetic Interference (Brouillage électromagnétique)
IFLS	Insulation Fault Location System (Système de localisation des défauts d'isolement)
IHM	Interface homme-machine
PDS	Power Drive System (Entraînement électrique de puissance)
TBTP	Très basse tension de protection
DDR	Dispositif différentiel résiduel
SPD	Surge Protective Devices (Parafoudres – Dispositifs de protection contre les surtensions)
DPCC	Dispositif de protection contre les courts-circuits
TBTS	Très basse tension de sécurité
SLP	Safely-Limited Position (Position limitée en toute sécurité)
STO	Safe Torque Off ("Suppression sûre du couple)

4 Exigences générales

4.1 Généralités

La présente norme spécifie les exigences concernant l'équipement électrique des machines.

Les risques associés aux dangers relatifs à l'équipement électrique doivent être appréciés dans le cadre des exigences globales pour l'appréciation du risque de la machine. Ceci:

– identifie la nécessité d'une réduction du risque; et
– détermine les réductions de risque adéquates; et
– détermine les mesures de protection nécessaires

pour les personnes qui peuvent être exposées à ces dangers, tout en continuant à maintenir un fonctionnement approprié de la machine et de ses équipements.

Les situations dangereuses peuvent être dues, sans toutefois s'y limiter, aux situations suivantes:

– des défaillances ou des défauts de l'équipement électrique conduisant à la possibilité de choc ou d'arc électrique ou de feu d'origine électrique;
– des défaillances ou des défauts dans les circuits de commande (ou les composants et appareils associés à ces circuits) conduisant à un dysfonctionnement de la machine;
– des perturbations ou des interruptions dans les sources d'alimentation ainsi que des défaillances ou des défauts dans les circuits de puissance conduisant à un dysfonctionnement de la machine;
– une perte de continuité dans les circuits, par exemple les circuits qui dépendent de contacts glissants ou roulants, qui peut conduire à une défaillance d'une fonction de sécurité;

– des perturbations électriques, par exemple, des perturbations électromagnétiques ou électrostatiques en provenance de l’extérieur de l’équipement électrique ou générées de façon interne, et conduisant à un dysfonctionnement de la machine;
– un relâchement d'énergie accumulée (électrique ou mécanique) conduisant à, par exemple, un choc électrique, un mouvement inattendu qui peut provoquer une blessure;
– un bruit acoustique et des vibrations mécaniques d'un niveau tel qu'ils provoquent des problèmes de santé aux personnes;
– des températures de surface qui peuvent provoquer des blessures.

Les mesures de sécurité combinent les mesures prises au niveau de la conception et celles à mettre en œuvre par l'utilisateur.

Le processus de conception et développement doit identifier les dangers et les risques résultant de ceux-ci. Lorsque les dangers ne peuvent être éliminés et/ou que les risques ne peuvent être suffisamment réduits par l'application de mesures de prévention intrinsèque, des mesures de protection (par exemple, la protection) doivent être fournies pour réduire le risque. Des dispositions complémentaires (par exemple, des moyens de sensibilisation) doivent être fournies si une réduction du risque plus importante est nécessaire. De plus, des procédures de travail réduisant le risque peuvent être nécessaires.

Il est recommandé, lorsque l'utilisateur est connu, d'utiliser l'Annexe B afin de faciliter l'échange d'informations entre l'utilisateur et le ou les fournisseurs concernant les conditions de base et les spécifications de l'utilisateur supplémentaires relatives à l'équipement électrique.

NOTE Ces spécifications supplémentaires peuvent:

– fournir les caractéristiques supplémentaires qui dépendent du type de machine (ou groupe de machines) et de l'application;
– faciliter la maintenance et la réparation; et
– améliorer la fiabilité et la facilité de fonctionnement.

4.2 Choix des équipements

4.2.1 Généralités

Les composants et appareils électriques doivent:

– convenir à l'usage auquel ils sont destinés; et
– être conformes aux normes correspondantes de l'IEC, lorsqu'elles existent; et
– être utilisés conformément aux instructions du fournisseur.

4.2.2 Appareillage de connexion

Outre les exigences de l'IEC 60204-1, selon la machine, l'usage auquel elle est destinée et son équipement électrique, le concepteur peut choisir des parties de l'équipement électrique de la machine qui sont en conformité avec les parties appropriées de la série IEC 61439 (voir aussi l'Annexe F).

4.3 Alimentation électrique

4.3.1 Généralités

L'équipement électrique doit être prévu pour fonctionner convenablement dans les conditions d'alimentation:

– comme spécifié en 4.3.2 ou 4.3.3, ou
– comme spécifié autrement par l'utilisateur, ou
– comme spécifié par le fournisseur d'une source d'alimentation spéciale (voir 4.3.4).

4.3.2 Alimentations en courant alternatif

Tension	Tension permanente: 0,9 à 1,1 de la tension nominale.
Fréquence	0,99 à 1,01 de la valeur nominale en régime permanent; 0,98 à 1,02 sur une courte période.
Harmoniques	Distorsion harmonique inférieure à 12 % de la tension efficace totale entre conducteurs actifs pour la somme des harmoniques de rang 2 à 30.
Déséquilibre de tension	Ni la tension de la composante inverse, ni la tension de la composante d'alimentation triphasée homopolaire ne sont supérieures à 2 % de la tension de la composante directe.
Coupure de tension	L'alimentation n'est pas coupée ou la tension ne tombe pas à zéro pendant plus de 3 ms à n'importe quel instant du cycle d'alimentation avec plus de 1 s entre deux coupures successives.
Creux de tension	Les creux de tension ne dépassent pas 20 % de la tension efficace de l'alimentation sur plus d'un cycle avec plus de 1 s entre des creux successifs.

4.3.3 Alimentations en courant continu

Par piles ou batteries:

Tension	0,85 à 1,15 de la tension nominale.
	0,7 à 1,2 de la tension nominale dans le cas de véhicules électriques.
Coupure de tension	Ne dépassant pas 5 ms.

Par convertisseur:

Tension	0,9 à 1,1 de la tension nominale.
Coupure de tension	Ne dépassant pas 20 ms avec plus de 1 s entre les coupures successives.

NOTE Cela diffère du Guide 106 de l'IEC afin de garantir un fonctionnement correct de l'équipement électronique.

Ondulation (de crête à crête) Ne dépassant pas 0,15 fois la tension nominale.

4.3.4 Systèmes d'alimentation spéciaux

Pour des systèmes d'alimentation spéciaux (par exemple, générateurs embarqués, barre à courant continu, etc.), les limites données en 4.3.2 et 4.3.3 peuvent être dépassées sous réserve que l'équipement soit conçu pour fonctionner correctement dans ces conditions.

4.4 Environnement physique et conditions de fonctionnement

4.4.1 Généralités

L'équipement électrique doit convenir à l'utilisation dans l'environnement physique et les conditions de fonctionnement de l'usage auquel il est destiné. Les exigences de 4.4.2 à 4.4.8 couvrent l'environnement physique et les conditions de fonctionnement de la plupart des machines relevant de la présente partie de l'IEC 60204. Lorsque des conditions particulières s'appliquent ou lorsque les limites spécifiées sont dépassées, un échange d'informations peut être nécessaire entre l'utilisateur et le fournisseur (voir 4.1).

4.4.2 Compatibilité électromagnétique (CEM)

L'équipement électrique ne doit pas engendrer de perturbations électromagnétiques de niveaux supérieurs à ceux appropriés à son environnement de fonctionnement prévu. De plus, l'équipement électrique doit présenter un niveau d'immunité approprié aux perturbations électromagnétiques de manière à pouvoir fonctionner dans son environnement prévu.

Des essais d'immunité et/ou d'émission sont exigés pour l'équipement électrique à moins que les conditions suivantes ne soient remplies:

- les dispositifs et les composants intégrés satisfont aux exigences CEM concernant l'environnement de même nature prévu, spécifiées dans la norme de produits correspondante (ou une norme générique en l'absence de norme de produits), et;
- l'installation et le câblage électriques sont conformes aux instructions fournies par le fournisseur des dispositifs et des composants eu égard aux influences réciproques (câblage, blindage, mise à la terre, etc.), ou à l'Annexe informative H si de telles instructions ne sont pas transmises par le fournisseur.

NOTE Les normes génériques de CEM telles que l'IEC 61000-6-1 ou l'IEC 61000-6-2 et l'IEC 61000-6-3 ou l'IEC 61000-6-4 donnent les limites générales d'émission et d'immunité CEM.

4.4.3 Température de l'air ambiant

L'équipement électrique doit pouvoir fonctionner correctement à la température de l'air ambiant prévue. Les exigences minimales pour tous les équipements électriques correspondent à un fonctionnement correct pour des températures de l'air ambiant à l'extérieur d'enveloppes (armoire ou coffret) comprises entre +5 °C et +40 °C.

4.4.4 Humidité

L'équipement électrique doit pouvoir fonctionner correctement en présence d'une humidité relative ne dépassant pas 50 % à une température maximale de +40 °C. Une humidité relative supérieure est admise pour des températures plus faibles (par exemple, 90 % à 20 °C).

Les effets dommageables d'une condensation occasionnelle doivent être évités par la conception de l'équipement ou, si nécessaire, par des mesures complémentaires (par exemple, le chauffage ou le conditionnement de l'air, ainsi que des trous d'évacuation incorporés).

4.4.5 Altitude

L'équipement électrique doit pouvoir fonctionner correctement jusqu'à une altitude de 1 000 m au-dessus du niveau moyen de la mer.

Pour pouvoir utiliser l'équipement à des altitudes plus élevées, il est nécessaire de tenir compte de la réduction de:

– la rigidité diélectrique, et;
– le pouvoir de coupure des dispositifs, et;
– l'effet de refroidissement de l'air.

Il est recommandé de solliciter l'avis du fabricant concernant les facteurs de correction à appliquer lorsque ces facteurs ne sont pas spécifiés dans les données de produits.

4.4.6 Polluants

L'équipement électrique doit être convenablement protégé contre la pénétration des corps solides et des liquides (voir 11.3).

L'équipement électrique doit être convenablement protégé contre les polluants (par exemple, les poussières, les acides, les gaz corrosifs, les sels) qui peuvent être présents dans l'environnement physique dans lequel l'équipement électrique doit être installé.

4.4.7 Rayonnements ionisants et non ionisants

Dans le cas où l'équipement est soumis à des rayonnements (par exemple, les micro-ondes, les rayonnements ultraviolets, les lasers, les rayons X), des mesures complémentaires doivent être prises pour éviter un dysfonctionnement de l'équipement et la détérioration accélérée des isolants.

4.4.8 Vibrations, chocs et coups

Les effets indésirables des vibrations, chocs et coups (aussi bien générés par la machine et son équipement associé que créés par l'environnement physique) doivent être évités par le choix d'un équipement approprié, par son montage loin de la machine, ou par la mise en place d'accessoires de montage antivibratoires.

4.5 Transport et stockage

L'équipement électrique doit pouvoir, par conception ou grâce à des mesures de précaution adéquates, supporter les effets de températures de transport et de stockage comprises entre –25 °C et +55 °C, et pouvant atteindre +70 °C durant de courtes périodes inférieures à 24 h. Des moyens adaptés doivent être prévus pour prévenir les dommages dus à l'humidité, aux vibrations et aux chocs.

NOTE Les câbles isolés au PVC constituent un équipement électrique sensible aux dommages causés par les basses températures.

4.6 Dispositions pour la manutention

Les équipements électriques lourds et massifs qui doivent être désolidarisés de la machine pour le transport, ou qui sont indépendants de celle-ci, doivent être équipés de moyens adaptés pour la manutention, y compris, le cas échéant, des moyens de manutention par grues ou équipement similaire.

