

REDLINE VERSION



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



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REDLINE VERSION



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

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**SAFETY OF MACHINERY –
ELECTRICAL EQUIPMENT OF MACHINES –****Part 1: General requirements****FOREWORD**

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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 mm² solid conductors within enclosures (USA).
- 12.2: The smallest power circuit conductor allowed on machines is 0,82 mm² (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 $U_o \geq 300V$, 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).

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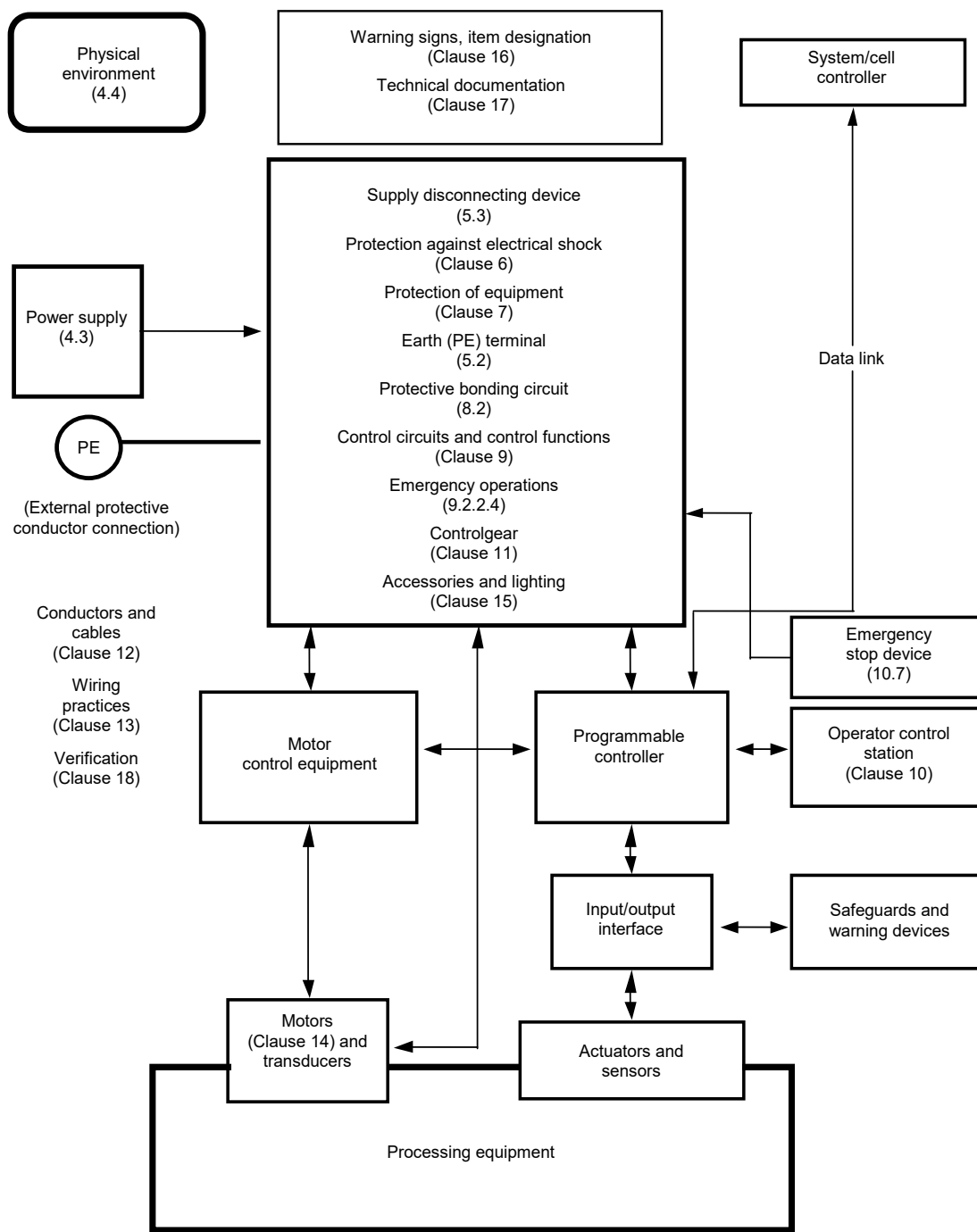
INTRODUCTION

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/fixtures, 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.



IEC

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 IECV 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 12100-4:2010, 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 $-25\text{ }^{\circ}\text{C}$ to $+55\text{ }^{\circ}\text{C}$ and for short periods not exceeding 24 h at up to $+70\text{ }^{\circ}\text{C}$. 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 systems.

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 mm ²	Minimum cross-sectional area of the external corresponding protective copper 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 ~~(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:

- switch-disconnector, with or without fuses, in accordance with IEC 60947-3, utilization category AC-23B or DC-23B;
- ~~disconnecter, 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 disconnecter;~~
- control and protective switching device suitable for isolation, in accordance with IEC 60947-6-2;
- a circuit-breaker suitable for isolation in accordance with IEC 60947-2;
- 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;~~
- 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 the~~

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).

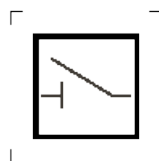


Figure 2 – Disconnecter isolator

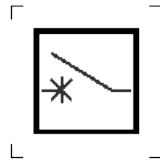


Figure 3 – Disconnecting circuit breaker

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 (t^2I) 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 temperatures

~~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.