5 Bornes des conducteurs d'alimentation à l'arrivée et appareils de sectionnement et de coupure

5.1 Bornes des conducteurs d'alimentation à l'arrivée

Lorsque la pratique le permet, il est recommandé de raccorder l'équipement électrique d'une machine à une source d'alimentation unique. Si une autre alimentation est nécessaire pour certaines parties de l'équipement (par exemple, un équipement électronique qui fonctionne sous une tension différente), il convient que cette alimentation soit autant que possible dérivée d'appareils (par exemple, des transformateurs, des convertisseurs) faisant partie de l'équipement électrique de la machine. Pour des machines complexes importantes, plusieurs alimentations peuvent s'avérer nécessaires selon les dispositions locales d'alimentation (voir 5.3.1).

À l'exception des cas où la machine est équipée d'une fiche de prise de courant pour le raccordement à l'alimentation (voir 5.3.2 e)), il est recommandé que les conducteurs d'alimentation se terminent aux bornes d'entrée de l'appareil de sectionnement de l'alimentation.

Si un conducteur neutre est utilisé, cela doit être clairement indiqué dans la documentation technique de la machine, par exemple dans le schéma d'installation et dans le schéma des circuits, et une borne isolée particulière, étiquetée N conformément au 16.1, doit être prévue pour le conducteur neutre. La borne de neutre peut être fournie comme partie intégrante de l'appareil de sectionnement de l'alimentation.

Il ne doit pas y avoir de raccordement entre le conducteur neutre et le circuit de protection à l'intérieur de l'équipement électrique.

Exception: un raccordement peut être effectué entre la borne de neutre et la borne PE au point de raccordement de l'équipement électrique à un schéma d'alimentation TN-C.

Pour les machines alimentées par des sources parallèles, les exigences de l'IEC 60364-1 concernant les schémas à sources multiples s'appliquent.

Les bornes pour le raccordement de l'alimentation doivent être clairement identifiées conformément à l'IEC 60445. La borne du conducteur de protection externe doit être identifiée conformément au 5.2.

5.2 Borne pour le raccordement du conducteur de protection externe

Pour chaque source d'alimentation, une borne doit être prévue dans le même compartiment que les bornes des conducteurs de phase associés pour le raccordement de la machine au conducteur de protection externe.

La dimension de la borne doit être suffisante pour permettre le raccordement d'un conducteur de protection externe en cuivre de section déterminée par rapport à la dimension des conducteurs de phase associés conformément au Tableau 1.

Tableau 1 – Section minimale des conducteurs de protection en cuivre

Section des conducteurs de phase S mm^2	Section minimale du conducteur de protection correspondant (PE) S_p mm^2
$S \leq 16$	S
$16 < S \leq 35$	16
$S > 35$	$S/2$

Lorsque le conducteur de protection externe utilisé n'est pas en cuivre, la dimension et le type de la borne doivent être choisis en conséquence.

Pour chaque entrée d'alimentation, la borne de raccordement au conducteur de protection externe doit être identifiée par un marquage ou étiquetée avec les lettres PE (voir l'IEC 60445).

5.3 Appareil de sectionnement de l'alimentation

5.3.1 Généralités

Un appareil de sectionnement de l'alimentation doit être fourni:

– pour chaque source d'alimentation d'une (des) machine(s);

NOTE L'alimentation peut être raccordée à l'appareil de sectionnement de l'alimentation de la machine directement ou à l'appareil de sectionnement de l'alimentation d'un réseau d'alimentation de cette même machine. Les réseaux d'alimentation peuvent inclure des câbles conducteurs, des barres conductrices, des ensembles de bagues collectrices, des systèmes de câbles souples (sur tourets, en guirlandes) ou des systèmes d'alimentation par induction.

– pour chaque alimentation embarquée.

L'appareil de sectionnement de l'alimentation doit séparer sur demande l'équipement électrique de la machine du réseau d'alimentation (par exemple, pour une intervention sur la machine, y compris sur l'équipement électrique).

Lorsqu'il y a deux appareils de sectionnement ou plus, des verrouillages de protection pour leur fonctionnement correct doivent aussi être fournis afin d'empêcher une situation dangereuse, y compris un dommage à la machine ou aux travaux en cours.

5.3.2 Type

L'appareil de sectionnement de l'alimentation doit être l'un des types suivants:

a) un interrupteur-sectionneur, avec ou sans fusibles, conformément à l'IEC 60947-3, de catégorie d'emploi AC-23B ou DC-23B;

b) un appareil de connexion de commande et de protection adapté au sectionnement, conformément à l'IEC 60947-6-2;

c) un disjoncteur adapté au sectionnement conformément à l'IEC 60947-2;

d) tout autre appareil de connexion conformément à une norme de produits IEC propre à cet appareil et qui satisfait aux exigences de sectionnement et de catégorie d'emploi et/ou d'endurance spécifiée appropriées, définies dans la norme de produits;

e) un ensemble fiche-prise pour une alimentation par câble souple.

5.3.3 Exigences

Lorsque l'appareil de sectionnement de l'alimentation est l'un des types spécifiés en 5.3.2 a) à d), il doit satisfaire à toutes les exigences suivantes:

– séparer l'équipement électrique de l'alimentation, et ne posséder qu'une position MISE HORS TENSION (sectionné) et une position MISE SOUS TENSION, clairement repérées par «O» et «I» (symboles IEC 60417-5008 (2002-10) et IEC 60417-5007 (2002-10), voir 10.2.2);

– comporter une ouverture visible ou un indicateur de position qui ne peut indiquer la position MISE HORS TENSION (sectionné) que si tous les contacts sont effectivement ouverts et si les exigences pour la fonction de sectionnement ont été satisfaites;

– être équipé d'un organe de manœuvre (voir 5.3.4);

– pouvoir être verrouillé en position MISE HORS TENSION (sectionné) (par exemple, à l'aide de cadenas). Lorsqu'il est ainsi verrouillé, une fermeture à distance ou en local doit être empêchée;

– couper tous les conducteurs actifs de son circuit d'alimentation. Cependant, dans les schémas d'alimentation TN, le conducteur neutre peut ou peut ne pas être commuté, excepté dans les pays pour lesquels la coupure du conducteur neutre (s'il est utilisé) est obligatoire;

– avoir un pouvoir de coupure suffisant pour interrompre le courant du moteur le plus puissant lorsque son rotor est bloqué, ainsi que la somme des courants en marche normale de tous les autres moteurs et de toutes les autres charges. Le pouvoir de coupure calculé peut être réduit en utilisant un facteur de diversité reconnu. Lorsque le ou les moteurs sont alimentés par un ou des convertisseurs ou des appareils similaires, il convient que le calcul tienne compte de l'effet possible sur le pouvoir de coupure exigé.

Lorsque l'appareil de sectionnement de l'alimentation est un ensemble fiche-prise, il doit satisfaire aux exigences de 13.4.5 et doit disposer du pouvoir de coupure ou être interverrouillé avec un appareil de connexion dont le pouvoir de coupure est suffisant pour interrompre le courant du moteur le plus puissant lorsque son rotor est bloqué, ainsi que la somme des courants en marche normale de tous les autres moteurs et de toutes les autres charges. Le pouvoir de coupure calculé peut être réduit en utilisant un facteur de diversité reconnu. Lorsque l'appareil de connexion verrouillé est manœuvré électriquement (par exemple, un contacteur), il doit relever d'une catégorie d'emploi appropriée. Lorsque le ou les moteurs sont alimentés par un ou des convertisseurs ou des appareils similaires, il convient que le calcul tienne compte de l'effet possible sur le pouvoir de coupure exigé.

NOTE Une fiche et le socle de prise de courant approprié, un prolongateur ou un connecteur correctement assignés, conformément à l'IEC 60309-1, peuvent satisfaire à ces exigences.

Lorsque l'appareil de sectionnement de l'alimentation est un ensemble fiche-prise, un appareil de connexion de catégorie d'emploi appropriée doit être prévu pour mettre la machine sous tension ou hors tension. Ceci peut être réalisé par l'emploi de l'appareil de connexion verrouillé décrit ci-dessus.

5.3.4 Moyens de manœuvre de l'appareil de sectionnement de l'alimentation

Les moyens de manœuvre (par exemple, une poignée) de l'appareil de sectionnement de l'alimentation doivent être externes à l'enveloppe de l'équipement électrique

Exception: il n'est pas nécessaire de prévoir une poignée sur un appareil de connexion à manœuvre motorisée à l'extérieur de l'enveloppe lorsqu'il existe d'autres moyens (par exemple, boutons-poussoirs) pour ouvrir l'appareil de sectionnement de l'alimentation de l'extérieur de l'enveloppe.

Les moyens de manœuvre de l'appareil de sectionnement de l'alimentation doivent être faciles à atteindre et situés entre 0,6 m et 1,9 m au-dessus du plancher de service. Une limite supérieure de 1,7 m est recommandée.

NOTE Le sens de manœuvre est donné dans l'IEC 61310-3.

Lorsque les moyens de manœuvre externes sont destinés aux manœuvres d'urgence, se reporter à 10.7.3 ou à 10.8.3.

Lorsque les moyens de manœuvre externes ne sont pas destinés aux manœuvres d'urgence:

- il est recommandé qu'ils soient colorés en NOIR ou GRIS (voir 10.2)
- un couvercle ou une porte supplémentaire qui peut être ouvert(e) aisément sans l'aide d'une clé ou d'un outil peut être fourni(e), par exemple, pour la protection contre les conditions d'environnement ou les dommages mécaniques. Ce couvercle/cette porte doit clairement indiquer qu'il/elle permet d'accéder aux moyens de manœuvre. Ceci peut être réalisé, par exemple, à l'aide du symbole IEC 60417-6169-1 (2012-08) (Figure 2) ou IEC 60417-6169-2 (2012-08) (Figure 3) approprié.

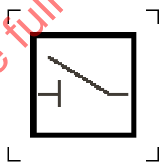


Figure 2 – Sectionneur

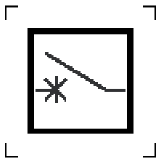


Figure 3 – Disjoncteur de sectionnement

5.3.5 Circuits exclus

Il n'est pas nécessaire que l'appareil de sectionnement de l'alimentation coupe les circuits suivants:

- les circuits d'éclairage alimentant des lampes nécessaires pendant les travaux de maintenance ou de réparation;
- les circuits d'alimentation socles de prises de courant utilisés exclusivement pour l'alimentation des matériels et outils de réparation et de maintenance (par exemple, les perceuses à main, le matériel d'essai) (voir 15.1);
- les circuits de protection à minimum de tension prévus uniquement pour se déclencher automatiquement lors d'une défaillance de l'alimentation;

– les circuits alimentant l'équipement qu'il convient de laisser sous tension pour un fonctionnement correct (par exemple, les appareils de mesure commandés par la température, les appareils de chauffage et les dispositifs de stockage de programme).

Il est cependant recommandé d'équiper ces circuits avec leur propre appareil de sectionnement.

Il n'est pas nécessaire que l'appareil de sectionnement de l'alimentation de l'équipement électrique coupe les circuits de commande alimentés via un autre appareil de sectionnement de l'alimentation, indépendamment du fait que l'appareil de sectionnement est situé dans l'équipement électrique ou dans une autre machine ou un autre équipement électrique.

Lorsque les circuits exclus ne sont pas coupés par l'appareil de sectionnement de l'alimentation:

– une ou des étiquettes d'avertissement permanentes doivent être convenablement placées à proximité des moyens de manœuvre de l'appareil de sectionnement de l'alimentation afin d'attirer l'attention sur le danger;
– une mention correspondante doit être incluse dans le manuel de maintenance et une ou plusieurs des mesures suivantes doivent s'appliquer:
  - les conducteurs sont identifiés par la couleur en prenant en compte les recommandations de 13.2.4;
  - les circuits exclus sont séparés des autres circuits;
  - les circuits exclus sont identifiés par une ou des étiquettes d'avertissement permanentes.

5.4 Appareils de coupure de l'alimentation pour éviter un démarrage fortuit

Des appareils de coupure de l'alimentation pour éviter un démarrage fortuit doivent être prévus lorsque la mise en marche de la machine ou d'une partie de la machine peut créer un danger (par exemple, au cours des opérations de maintenance). De tels appareils doivent être appropriés et convenir à l'usage auquel ils sont destinés, doivent être convenablement situés, et être aisément identifiables eu égard à leur fonction et leur objet. Lorsque leur fonction et leur objet ne sont pas identifiés aisément par toute autre manière (par exemple, par leur emplacement), ces appareils doivent comporter un marquage qui indique le degré de coupure de l'alimentation.

NOTE 1 La présente partie de l'IEC 60204 ne donne pas toutes les dispositions pour empêcher les démarrages fortuits. D'autres dispositions sont données dans l'ISO 14118.

NOTE 2 La coupure de l'alimentation signifie la suppression du raccordement à la source d'énergie électrique, mais n'implique pas un sectionnement.

L'appareil de sectionnement de l'alimentation ou d'autres appareils conformes à 5.3.2 peuvent être utilisés pour empêcher les démarrages fortuits.

Les sectionneurs, les fusibles débrochables et les liaisons démontables peuvent être utilisés pour assurer une protection contre les démarrages fortuits uniquement s'ils sont situés dans une zone fermée de service électrique (voir 3.1.23).

Les appareils ne réalisant pas la fonction de sectionnement (par exemple, un contacteur ouvert par un circuit de commande ou un entraînement électrique de puissance (PDS) avec une fonction "Suppression sûre du couple" (STO) conforme à l'IEC 61800-5-2) peuvent n'être employés que pour empêcher les démarrages fortuits au cours de tâches telles que:

– les inspections;
– les réglages;
– les travaux sur l'équipement électrique lorsque:
  - il n'y a pas de danger lié aux chocs électriques (voir Article 6) et aux brûlures;

- les moyens de coupure restent efficaces pendant les travaux;
- le travail est de nature mineure (par exemple, le remplacement d'appareils embrochables sans perturber le câblage existant).

Le choix d'un appareil dépend de l'appréciation du risque, en prenant en compte l'utilisation prévue de l'appareil, et les personnes chargées de son utilisation.

5.5 Appareils de sectionnement pour l'équipement électrique

Des appareils doivent être fournis pour le sectionnement de l'équipement électrique ou d'une (des) partie(s) de l'équipement électrique afin de rendre possible des interventions lorsqu'il est hors tension et sectionné. De tels appareils doivent être:

– appropriés et convenir à l'usage auquel ils sont destinés;

– placés convenablement;

– aisément identifiables par la ou les parties ou circuits de l'équipement desservi. Lorsque leur fonction et leur objet ne sont pas identifiés aisément par toute autre manière (par exemple, par leur emplacement), ces appareils doivent comporter un marquage qui indique l'étendue de l'équipement qu'ils sectionnent.

L'appareil de sectionnement de l'alimentation (voir 5.3) peut, dans certains cas, remplir cette fonction. Cependant, lorsqu'il est nécessaire d'intervenir sur des parties individuelles de l'équipement électrique d'une machine, ou sur une des machines alimentées par un collecteur à barres, un câble conducteur ou un système d'alimentation par induction commun, un appareil de sectionnement doit être prévu pour chaque partie, ou pour chaque machine nécessitant un sectionnement séparé.

En complément à l'appareil de sectionnement de l'alimentation, les appareils suivants qui remplissent la fonction de sectionnement peuvent être fournis pour satisfaire à ce besoin:

– les appareils décrits en 5.3.2;

– les sectionneurs, les fusibles débrochables et les liaisons démontables uniquement s'ils sont situés dans une zone fermée de service électrique (voir 3.1.23) et les informations appropriées sont fournies avec l'équipement électrique (voir Article 17).

5.6 Protection contre une fermeture non autorisée, par inadvertance et/ou par erreur

Lorsque les appareils décrits en 5.4 et 5.5 sont situés à l'extérieur d'une zone fermée de service électrique, ils doivent être équipés de moyens pour les sécuriser en position MISE HORS TENSION (état sectionné), (par exemple par des dispositions permettant la pose d'un cadenas, ou un verrouillage par clé captive). Lorsqu'ils sont ainsi sécurisés, la reconnexion à distance aussi bien qu'en local doit être empêchée.

Lorsque les appareils décrits en 5.4 et 5.5 sont situés à l'intérieur d'une zone fermée de service électrique, d'autres moyens de protection contre la reconnexion (par exemple, étiquettes d'avertissement) peuvent s'avérer suffisants.

Cependant, lorsqu'un ensemble fiche-prise utilisé selon 5.3.2 e) est situé de manière à pouvoir être maintenu sous la surveillance directe de l'opérateur, il n'est pas nécessaire de prévoir des moyens de sécurisation à l'état sectionné.

6 Protection contre les chocs électriques

6.1 Généralités

L'équipement électrique doit assurer la protection des personnes contre les chocs électriques par:

– une protection principale (voir 6.2 et 6.4), et;

– une protection en cas de défaut (voir 6.3 et 6.4).

Les mesures de protection données en 6.2, 6.3 et, dans le cas de la TBTP, en 6.4, sont sélectionnées dans l'IEC 60364-4-41. Lorsque ces mesures ne sont pas applicables, par exemple, en raison des conditions physiques ou des conditions de fonctionnement, d'autres mesures de l'IEC 60364-4-41 peuvent être utilisées (par exemple, la TBTS).

6.2 Protection principale

6.2.1 Généralités

Pour chaque circuit ou chaque partie de l'équipement électrique, les mesures définies soit en 6.2.2, soit en 6.2.3, et, le cas échéant, en 6.2.4 doivent être appliquées.

Exception: Lorsque ces mesures ne sont pas appropriées, d'autres mesures pour la protection principale (par exemple, par l'utilisation de barrières de protection, par mise hors de portée ou par la mise en place d'obstacles, par des techniques de construction ou d'installation empêchant l'accès) telles que définies dans l'IEC 60364-4-41 peuvent être appliquées (voir aussi 6.2.5 et 6.2.6).

Lorsque l'équipement est situé dans des emplacements ouverts à toute personne, ce qui peut inclure des enfants, les mesures de 6.2.2 avec un degré minimal de protection contre les contacts avec les parties actives correspondant à IP4X ou IPXXD (voir l'IEC 60529), ou de 6.2.3 doivent être appliquées.

6.2.2 Protection au moyen d'enveloppes

Les parties actives doivent être placées à l'intérieur d'enveloppes qui assurent un degré de protection contre les contacts avec les parties actives d'au moins IP2X ou IPXXB (voir l'IEC 60529).

Lorsque le dessus de l'enveloppe est aisément accessible, le degré minimal de protection contre les contacts avec les parties actives assuré par le dessus de l'enveloppe doit être IP4X ou IPXXD.

L'ouverture d'une enveloppe (c'est-à-dire l'ouverture des portes, des couvercles, des plaques de fermeture, et équivalent) ne doit être possible qu'à une des conditions suivantes:

a) La nécessité d'utiliser une clé ou un outil pour l'accès.

   NOTE 1 L'utilisation d'une clé ou d'un outil est destinée à restreindre l'accès aux personnes qualifiées ou averties (voir 17.2 f)).

   Toutes les parties actives (y compris celles situées à l'intérieur des portes) qui sont susceptibles d'être touchées lors du réarmement ou de l'ajustement des appareils prévus pour de telles opérations alors que l'équipement est encore connecté, doivent être protégées contre les contacts avec un degré minimal de protection de IP2X ou IPXXB. Les autres parties actives situées à l'intérieur des portes doivent être protégées contre les contacts directs involontaires avec un degré minimal de protection de IP1X ou IPXXA.

b) Le sectionnement des parties actives situées à l'intérieur de l'enveloppe avant que l'enveloppe ne puisse être ouverte.

   Cette mesure peut être réalisée par l'interverrouillage de la porte avec un appareil de sectionnement (par exemple, l'appareil de sectionnement de l'alimentation) de telle façon que la porte ne puisse être ouverte que lorsque l'appareil de sectionnement est ouvert, et que l'appareil de sectionnement ne puisse être fermé que lorsque la porte est fermée.

   Exception: une clé ou un outil, correspondant aux exigences du fournisseur, peut permettre de neutraliser le verrouillage à condition de satisfaire aux conditions suivantes:

   – qu'il soit toujours possible d'ouvrir l'appareil de sectionnement alors que le verrouillage est neutralisé, et de verrouiller l'appareil de sectionnement en position MISE HORS

TENSION ou d'empêcher par un autre moyen la fermeture non autorisée de l'appareil de sectionnement;

– que le verrouillage soit automatiquement remis en service à la fermeture de la porte;

– que toutes les parties actives, y compris celles situées à l'intérieur des portes, qui sont susceptibles d'être touchées lors du réarmement ou de l'ajustement des appareils prévus pour de telles opérations alors que l'équipement est encore connecté, soient protégées contre les contacts involontaires avec les parties actives avec un degré minimal de protection de IP2X ou IPXXB, et que les autres parties actives situées à l'intérieur des portes aient un degré minimal de protection contre les contacts involontaires de IP1X ou IPXXA.

– que les informations appropriées concernant les procédures de neutralisation du verrouillage soient fournies avec les instructions d'emploi de l'équipement électrique (voir Article 17).

– que des moyens soient fournis pour restreindre l'accès des personnes qualifiées ou averties aux parties actives derrière les portes non directement verrouillées avec des moyens de sectionnement. (Voir 17.2 b)).

Toutes les parties qui restent actives après la coupure du ou des appareils de sectionnement (voir 5.3.5) doivent être protégées contre les contacts directs avec un degré minimal de protection de IP2X ou IPXXB (voir l'IEC 60529). Ces parties doivent comporter un panneau de mise en garde conforme au 16.2.1 (voir aussi 13.2.4 pour l'identification des conducteurs par la couleur), sauf:

– les parties qui ne peuvent être actives que par une liaison aux circuits de verrouillage et qui sont identifiées par la couleur comme potentiellement actives conformément au 13.2.4;

– les bornes d'alimentation de l'appareil de sectionnement de l'alimentation lorsque ce dernier est monté seul dans une enveloppe séparée.

c) L'ouverture sans l'utilisation d'une clé ou d'un outil et sans le sectionnement des parties actives ne doit être possible que lorsque toutes les parties actives comportent un degré minimal de protection contre les contacts de IP2X ou IP2XXB (voir l'IEC 60529). Les barrières de protection assurant cette protection doivent soit nécessiter l'utilisation d'un outil pour leur démontage, soit entraîner automatiquement le sectionnement de toutes les parties actives qu'elles protègent lors de leur suppression. Lorsque la protection contre les contacts est réalisée conformément à 6.2.2 c) et qu'un danger peut être provoqué par une manœuvre manuelle des appareils (par exemple, la fermeture manuelle des contacteurs ou des relais), il convient d'empêcher une telle manœuvre par des barrières de protection ou des obstacles nécessitant un outil pour leur démontage.

6.2.3 Protection par isolant des parties actives

Les parties actives protégées par isolant doivent être complètement recouvertes d'un isolant qui ne peut être enlevé que par destruction. Cet isolant doit présenter une résistance aux contraintes mécaniques, chimiques, électriques et thermiques auxquelles il peut être soumis dans les conditions normales de fonctionnement.

NOTE Les peintures, vernis, laques et produits similaires utilisés seuls ne sont en général pas considérés comme pouvant assurer une protection contre les chocs électriques dans les conditions normales de fonctionnement.

6.2.4 Protection contre les tensions résiduelles

Les parties actives dont la tension résiduelle est supérieure à 60 V en cas de coupure de l'alimentation doivent être déchargées jusqu'à 60 V ou moins, en moins de 5 s sous réserve que ce taux de décharge ne perturbe pas le bon fonctionnement de l'équipement. Cette exigence ne s'applique pas aux composants de capacité 60 μC, ou moins. Lorsque le taux de décharge spécifié perturbe le bon fonctionnement de l'équipement, un avis de mise en garde durable qui attire l'attention sur le danger, et indique le délai à respecter avant de pouvoir ouvrir l'enveloppe, doit être placé dans un endroit aisément visible ou à proximité immédiate de l'enveloppe contenant les parties actives.

Dans le cas de fiches ou d'appareils similaires dont le retrait se traduit par l'exposition de conducteurs (par exemple, des broches), le temps de décharge à une tension de 60 V ne doit pas dépasser 1 s, sinon ces conducteurs doivent présenter un degré minimal de protection contre les contacts de IP2X ou IPXXB. Si ni un temps de décharge de 1 s, ni un degré minimal de protection de IP2X ou IPXXB ne peuvent être obtenus (par exemple, dans le cas de collecteurs démontables sur les câbles conducteurs, sur les barres conductrices ou sur les ensembles de bagues collectrices, voir 12.7.4), des appareils de connexion supplémentaires ou un dispositif d'avertissement approprié, par exemple un panneau de mise en garde qui attire l'attention sur le danger et indique le délai à respecter, doivent être fournis. Lorsque l'équipement est situé dans des emplacements ouverts à toute personne, ce qui peut inclure des enfants, les mises en garde sont insuffisantes et un degré minimal de protection contre les contacts avec les parties actives correspondant à IP4X ou IPXXD est par conséquent exigé.

NOTE Généralement, le temps de décharge des convertisseurs de fréquence et des alimentations de barres omnibus à courant continu peut être supérieur à 5 s.

6.2.5 Protection par barrières

Pour la protection par barrières, les exigences de l'IEC 60364-4-41 doivent s'appliquer.

6.2.6 Protection par mise hors de portée ou protection par mise en place d'obstacles

Pour la protection par mise hors de portée, les exigences de l'IEC 60364-4-41 doivent s'appliquer. Pour la protection par mise en place d'obstacles, les exigences de l'IEC 60364-4-41 doivent s'appliquer.

Pour les systèmes à câbles conducteurs ou à barres conductrices dont le degré de protection est inférieur à IP2X ou IPXXB, voir 12.7.1.

6.3 Protection en cas de défaut

6.3.1 Généralités

La protection en cas de défaut (3.31) est destinée à empêcher les situations dangereuses dues à un défaut d'isolement entre les parties actives et les masses.

Pour chaque circuit ou partie de l'équipement électrique, au moins une des mesures conformes à 6.3.2 à 6.3.3 doit être appliquée:

- des mesures pour empêcher l'apparition d'une tension de contact (6.3.2); ou
- la coupure automatique de l'alimentation avant que la durée de contact avec une tension de contact ne devienne dangereuse (6.3.3).

NOTE 1 Le risque des effets physiologiques dommageables liés à une tension de contact dépend de la valeur de la tension de contact et de la durée de l'exposition possible.

NOTE 2 L'IEC 61140 fournit des informations sur les classes de matériels et les dispositions de protection.

6.3.2 Prévention contre l'apparition d'une tension de contact

6.3.2.1 Généralités

Les mesures pour empêcher l'apparition d'une tension de contact comprennent les mesures suivantes:

- l'utilisation de matériels de classe II ou d'isolation équivalente;
- la séparation électrique.

6.3.2.2 Protection par l'emploi de matériels de classe II ou par isolation équivalente

Cette mesure est destinée à empêcher l'apparition de tensions de contact sur les parties accessibles en cas de défaut de l'isolation principale.

Cette protection est obtenue par un ou plusieurs des moyens suivants:

– des matériels ou appareils électriques de classe II (double isolation, isolation renforcée ou équivalente conformément à l'IEC 61140);
– des ensembles d'appareillage possédant une isolation totale conforme à l'IEC 61439-1;
– une isolation supplémentaire ou une isolation renforcée conforme à l'IEC 60364-4-41.

6.3.2.3 Protection par séparation électrique

La séparation électrique d'un circuit individuel est destinée à empêcher des tensions de contact résultant d'un contact avec des masses qui peuvent être mises sous tension en cas de défaut de l'isolation principale des parties actives de ce circuit.

Pour ce type de protection, les exigences de l'IEC 60364-4-41 s'appliquent.

6.3.3 Protection par coupure automatique de l'alimentation

La coupure automatique de l'alimentation d'un quelconque circuit affecté par un défaut d'isolement est destinée à empêcher une situation dangereuse due à une tension de contact.

Cette mesure consiste à couper un ou plusieurs conducteurs de phase par la manœuvre automatique d'un dispositif de protection en cas de défaut. Cette coupure doit se produire dans un délai suffisamment court afin de limiter la durée d'une tension de contact à une valeur comprise dans les limites spécifiées en Annexe A pour les schémas TN et TT.

Cette mesure nécessite une coordination entre:

– le type du système d'alimentation, l'impédance de la source d'alimentation et le schéma de mise à la terre;
– les valeurs d'impédance des différents éléments du conducteur de phase et des chemins de courant de défaut associés à travers le circuit de protection;
– les caractéristiques des dispositifs de protection qui détectent le ou les défauts d'isolement.

NOTE 1 Les détails de vérification des conditions de protection par une coupure automatique de l'alimentation sont donnés en 18.2.

Cette mesure de protection comprend à la fois:

– la liaison de protection des masses (voir 8.2.3),
– et une des mesures suivantes:
  a) Dans les schémas TN, les dispositifs de protection suivants peuvent être utilisés:
    - dispositifs de protection contre les surintensités;
    - dispositifs différentiels résiduels (DDR) et dispositif(s) de protection contre les surintensités associé(s).

    NOTE 2 La maintenance préventive peut être améliorée par l'utilisation d'un contrôleur d'isolement à courant différentiel résiduel, RCM, conforme à l'IEC 62020.
  b) Dans les schémas TT:
    - des DDR et dispositif(s) de protection contre les surintensités associé(s) pour initier la coupure automatique de l'alimentation sur détection d'un défaut d'isolement d'une partie active par rapport aux masses ou par rapport à la terre, ou

- des dispositifs de protection contre les surintensités peuvent être utilisés pour la protection en cas de défaut à condition qu'une valeur raisonnablement basse de l'impédance de boucle de défaut Z_S (voir A.2.2.3) soit garantie de façon permanente et en toute fiabilité;

NOTE 3 La maintenance préventive peut être améliorée par l'utilisation d'un contrôleur d'isolement à courant différentiel résiduel, RCM, conforme à l'IEC 62020.

c) Dans les schémas IT, les exigences correspondantes de l'IEC 60364-4-41 doivent être satisfaites. Lors d'un défaut d'isolement, un signal acoustique et optique doit être émis de façon durable. Après indication, le signal acoustique peut alors être désactivé manuellement. Ceci peut exiger un accord entre le fournisseur et l'utilisateur concernant la disposition de contrôleurs d'isolement et/ou de systèmes de localisation des défauts d'isolement.

NOTE 4 Dans les machines importantes, la mise en place d'un système de localisation des défauts d'isolement (IFLS) conformément à l'IEC 61557-9 peut faciliter la maintenance.

Lorsque la coupure automatique est prévue conformément à a), et que la coupure dans le délai spécifié en A.1.1 ne peut être assurée, il doit être prévu une liaison équipotentielle de protection supplémentaire si nécessaire pour satisfaire aux exigences de A.1.3.

Lorsqu'un entraînement électrique de puissance (PDS) est fourni, une protection en cas de défaut doit être prévue pour les circuits de l'entraînement électrique de puissance alimentés par le convertisseur. Lorsque cette protection n'est pas prévue dans le convertisseur, les mesures de protection nécessaires doivent être conformes aux instructions du fabricant du convertisseur.

6.4 Protection par l'utilisation de la TBTP

6.4.1 Exigences générales

L'utilisation de la TBTP (Très basse tension de protection) permet de protéger les personnes contre les chocs électriques dus aux contacts indirects ou aux contacts directs sur de petites surfaces (voir 8.2.1).

Les circuits TBTP doivent satisfaire à l'ensemble des conditions suivantes:

a) la tension nominale ne doit pas dépasser:
   - 25 V en courant alternatif (en valeur efficace) ou 60 V en courant continu sans ondulation lorsque l'équipement est normalement utilisé dans des emplacements secs et lorsqu'un contact sur de larges surfaces de parties actives avec le corps humain n'est pas prévu; ou
   - 6 V en courant alternatif (en valeur efficace) ou 15 V en courant continu sans ondulation dans tous les autres cas;

NOTE "Sans ondulation" est conventionnellement défini pour une tension d'ondulation sinusoïdale comme un taux d'ondulation efficace inférieur ou égal à 10 % en valeur efficace.

b) un côté du circuit ou un point de la source d'alimentation de ce circuit doit être raccordé au circuit de protection;

c) les parties actives des circuits TBTP doivent être électriquement séparées des autres circuits actifs. La séparation électrique ne doit pas être inférieure à celle exigée entre les circuits primaires et secondaires d'un transformateur de sécurité (voir l'IEC 61558-1 et l'IEC 61558-2-6);

d) les conducteurs de chaque circuit TBTP doivent être physiquement séparés des conducteurs d'un autre circuit. Lorsque cette exigence est irréalisable, les dispositions d'isolation de 13.1.3 doivent s'appliquer;

e) les fiches et socles de prises de courant pour un circuit TBTP doivent être conformes aux points suivants:
   - les fiches ne doivent pas pouvoir entrer dans les socles d'autres réseaux de tension;

- les socles ne doivent pas admettre des prises d'autres réseaux de tension.

6.4.2 Sources pour la TBTP

La source pour la TBTP doit être l'une des suivantes:

– un transformateur de sécurité conformément à l'IEC 61558-1 et l'IEC 61558-2-6;

– une source de courant assurant un degré de sécurité équivalent à celui du transformateur de sécurité (par exemple une génératrice à moteur avec enroulement fournissant une isolation équivalente);

– une source électrochimique (par exemple, une batterie) ou autre source indépendante d'un circuit de tension plus élevée (par exemple, une génératrice à moteur diesel);

– une alimentation électronique conforme aux normes appropriées précisant les mesures à prendre pour assurer que, même dans le cas d'un défaut interne, la tension aux bornes de sortie ne peut pas dépasser les valeurs spécifiées en 6.4.1.

7 Protection de l'équipement

7.1 Généralités

Cet Article 7 détaille les mesures à prendre pour protéger l'équipement contre les effets:

– des surintensités résultant d'un court-circuit;

– de la surcharge et/ou de la perte de réfrigérant de moteurs;

– d'une température anormale:

– de la perte ou de la diminution de la tension d'alimentation;

– de la survitesse des machines/éléments de machine;

– des défauts à la terre/courants résiduels;

– d'une séquence de phases erronée;

– des surtensions de foudre ou de manœuvre.

7.2 Protection contre les surintensités

7.2.1 Généralités

Une protection contre les surintensités doit être prévue lorsque le courant dans un circuit quelconque peut dépasser soit la valeur assignée d'un composant, soit le courant maximal admissible des conducteurs, la valeur la plus faible des deux étant retenue. Les caractéristiques assignées ou les réglages à choisir sont détaillés en 7.2.10.

7.2.2 Conducteurs d'alimentation

Sauf spécification contraire par l'utilisateur, le fournisseur de l'équipement électrique n'est pas responsable de la fourniture des conducteurs d'alimentation et du dispositif de protection contre les surintensités pour les conducteurs d'alimentation de l'équipement électrique.

Le fournisseur de l'équipement électrique doit indiquer dans les documents d'installation les renseignements nécessaires pour le dimensionnement des conducteurs (y compris la section maximale du conducteur d'alimentation qui peut être raccordé aux bornes de l'équipement électrique) et pour le choix du dispositif de protection contre les surintensités (voir 7.2.10 et Article 17).

7.2.3 Circuits de puissance

Des dispositifs de détection et de coupure des surintensités, choisis conformément à 7.2.10, doivent être insérés dans chaque conducteur actif, y compris les circuits qui alimentent les transformateurs des circuits de commande.

Les conducteurs suivants, le cas échéant, ne doivent pas être commutés sans que tous les conducteurs actifs associés le soient également:

– le conducteur neutre des circuits de puissance en courant alternatif;
– le conducteur mis à la terre des circuits de puissance en courant continu;
– les conducteurs de puissance en courant continu reliés aux masses des machines mobiles.

Lorsque la section du conducteur neutre est au moins égale ou équivalente à celle des conducteurs de phase, il n'est pas nécessaire de prévoir une détection de surintensité ou un dispositif de coupure pour le conducteur neutre. Pour un conducteur neutre ayant une section inférieure à celle des conducteurs de phase associés, les mesures détaillées en 524 de l'IEC 60364-5-52:2009 doivent s'appliquer.

Dans les schémas IT, il est recommandé de ne pas utiliser le conducteur neutre. Cependant, si un tel conducteur neutre est utilisé, les mesures détaillées en 431.2.2 de l'IEC 60364-4-43:2008 doivent s'appliquer.

7.2.4 Circuits de commande

Les conducteurs des circuits de commande reliés directement à la tension d'alimentation doivent être protégés contre les surintensités conformément à 7.2.3.

Les conducteurs des circuits de commande alimentés par l'intermédiaire d'un transformateur ou alimentés en courant continu doivent être protégés contre les surintensités (voir aussi 9.4.3.1.1):

– pour les circuits de commande reliés au circuit de protection, par la mise en place d'un dispositif de protection contre les surintensités sur le conducteur commuté;
– pour les circuits de commande non reliés au circuit de protection;
  • lorsque tous les circuits de commande de l'équipement ont le même courant maximal admissible, par la mise en place d'un dispositif de protection contre les surintensités sur le conducteur commuté, ou;
  • lorsque différents circuits de commande de l'équipement ont un courant maximal admissible différent, par la mise en place d'un dispositif de protection contre les surintensités sur le conducteur commuté et sur le conducteur commun de chaque circuit de commande.

Exception: Lorsque le bloc d'alimentation fournit une valeur de courant inférieure à la fois au courant maximal admissible des conducteurs dans un circuit et au courant assigné des composants raccordés, aucun dispositif séparé de protection contre les surintensités n'est exigé.

7.2.5 Socles de prises de courant et conducteurs associés

La protection contre les surintensités doit être fournie pour les circuits alimentant les socles de prises de courant polyvalents destinés principalement à fournir la puissance aux matériels de maintenance. Des dispositifs de protection contre les surintensités doivent être prévus sur les conducteurs actifs non mis à la terre de chaque circuit alimentant de tels socles de prises de courant. Voir aussi 15.1.

7.2.6 Circuits d'éclairage

Tous les conducteurs non mis à la terre des circuits alimentant l'éclairage doivent être protégés contre les effets des courts-circuits par des dispositifs de protection contre les surintensités indépendants de ceux protégeant les autres circuits.

7.2.7 Transformateurs

Les transformateurs doivent être protégés par un dispositif de protection contre les surintensités dont le type et le réglage sont conformes aux instructions du fabricant du transformateur. Une telle protection doit (voir aussi 7.2.10):

– éviter le déclenchement de nuisance dû aux courants d'appel magnétisants des transformateurs;

– éviter un échauffement des enroulements qui dépasse la valeur permise pour la classe d'isolement du transformateur lorsqu'il est soumis aux effets d'un court-circuit à ses bornes secondaires.

7.2.8 Emplacement des dispositifs de protection contre les surintensités

Les dispositifs de protection contre les surintensités doivent être situés à l'endroit de réduction de la section des conducteurs ou autre modification qui réduit le courant maximal admissible dans les conducteurs, excepté lorsque toutes les conditions suivantes sont satisfaites:

– le courant maximal admissible dans les conducteurs est au moins égal à celui de la charge;

– la longueur du ou des conducteurs entre l'endroit de réduction du courant maximal admissible et la position du dispositif de protection contre les surintensités ne dépasse pas 3 m;

– les conducteurs sont installés de façon à réduire la possibilité de court-circuit, par exemple, s'ils sont protégés par une enveloppe ou une canalisation.

7.2.9 Dispositifs de protection contre les surintensités

Le pouvoir de coupure assigné en court-circuit doit être au moins égal au courant de défaut présumé au point de l'installation. Lorsque le courant de court-circuit fourni au dispositif de protection contre les surintensités peut inclure des courants supplémentaires autres que ceux de l'alimentation (par exemple, de moteurs, de capacités de correction du facteur de puissance), ces courants doivent être pris en compte.

NOTE Les informations concernant la coordination en conditions de court-circuit entre un disjoncteur et un autre dispositif de protection contre les courts-circuits sont données à l'Annexe A de l'IEC 60947-2:2006, IEC 60947-2:2006/AMD1:2009 and IEC 60947-2:2006/AMD2:2013.

Lorsque des fusibles sont utilisés en tant que dispositifs de protection contre les surintensités, un type aisément disponible dans le pays d'utilisation doit être choisi, ou des dispositions doivent être prises pour la fourniture de pièces détachées.

7.2.10 Calibrage et réglage des dispositifs de protection contre les surintensités

Le courant assigné des fusibles ou le courant de réglage des autres dispositifs de protection contre les surintensités doit être choisi aussi faible que possible, mais être adapté aux surintensités prévues (par exemple, lors du démarrage de moteurs ou de la mise sous tension de transformateurs). Lors du choix de tels dispositifs de protection, il doit être tenu compte de la protection des appareils de connexion contre les dommages dus aux surintensités.

Le courant assigné ou le réglage d'un dispositif de protection contre les surintensités pour les conducteurs est déterminé par le courant maximal admissible dans les conducteurs à protéger conformément à 12.4, à l'Article D.3, et par le temps de coupure maximal admissible t conformément à l'Article D.4, en prenant en compte les besoins de coordination avec les autres appareils électriques dans le circuit protégé.

7.3 Protection des moteurs contre la surchauffe

7.3.1 Généralités

La protection des moteurs contre la surchauffe doit être assurée pour chaque moteur d'une puissance assignée supérieure à 0,5 kW.

Exception: Pour des applications dans lesquelles une interruption automatique du fonctionnement du moteur n'est pas acceptable (par exemple, les pompes à incendie), les moyens de détection doivent délivrer un signal d'avertissement auquel l'opérateur peut répondre.

La protection des moteurs contre la surchauffe peut être réalisée par:

– une protection contre les surcharges (7.3.2),

NOTE 1 Les dispositifs de protection contre les surcharges détectent les relations temps/courant (I^2t) dans un circuit qui dépassent la charge totale assignée du circuit et initient les réponses appropriées de la commande.

– une protection contre les températures excessives (7.3.3), ou

NOTE 2 Les appareils de détection de température captent une température excessive et initient les réponses appropriées de la commande.

– une protection par limitation de courant.

La remise en marche automatique d'un moteur après le fonctionnement d'une protection contre les surchauffes doit être empêchée si cela peut provoquer une situation dangereuse ou un dommage à la machine ou au travail en cours.

7.3.2 Protection contre les surcharges

Lorsque la protection contre les surcharges est utilisée, la détection de la ou des surcharges doit être prévue dans chaque conducteur actif, à l'exception du conducteur neutre.

Cependant, lorsque la détection des surcharges d'un moteur n'est pas utilisée pour la protection contre les surcharges de câbles (voir aussi l'Article D.2), la détection des surcharges peut être omise dans l'un des conducteurs actifs. Pour des moteurs monophasés ou à alimentation à courant continu, la détection sur un seul conducteur actif non relié à la terre est admise.

Lorsque la protection contre les surcharges est réalisée par coupure, l'appareil de connexion doit couper tous les conducteurs actifs. La coupure du conducteur neutre n'est pas nécessaire pour la protection contre les surcharges.

Lorsque des moteurs ayant des caractéristiques assignées à usage spécial de service doivent démarrer ou freiner fréquemment (par exemple, les moteurs pour l'avance ou le retour rapides, le verrouillage, le perçage sensitif), il peut être difficile de réaliser une protection contre les surcharges dont la constante de temps s'accorde avec celle de l'enroulement à protéger. Des dispositifs de protection appropriés conçus pour des moteurs à usage spécial ou une protection contre les températures excessives (voir 7.3.3) peuvent être nécessaires.

Pour des moteurs qui ne peuvent pas être surchargés (par exemple, les moteurs à couple constant, les commandes de mouvement qui sont soit protégées par des dispositifs mécaniques de protection contre les surcharges, soit correctement dimensionnées), il n'est pas exigé de protection contre les surcharges.

7.3.3 Protection contre les températures excessives

La fourniture de moteurs avec protection contre les températures excessives conformément à l'IEC 60034-11 est recommandée dans les cas où le refroidissement peut être altéré (par exemple, dans des environnements poussiéreux). Selon le type de moteur, la protection contre un blocage du rotor ou une perte de phase n'est pas toujours assurée par une protection contre les températures excessives, il convient alors de prévoir une protection complémentaire.

Une protection contre les températures excessives est aussi recommandée dans le cas des moteurs qui ne peuvent pas être surchargés (par exemple, les moteurs à couple constant, les commandes de mouvement qui sont soit protégées par des dispositifs mécaniques de protection contre les surcharges, soit correctement dimensionnées), lorsque la possibilité de températures excessives existe (par exemple, en raison d'un refroidissement plus faible).

7.4 Protection contre les températures anormales

Les équipements doivent être protégés contre les températures anormales qui peuvent occasionner une situation dangereuse.

7.5 Protection contre les effets de l'interruption de l'alimentation ou la réduction de la tension et leur rétablissement ultérieur

Lorsqu'une interruption d'alimentation ou une réduction de tension peut entraîner une situation dangereuse, des dommages à la machine ou aux travaux en cours, une protection à minimum de tension doit être prévue, par exemple, par mise hors tension de la machine à un niveau de tension prédéterminé.

Lorsque le fonctionnement de la machine peut accepter une interruption ou une réduction de la tension pendant une courte durée, une protection temporisée à minimum de tension peut être prévue. Le fonctionnement du dispositif de protection à minimum de tension ne doit compromettre le fonctionnement d'aucune commande d'arrêt de la machine.

Lors du rétablissement de la tension ou de l'ouverture de l'interrupteur d'alimentation, le redémarrage automatique ou fortuit de la machine doit être empêché lorsque ce redémarrage peut entraîner une situation dangereuse.

Dans le cas d'une réduction de tension ou d'une interruption d'alimentation affectant seulement une partie de la machine, ou du groupe de machines fonctionnant ensemble de manière coordonnée, la protection à minimum de tension doit initier les commandes de contrôle appropriées pour assurer la coordination.

7.6 Protection contre la survitesse des moteurs

Une protection contre la survitesse doit être prévue dans le cas où une survitesse peut survenir et entraîner éventuellement une situation dangereuse en tenant compte des mesures conformes à 9.3.2. La protection contre la survitesse doit initier les réactions appropriées de la commande et empêcher un redémarrage automatique.

Il convient que la protection contre la survitesse fonctionne de façon telle que la limite de vitesse mécanique du moteur ou de sa charge ne soit pas dépassée.

NOTE Cette protection peut consister, par exemple, en un dispositif centrifuge ou un limiteur de vitesse.

7.7 Protection supplémentaire contre les défauts à la terre/courants résiduels

En complément à la protection contre les surintensités pour la coupure automatique telle que décrite en 6.3, la protection contre les défauts à la terre/courants résiduels peut être prévue pour réduire les dommages à l'équipement dus à des courants de défaut à la terre inférieurs au niveau de détection de la protection contre les surintensités.

Le réglage des dispositifs doit être aussi bas que possible en cohérence avec un fonctionnement correct de l'équipement.

Lorsque des courants de défaut sont possibles avec des composants à courant continu, un DDR de type B conformément à l'IEC TR 60755 peut être exigé.

7.8 Protection de l'ordre des phases

Lorsqu'un ordre erroné des phases de la tension d'alimentation peut entraîner une situation dangereuse ou des dommages à la machine, une protection doit être prévue.

NOTE Les conditions d'utilisation qui peuvent mener à un ordre de phases erroné comprennent:

– une machine transférée d'une source d'alimentation à une autre;
– une machine mobile équipée pour le raccordement à une alimentation externe.

7.9 Protection contre les surtensions de foudre et de manœuvre

Des parafoudres (SPD) peuvent être prévus pour la protection contre les effets des surtensions de foudre ou de manœuvre.

Lorsque tel est le cas:

– les parafoudres pour la suppression des surtensions de foudre doivent être connectés aux bornes d'alimentation de l'appareil de sectionnement de l'alimentation.
– les parafoudres pour la suppression des surtensions de manœuvre doivent être connectés si nécessaire pour les équipements qui exigent une telle protection.

NOTE 1 Les informations concernant le choix et l'installation corrects des parafoudres sont données, par exemple, dans l'IEC 60364-4-44, l'IEC 60364-5-53, l'IEC 61643-12, l'IEC 62305-1 et l'IEC 62305-4.

NOTE 2 La liaison équipotentielle de la machine, de ses équipements électriques et des éléments conducteurs étrangers avec un réseau de liaison commun du bâtiment/site peut faciliter la réduction des perturbations électromagnétiques, y compris les effets de la foudre sur les équipements.

7.10 Courant assigné de court-circuit

Le courant assigné de court-circuit des équipements électriques doit être déterminé. Ceci peut être réalisé par l'application de règles de conception, par calcul ou par essai.

NOTE Le courant assigné de court-circuit peut être déterminé, par exemple, conformément à l'IEC 61439-1, l'IEC 60909-0, l'IEC/TR 60909-1 ou l'IEC/TR 61912-1.

8 Liaisons équipotentielles

8.1 Généralités

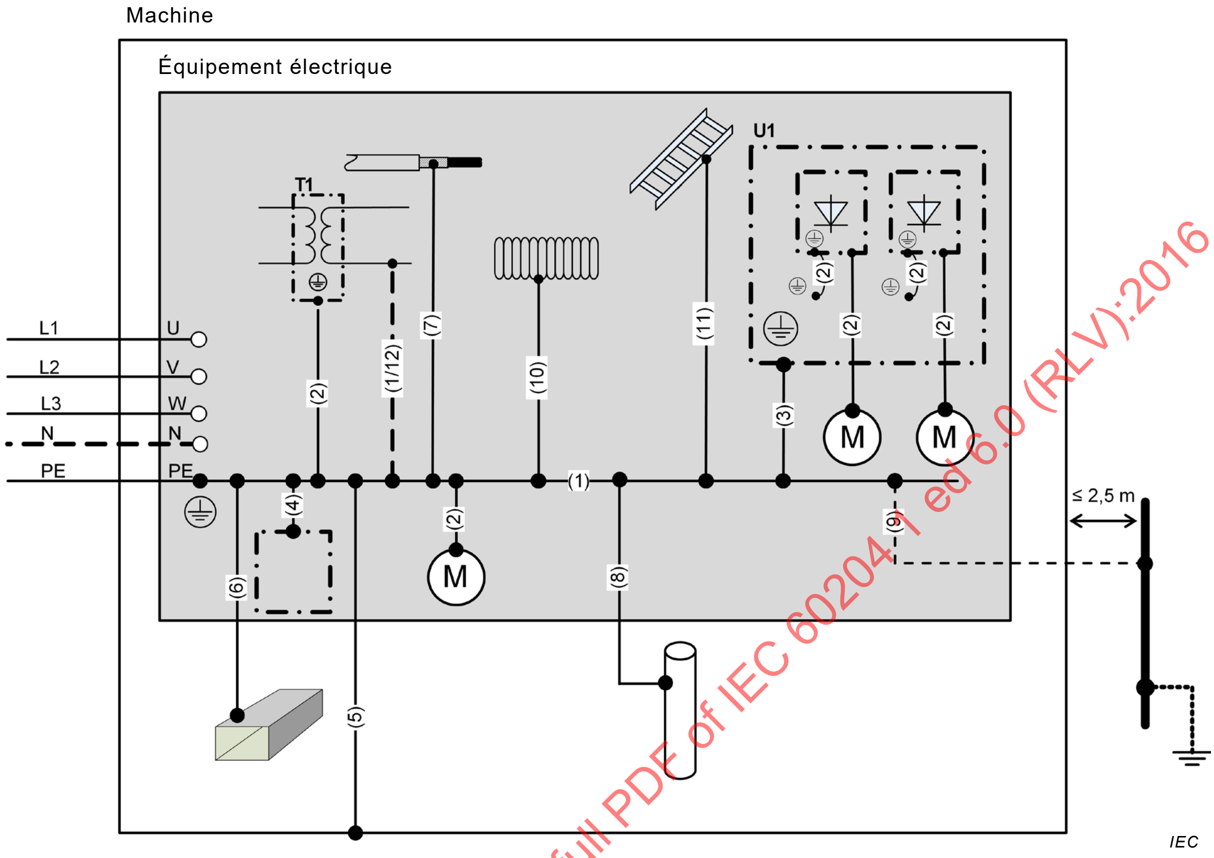
Le présent Article 8 fournit les exigences relatives aux liaisons de protection et aux liaisons fonctionnelles. La Figure 4 représente ces concepts.

La liaison de protection est une disposition de base pour la protection en cas de défaut afin d'assurer la protection des personnes contre les chocs électriques (voir 6.3.3 et 8.2).

L'objectif de la liaison fonctionnelle (voir 8.4) est de réduire:

– la conséquence d'un défaut d'isolement qui peut nuire au fonctionnement de la machine;
– les perturbations électriques pour les équipements électriques sensibles qui peuvent nuire au fonctionnement de la machine;
– les courants induits provenant de la foudre qui peuvent endommager l'équipement électrique.

La liaison fonctionnelle est assurée par le raccordement au circuit de protection, mais, lorsque le niveau des perturbations électriques sur le circuit de protection n'est pas suffisamment faible pour assurer un fonctionnement correct de l'équipement électrique, il peut être nécessaire d'utiliser des conducteurs séparés pour la liaison de protection et la liaison fonctionnelle.



Circuit de protection:	
(1)	Interconnexion du ou des conducteurs de protection et de la borne PE
(2)	Raccordement des masses
(3)	Raccordement du conducteur de protection à une plaque d'assemblage de l'équipement électrique utilisée comme conducteur de protection
(4)	Raccordement des parties conductrices structurelles de l'équipement électrique
(5)	Parties conductrices structurelles de la machine
Parties raccordées au circuit de protection qui ne doivent pas être utilisées comme conducteur de protection:	
(6)	Canalisations métalliques souples ou rigides
(7)	Gaines ou armure de câbles métalliques
(8)	Tuyauteries métalliques contenant des matériaux inflammables
(9)	Éléments conducteurs étrangers, si mis à la terre de manière indépendante de l'alimentation de la machine et susceptibles d'introduire un potentiel, généralement le potentiel de terre, (voir 17.2 d)), par exemple: tuyauteries métalliques, clôtures, échelles, mains courantes.
(10)	Conduits métalliques souples ou cintrés
(11)	Liaison de protection des câbles d'appui, chemins et échelles de câbles
Raccordements au circuit de protection pour des raisons fonctionnelles:	
(12)	Liaisons fonctionnelles
Légende des désignations de référence:	
T1	Transformateur auxiliaire
U1	Plaque d'assemblage de l'équipement électrique

Figure 4 – Exemple de liaison équipotentielle pour l'équipement électrique d'une machine

8.2 Circuit de protection

8.2.1 Généralités

Le circuit de protection comprend l'interconnexion:

- de la ou des bornes PE (voir 5.2);
- des conducteurs de protection (voir 3.1.51) dans l'équipement de la machine, y compris les contacts glissants lorsqu'ils font partie du circuit;
- des parties conductrices structurelles et des masses de l'équipement électrique;

Exception: voir 8.2.5.

- des parties conductrices structurelles de la machine

Toutes les parties du circuit de protection doivent être conçues pour être capables de résister aux contraintes thermiques et mécaniques les plus importantes qui peuvent être provoquées par des courants de défaut à la terre susceptibles de circuler dans ces parties du circuit de protection.

- La section de chaque conducteur de protection qui ne fait pas partie intégrante d'un câble ou qui ne se situe pas dans une enveloppe commune avec le conducteur de phase ne doit pas être inférieure à
  - 2,5 mm^2 Cu ou 16 mm^2 Al en cas de protection contre les dommages mécaniques,
  - 4 mm^2 Cu ou 16 mm^2 Al en l'absence de protection contre les dommages mécaniques.

NOTE L'utilisation de l'acier pour un conducteur de protection n'est pas exclue.

Un conducteur de protection qui ne pas partie intégrante d'un câble est considéré comme protégé mécaniquement s'il est installé dans un conduit, une goulotte ou s'il fait l'objet d'une protection similaire. Il n'est pas nécessaire de raccorder les parties conductrices structurelles de l'équipement conforme à 6.3.2.2 au circuit de protection. Il n'est pas nécessaire de raccorder les parties conductrices structurelles de la machine au circuit de protection si tout l'équipement fourni est conforme à 6.3.2.2.

Les masses de l'équipement conforme à 6.3.2.3 ne doivent pas être raccordées au circuit de protection.

Il n'est pas nécessaire de raccorder les masses au circuit de protection lorsque, par leur montage, celles-ci ne présentent pas de danger du fait:

– qu'elles ne peuvent pas être touchées sur de larges surfaces ou saisies par la main et qu'elles sont de faibles dimensions (moins de 50 mm × 50 mm environ); ou
– qu'elles sont placées de telle façon qu'un contact avec des parties actives ou un défaut d'isolement soit improbable.

Cela s'applique aux petites parties telles que vis, rivets, plaques signalétiques et aux parties situées à l'intérieur d'une enveloppe quelles que soient leurs dimensions (par exemple, les électroaimants de contacteurs ou de relais et les parties mécaniques des appareils).

8.2.2 Conducteurs de protection

Les conducteurs de protection doivent être identifiés conformément à 13.2.2.

Les conducteurs en cuivre sont préférentiels. Dans le cas de l'utilisation d'un matériau conducteur autre que le cuivre, la résistance électrique par unité de longueur ne doit pas dépasser la valeur admissible pour un conducteur en cuivre et la section de tels conducteurs ne doit pas être inférieure à 16 mm^2 pour des raisons de durabilité mécanique.

Les enveloppes ou cadres métalliques, voire les plaques d'assemblage de l'équipement électrique, raccordés au circuit de protection, peuvent être utilisés comme conducteurs de protection s'ils satisfont aux trois exigences suivantes:

- leur continuité électrique doit être assurée par construction ou par un raccordement adapté, de manière à garantir une protection contre toute détérioration mécanique, chimique ou électrochimique;
- ils satisfont aux exigences de 543.1 de l'IEC 60364-5-54:2011;
- ils doivent permettre le raccordement d'autres conducteurs de protection à chaque point de prélèvement prédéterminé.

La section des conducteurs de protection doit être calculée conformément à 543.1.2 de l'IEC 60364-5-54:2011, ou choisie conformément au Tableau 1 (voir 5.2). Voir aussi 8.2.6. et 17.2 (d) du présent document.

Chaque conducteur de protection doit:

- faire partie intégrante d'un câble multiconducteur, ou;
- être dans une enveloppe commune avec le conducteur de phase, ou;
- avoir une section minimale de:
- 2,5 mm^2 Cu ou 16 mm^2 Al en cas de protection contre les dommages mécaniques;
- 4 mm^2 Cu ou 16 mm^2 Al en l'absence de protection contre les dommages mécaniques.

NOTE 1 L'utilisation de l'acier pour un conducteur de protection n'est pas exclue.

Un conducteur de protection qui ne pas partie intégrante d'un câble est considéré comme protégé mécaniquement s'il est installé dans un conduit, une goulotte ou s'il fait l'objet d'une protection similaire.

Les parties suivantes de la machine et son équipement électrique doivent être raccordés au circuit de protection, mais ne doivent pas être utilisés comme conducteurs de protection:

- parties conductrices structurelles de la machine;
- canalisations métalliques souples ou rigides;
- gaines ou armure de câbles métalliques;
- tuyauteries métalliques contenant des matériaux inflammables tels que des gaz, des liquides ou des poudres;
- conduits métalliques souples ou cintrés;
- éléments structuraux soumis à une contrainte mécanique en service normal;
- parties métalliques souples; câbles d'appui, chemins et échelles de câble.

NOTE 2 Les informations concernant la protection cathodique sont données en 542.2.5 et 542.2.6 de l'IEC 60364-5-54:2011.

8.2.3 Continuité du circuit de protection

Lorsqu'un élément est retiré quelle que soit la raison (par exemple, un entretien de routine), le circuit de protection pour les éléments restants ne doit pas être coupé.

Les points de raccordement et de liaison doivent être conçus de façon que leur courant maximal admissible ne soit pas diminué par des influences mécaniques, chimiques ou électrochimiques. Lors de l'utilisation d'enveloppes et de conducteurs en aluminium ou alliages d'aluminium, il convient d'accorder une attention particulière à une éventuelle corrosion électrolytique.

Lorsque l'équipement électrique est monté sur des couvercles, des portes ou des plaques de fermeture, la continuité du circuit de protection doit être assurée et un conducteur de protection est recommandé (voir 8.2.2). Lorsqu'un conducteur de protection n'est pas prévu, des systèmes de fermeture, des charnières ou des contacts glissants conçus pour présenter une faible résistance doivent être utilisés (voir 18.2.2, Essai 1).

La continuité des conducteurs au sein de câbles susceptibles d'être endommagés (par exemple, les câbles souples rampants) doit être assurée par des mesures appropriées (par exemple, la surveillance).

Pour les exigences relatives à la continuité des conducteurs utilisant des câbles conducteurs, des barres conductrices et des ensembles de bagues collectrices, voir 12.7.2.

Le circuit de protection ne doit comprendre ni appareil de connexion, ni dispositif de protection contre les surintensités (par exemple, un interrupteur, un fusible), ni d'autres moyens de coupure.

Exception: les liaisons qui ne peuvent pas être ouvertes sans l'usage d'un outil et qui sont situées dans une zone fermée de service électrique peuvent être assurées pour les besoins des essais ou des mesurages.

Lorsque la continuité du circuit de protection peut être interrompue par des collecteurs mobiles de courant ou des ensembles fiche-prise, le circuit de protection doit être coupé par des contacts séquentiels. Cela concerne aussi les éléments démontables ou débrochables (voir aussi 13.4.5).

8.2.4 Points de raccordement du conducteur de protection

Les extrémités de tous les conducteurs de protection doivent être conformes à 13.1.1. Les points de raccordement des conducteurs de protection ne sont pas destinés, par exemple, à fixer des appareils ou des éléments.

Chaque point de raccordement des conducteurs de protection doit être marqué ou étiqueté comme tel par le symbole IEC 60417-5019:2006-08, comme représenté à la Figure 5:

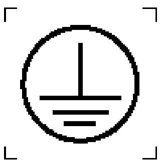


Figure 5 – Symbole IEC 60417-5019: Terre de protection

soit par les lettres PE, le symbole graphique étant préférentiel ou par la combinaison bicolore VERT-ET-JAUNE, ou par toute combinaison des moyens précités.

8.2.5 Machines mobiles

Pour les machines mobiles disposant d'alimentations de puissance embarquées, les conducteurs de protection, les parties conductrices structurelles de l'équipement électrique ainsi que les éléments conducteurs étrangers formant la structure de la machine doivent être tous raccordés à une borne du circuit de protection afin d'assurer la protection contre les chocs électriques. Lorsqu'une machine mobile peut aussi être raccordée à une alimentation extérieure, la borne du circuit de protection doit être le point de connexion du conducteur de protection externe.

NOTE Lorsque l'alimentation électrique est incorporée dans les parties fixes, mobiles ou portatives de l'équipement, et lorsqu'il n'existe pas de source extérieure d'alimentation (par exemple, dans le cas d'un chargeur de batteries embarqué non raccordé), il n'est pas nécessaire de raccorder un tel équipement à un conducteur de protection externe.

8.2.6 Exigences supplémentaires pour un équipement électrique dont les courants de fuite à la terre sont supérieurs à 10 mA

Lorsque l'équipement électrique a un courant de fuite à la terre supérieur à 10 mA en courant alternatif ou en courant continu sur l'un quelconque des conducteurs de protection, une ou plusieurs des conditions suivantes pour l'intégrité de chaque section du circuit de protection associé qui transporte le courant de fuite à la terre doivent être satisfaites:

a) le conducteur de protection est totalement intégré dans des enveloppes d'équipement électrique ou protégé d'une tout autre manière contre les dommages mécaniques sur toute sa longueur;

b) le conducteur de protection a une section au moins égale à 10 mm^2 Cu ou 16 mm^2 Al;

c) lorsque le conducteur de protection a une section inférieure à 10 mm^2 Cu ou 16 mm^2 Al, un second conducteur de protection de section au moins égale est amené jusqu'au point où le conducteur de protection a une section non inférieure à 10 mm^2 Cu ou 16 mm^2 Al. Ceci peut nécessiter que l'équipement électrique dispose d'une borne séparée pour un second conducteur de protection.

d) l'alimentation est automatiquement coupée en cas de perte de continuité du conducteur de protection.

e) lorsqu'un ensemble fiche-prise est utilisé, un connecteur industriel conforme à la série IEC 60309, avec une relaxation appropriée des contraintes et une section minimale du conducteur de terre de protection de 2,5 mm^2 comme partie intégrante d'un câble d'alimentation multiconducteur est prévu.

Les instructions d'installation doivent comporter une indication stipulant que l'équipement doit être installé tel que décrit en 8.2.6.

NOTE Une étiquette d'avertissement peut également être placée de façon contiguë à la borne PE afin d'indiquer que le courant du conducteur de protection dépasse 10 mA.

8.3 Mesures pour limiter les effets d'un courant de fuite élevé

Les effets d'un courant de fuite élevé peuvent être limités à l'équipement sujet à ce courant de fuite élevé par raccordement de cet équipement à un transformateur d'alimentation dédié disposant d'enroulements séparés. Le circuit de protection doit être raccordé aux masses de l'équipement ainsi qu'à l'enroulement secondaire du transformateur. Le ou les conducteurs de protection entre l'équipement et l'enroulement secondaire du transformateur doivent être conformes à une ou plusieurs des dispositions décrites en 8.2.6.

8.4 Liaisons fonctionnelles

La protection contre un fonctionnement impropre, conséquence de défauts d'isolement, peut être assurée par le raccordement à un conducteur commun conformément à 9.4.3.1.1.

Pour les recommandations concernant les liaisons fonctionnelles afin d'éviter un fonctionnement impropre de la machine dû à des perturbations électromagnétiques, voir 4.4.2 et l'Annexe H.

Il convient que les points de raccordement de liaison fonctionnelle soient marqués ou étiquetés comme tel par le symbole IEC 60417-5020:2002-10 (voir Figure 6):

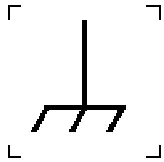


Figure 6 – Symbole IEC 60417-5020: Masse ou châssis

9 Circuits de commande et fonctions de commande

9.1 Circuits de commande

9.1.1 Alimentation des circuits de commande

Lorsque les circuits de commande sont alimentés par une source alternative, les transformateurs disposant d'enroulements séparés doivent être utilisés pour séparer l'alimentation électrique provenant de la source d'alimentation de commande.

Par exemple:

- les transformateurs de commande disposant d'enroulements séparés conformes à l'IEC 61558-2-2,
- les blocs d'alimentation à découpage (conformes à l'IEC 61558-2-16) équipés de transformateurs à enroulements séparés,
- les alimentations basse tension (conformes à l'IEC 61204-7) équipées de transformateurs à enroulements séparés.

Lorsque plusieurs transformateurs sont utilisés, il est recommandé de raccorder leurs enroulements de manière que les tensions secondaires soient en phase.

Exception: Les transformateurs ou les blocs d'alimentation à découpage équipés de transformateurs ne sont pas obligatoires pour les machines à démarreur simple et/ou avec deux dispositifs de commande au maximum (par exemple, dispositif de verrouillage, poste de commande marche/arrêt).

Lorsque des circuits de commande en courant continu issus d'une alimentation en courant alternatif sont raccordés au circuit de protection (voir 8.2.1), ils doivent être alimentés par un enroulement séparé du transformateur de circuit de commande en courant alternatif ou par un autre transformateur de circuit de commande.

9.1.2 Tensions du circuit de commande

La valeur nominale de la tension de commande doit être compatible avec un fonctionnement correct du circuit de commande.

Il convient que la tension nominale des circuits de commande en courant alternatif ne dépasse pas de préférence:

– 230 V pour les circuits à fréquence nominale de 50 Hz,

– 277 V pour les circuits à fréquence nominale de 60 Hz.

Il convient que la tension nominale des circuits de commande en courant continu ne dépasse pas de préférence 220 V.

9.1.3 Protection

Les circuits de commande doivent être fournis avec une protection contre les surintensités conformément à 7.2.4 et 7.2.10.

9.2 Fonctions de commande

9.2.1 Généralités

NOTE Le 9.2 ne spécifie pas les exigences pour les dispositifs utilisés pour mettre en œuvre des fonctions de commande. Des exemples d'exigences concernant les dispositifs sont donnés dans l'Article 10.

9.2.2 Catégories de fonctions d'arrêt

Il existe trois catégories de fonctions d'arrêt:

– arrêt de catégorie 0: arrêt par coupure immédiate de l'alimentation aux actionneurs (c'est-à-dire, un arrêt non contrôlé – voir 3.1.64);
– arrêt de catégorie 1: arrêt contrôlé (voir 3.1.14) en maintenant l'alimentation aux actionneurs jusqu'à l'arrêt de la machine, puis coupure de l'alimentation lorsque l'arrêt est obtenu;
– arrêt de catégorie 2: arrêt contrôlé avec maintien de l'alimentation des actionneurs.

NOTE Pour la coupure de l'alimentation, il peut être suffisant de couper l'alimentation nécessaire pour générer un couple ou une force. Ceci peut être réalisé par débrayage, sectionnement ou coupure, ou par moyen électronique (par exemple, un PDS conformément à la série IEC 61800), etc.

9.2.3 Fonctionnement

9.2.3.1 Généralités

Les fonctions de sécurité et/ou les mesures de protection (par exemple, les verrouillages (voir 9.3)) doivent être prévues si nécessaire pour réduire la possibilité de situations dangereuses.

Dans le cas d'une machine disposant de plus d'un poste de commande, des mesures doivent être prises afin d'assurer que l'initiation des commandes à partir de postes de commande différents ne conduit pas à une situation dangereuse.

9.2.3.2 Marche

Les fonctions de marche doivent agir par mise sous tension du circuit correspondant.

Le démarrage ne doit être possible que si toutes les fonctions de sécurité et/ou les mesures de protection appropriées sont en place et opérationnelles, excepté dans les conditions décrites en 9.3.6.

Pour les machines (par exemple, les machines mobiles) dont les fonctions de sécurité et/ou les mesures de protection ne peuvent pas être utilisées pour certaines manœuvres, le démarrage de telles manœuvres doit être effectué par des commandes à action maintenue associées à des dispositifs de validation, suivant le cas.

Il convient d'envisager de mettre en place des signaux de mise en garde acoustiques et/ou visuels avant le démarrage de manœuvres dangereuses des machines.

Des verrouillages appropriés doivent être prévus si nécessaires pour une séquence de démarrage correcte.

Dans le cas de machines nécessitant l'utilisation de plusieurs postes de commande pour déclencher une mise en marche, chacun de ces postes de commande doit avoir un appareil de commande de mise en marche séparé et actionné manuellement. Les conditions pour déclencher une mise en marche doivent être:

- toutes les conditions exigées pour le fonctionnement de la machine doivent être satisfaites, et
- tous les dispositifs de commande de mise en marche doivent être en position «relâchée», puis
- tous les dispositifs de commande de mise en marche doivent être manœuvrés de façon concomitante (voir 3.1.7).

9.2.3.3 Arrêt

Des fonctions d'arrêt de catégorie 0 et/ou arrêt de catégorie 1 et/ou arrêt de catégorie 2 doivent être prévues comme indiqué par l'appréciation du risque et par les exigences fonctionnelles pour la machine (voir 4.1).

NOTE 1 L'appareil de sectionnement de l'alimentation (voir 5.3), lorsqu'il est manœuvré, réalise un arrêt de catégorie 0.

Les fonctions d'arrêt doivent être prioritaires sur les fonctions associées de mise en marche.

Lorsque plus d'un poste de commande est fourni, les commandes d'arrêt de chaque poste de commande doivent être effectives lorsque l'appréciation du risque de la machine l'exige.

NOTE 2 Lorsque les fonctions d'arrêt sont déclenchées, il peut être nécessaire d'interrompre les fonctions de la machine autres que les fonctions de déplacement.

9.2.3.4 Manœuvres d'urgence (arrêt d’urgence, coupure d'urgence)

9.2.3.4.1 Généralités

L'arrêt d'urgence et la coupure d'urgence sont des mesures de protection complémentaires qui ne constituent pas des dispositifs principaux de réduction du risque pour les dangers (par exemple, emprisonnement, happement, enroulement, choc électrique ou brûlure) sur une machine (voir l’ISO 12100).

La présente partie de l'IEC 60204 spécifie les exigences relatives aux fonctions d'arrêt d'urgence et de coupure d'urgence pour les manœuvres d'urgence énumérées dans l'Annexe E, ces deux fonctions étant destinées à être déclenchées par une seule action humaine.

Une fois que la manœuvre active d'un organe de manœuvre d'arrêt d'urgence (voir 10.7) ou de coupure d'urgence (voir 10.8) a cessé après une commande d'arrêt ou de coupure, l'effet de cette commande doit être maintenu jusqu'à ce qu'elle soit réinitialisée. Cette réinitialisation ne doit être possible que par une action manuelle sur le dispositif pour lequel la commande a été initiée. La réinitialisation de la commande ne doit pas redémarrer la machine, mais seulement autoriser le redémarrage.

Il ne doit pas être possible de redémarrer la machine tant que toutes les commandes d'arrêt d'urgence n'ont pas été réinitialisées. Il ne doit pas être possible de réalimenter la machine tant que toutes les commandes de coupure d'urgence n'ont pas été réinitialisées.

9.2.3.4.2 Arrêt d'urgence

Les exigences relatives aux aspects fonctionnels des équipements d'arrêt d'urgence sont données dans l'ISO 13850.

L'arrêt d'urgence doit fonctionner soit comme un arrêt de catégorie 0 soit comme un arrêt de catégorie 1. Le choix de la catégorie d'arrêt de l'arrêt d'urgence dépend des résultats de l'appréciation du risque de la machine.

Exception: Pour éviter de créer d’autres risques, il peut être nécessaire, dans certains cas, de réaliser un arrêt contrôlé et de maintenir l’énergie fournie aux actionneurs même après l’arrêt.

La condition d'arrêt doit être surveillée et dès détection de la défaillance de cette condition, l'énergie doit être supprimée sans créer une situation dangereuse.

Outre les exigences pour un arrêt données en 9.2.3.3, la fonction d'arrêt d'urgence est soumise aux exigences suivantes:

- elle doit être prioritaire par rapport à toutes les autres fonctions et manœuvres dans tous les modes;
- elle doit arrêter le mouvement dangereux aussi rapidement que possible sans créer d'autres dangers;
- la réinitialisation ne doit pas provoquer un redémarrage.

9.2.3.4.3 Coupure d'urgence

Les aspects fonctionnels de la coupure d'urgence sont donnés en 536.4 de l'IEC 60364-5-53:2001.

Il convient de fournir une coupure d'urgence dans les cas où:

- la protection principale (par exemple, pour des câbles conducteurs, des barres conductrices, des ensembles de bagues collectrices, l'appareillage de commande dans des zones de service électrique) est seulement réalisée par mise hors de portée, ou par mise en place d'obstacles (voir 6.2.6); ou
- d'autres dangers ou dommages dus à l'électricité peuvent se produire.

La coupure d'urgence est réalisée par la coupure de l'alimentation appropriée de la machine au moyen d'appareils de connexion électromécaniques, réalisant un arrêt de catégorie 0 des actionneurs raccordés à cette alimentation. Lorsqu'une machine ne peut supporter cet arrêt de catégorie 0, il peut être nécessaire de prévoir d'autres mesures, par exemple, une protection principale, de manière que cette coupure d'urgence ne soit pas nécessaire.

9.2.3.5 Modes de fonctionnement

Chaque machine peut avoir un ou plusieurs modes de fonctionnement (par exemple, mode manuel, mode automatique, mode de réglage, mode de maintenance) déterminés par le type de machine et son application.

Lorsque la machine a été conçue et fabriquée de manière à pouvoir être utilisée dans plusieurs modes de commande ou de fonctionnement nécessitant différentes mesures de protection et ayant une incidence différente sur la sécurité, elle doit être équipée d'un sélecteur de mode qui peut être verrouillé dans chaque position (par exemple, un commutateur à clé). Chaque position du sélecteur doit être clairement identifiable et doit correspondre à un seul mode de fonctionnement ou de commande.

Le sélecteur de mode peut être remplacé par une autre méthode de sélection (par exemple, un code d'accès) qui restreint l'utilisation de certaines fonctions de la machine à certaines catégories d'opérateurs.

La sélection d'un mode ne doit pas par elle-même provoquer la mise en marche de la machine. Une manœuvre séparée de la commande de mise en marche doit être exigée.

Les fonctions de sécurité et/ou les mesures de protection appropriées pour chaque mode de fonctionnement particulier doivent être mises en œuvre.

L'indication du mode de fonctionnement choisi doit être prévue (par exemple, la position du sélecteur de mode, la mise en place d'un voyant lumineux, l'indication visuelle sur un écran).

9.2.3.6 Surveillance de l'action des commandes

Tout mouvement ou toute action d'une machine ou d'une partie de machine qui peut entraîner une situation dangereuse doit être surveillé(e) en prévoyant, par exemple, des limiteurs de course, la détection de la survitesse des moteurs, la détection de la surcharge mécanique ou des appareils anticollision.

NOTE Sur certaines machines à commande manuelle (par exemple, machine de perçage à commande manuelle), les opérateurs assurent la surveillance.

9.2.3.7 Commandes nécessitant une action maintenue

Les commandes nécessitant une action maintenue doivent nécessiter une activation continue du ou des dispositifs de commande pour effectuer une manœuvre.

9.2.3.8 Commandes bimanuelles

Trois types de commandes bimanuelles sont définis dans l'ISO 13851, leur choix dépendant de l'appréciation du risque. Elles doivent comporter les caractéristiques suivantes:

Type I: ce type exige:

- la présence de deux dispositifs de commande et leur manœuvre concomitante par les deux mains;
- une manœuvre concomitante et continue au cours d'une situation dangereuse;
- le fonctionnement de la machine doit s'interrompre dès que l'un des deux ou les deux dispositifs de commande sont relâchés alors que la situation dangereuse est encore présente.

Un dispositif de commande bimanuelle de Type I n'est pas considéré comme étant adapté pour le démarrage d'une manœuvre dangereuse.

Type II: une commande de Type I nécessitant le relâchement des deux dispositifs de commande avant de pouvoir réinitialiser la mise en marche de la machine.

Type III: une commande de Type II nécessitant une action concomitante des dispositifs de commande dans les conditions suivantes:

- il doit être nécessaire de manœuvrer les dispositifs de commande dans un intervalle de temps limité ne dépassant pas 0,5 s;
- si cette limite de temps est dépassée, les deux dispositifs de commande doivent être relâchés avant de pouvoir réinitialiser la mise en marche de la machine.

9.2.3.9 Appareil de commande de validation

Un appareil de commande de validation (voir aussi 10.9) est un verrouillage de fonction de commande manœuvré manuellement qui:

a) lorsqu'il est activé, autorise la mise en marche d'une machine par une commande de démarrage séparée, et
b) lorsqu'il est désactivé
   - initie une fonction d'arrêt, et
   - empêche la mise en marche de la machine.

Un appareil de commande de validation doit être disposé de façon à réduire le plus possible la possibilité de neutralisation, par exemple, en exigeant la désactivation de l'appareil de commande de validation avant de pouvoir réinitialiser la mise en marche de la machine.