# IEC 60204-11

Edition 2.0 2018-07
REDLINE VERSION

# INTERNATIONAL STANDARD





## Safety of machinery – Electrical equipment of machines – Part 11: Requirements for ~~HV~~ equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV

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## Safety of machinery – Electrical equipment of machines – Part 11: Requirements for ~~HV~~ equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV

INTERNATIONAL
ELECTROTECHNICAL
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CONTENTS

FOREWORD....6
INTRODUCTION....8
1 Scope....10
2 Normative references....11
3 Terms and definitions....13
4 General requirements....21
4.1 General ~~considerations~~....21
4.2 Selection of electrical equipment....22
4.3 Electrical power supply....22
4.3.1 General....22
4.3.2 ~~Supplies~~ Voltage characteristics....22
4.3.3 On-board power supply....23
4.4 Physical environment and operating conditions....23
4.4.1 General....23
4.4.2 Electromagnetic compatibility (EMC)....23
4.5 Transportation and storage....24
4.6 Provisions for handling....24
4.7 Installation....24
4.7.1 General....24
4.7.2 Assembly and mounting....24
5 Incoming supply conductor terminations and devices for disconnecting and switching off~~, and means for earthing~~....24
5.1 Incoming ~~supply~~ high-voltage conductor terminations....24
5.2 Earthing terminal of high-voltage equipment....24
5.3 Supply disconnecting ~~(isolating)~~ devices and means for earthing....25
5.3.1 General....25
5.3.2 Type....25
5.3.3 Requirements for disconnectors....26
5.3.4 ~~Means~~ Requirements for earthing and short-circuiting....27
~~Operating handle....~~
5.3.5 Arrangement of disconnecting and earthing devices....27
5.4 Devices for switching off for prevention of unexpected start-up....28
5.5 Devices for disconnecting and means for earthing HV equipment....28
5.6 Protection against unauthorized, inadvertent and/or mistaken operation....29
6 Protection against electric shock....29
6.1 General....29
6.2 Protection against direct contact....30
6.3 Protection against indirect contact....30
6.3.1 General....30
6.3.2 Measures to prevent the occurrence of a hazardous touch voltage for an unlimited time of fault duration....31
6.3.3 Protection by automatic disconnection of supply within a limited time of fault duration....31
6.3.4 Protection for mobile machines....31
7 Protection of HV equipment....32
7.1 General....32

7.2 Overcurrent protection ..... 32
7.2.1 General ..... 32
7.2.2 Supply conductors ..... 32
7.2.3 Power circuits ..... 32
7.2.4 Transformers ..... 33
7.2.5 Overcurrent protective devices ..... 33
7.2.6 Rating and setting of overcurrent protective devices ..... 33
7.3 Protection of motors against overheating ..... 33
7.4 Protection against abnormal temperature ..... 33
7.5 Protection against the effects of supply interruption or voltage reduction and subsequent restoration ..... 33
7.6 Motor overspeed protection ..... 34
7.7 Earth fault protection ..... 34
7.8 Protection against overvoltages due to lightning and to switching surges ..... 34
~~Protection against abnormal conditions ..... .....~~
7.9 Protection against hazards due to arc faults ..... 35
7.10 Protection against overpressure and leakage ..... 35
7.11 Protection against fire ..... 35
8 Equipotential bonding ..... 35
8.1 General ..... 35
8.2 Protective bonding circuit ..... 37
8.2.1 General ..... 37
8.2.2 Protective conductors ..... 38
8.2.3 Continuity of the protective bonding circuit ..... 39
~~Exclusion of switching devices from the protective bonding circuit ..... .....~~
~~Interruption of the protective bonding circuit ..... .....~~
8.2.4 Mobile machines ..... 40
8.2.5 Protective bonding circuit connecting points ..... 40
8.2.6 Supplementary ~~equipotential~~ protective bonding conductors ..... 40
9 Control systems, control circuits and control functions ..... 40
10 Operator interface and machine-mounted control devices ..... 41
11 Electronic equipment ..... 41
12 Controlgear: location, mounting, and enclosures ..... 41
12.1 General requirements ..... 41
12.2 Location and mounting ..... 41
12.2.1 Accessibility and maintenance ..... 41
12.2.2 Physical separation ..... 42
12.3 Degrees of protection ..... 42
12.4 Enclosures, doors and openings ..... 43
12.5 Access to HV equipment ..... 44
13 Conductors and cables ..... 44
13.1 General requirements ..... 44
13.2 Conductors ..... 44
13.3 Insulation and sheath materials ..... 45
13.4 Current-carrying capacity in normal service ..... 45
13.5 Conductor and cable voltage drop ..... 46
13.6 Minimum cross-sectional area ..... 46
13.7 Flexible cables ..... 46

13.7.1 General ..... 46
13.7.2 Mechanical rating ..... 46
13.7.3 Current-carrying capacity of cables wound on drums ..... 46
13.8 Conductor wires, conductor bars and slip-ring assemblies ..... 47
13.8.1 Protection against direct contact ..... 47
13.8.2 Protective bonding circuit ..... 47
13.8.3 Protective conductor current collectors ..... 48
13.8.4 Clearances in air ..... 48
13.8.5 Creepage distances ..... 48
13.8.6 Conductor system sectioning ..... 49
13.8.7 Construction and installation of conductor wire, conductor bar systems and slip-ring assemblies ..... 49
14 Wiring practices ..... 50
14.1 Connections and routing ..... 50
14.1.1 General requirements ..... 50
14.1.2 Cable runs ..... 50
14.2 Identification of conductors ..... 51
14.3 Flexible cables ..... 51
14.4 Plug-socket combinations ..... 52
14.5 Dismantling for shipment ..... 52
14.6 Cable trays ..... 52
15 Electric motors and associated equipment ..... 52
15.1 General ..... 52
15.2 Motor connection boxes ..... 52
~~Accessories~~ .....
~~Accessories for earthing and short-circuiting live parts~~ .....
~~Voltage detectors~~ .....
~~Accessories for safe working~~ .....
16 Means to protect persons working on electrical installations ..... 53
16.1 General ..... 53
16.2 Equipment for isolating installations or apparatus ..... 53
16.3 Devices to prevent reclosing of isolating devices ..... 53
16.4 Devices for determining the de-energized state ..... 53
16.5 Devices for earthing and short-circuiting ..... 53
16.6 Equipment acting as protective barriers against adjacent live parts ..... 53
16.7 Storage of personal protection equipment ..... 53
17 Marking, warning signs and reference designations ..... 54
17.1 General ..... 54
17.2 Warning signs ..... 54
18 Technical documentation ..... 55
18.1 General ..... 55
18.2 Instructions for use ..... 55
18.2.1 General ..... 55
18.2.2 Provisions for handling ..... 55
18.2.3 Assembly and mounting ..... 55
18.2.4 Connections ..... 55
18.2.5 Final installation inspection ..... 55
18.2.6 Warning sign ..... 56

19 Testing and verification ..... 56
19.1 General ..... 56
19.2 Earthing system tests ..... 56
19.3 Insulation resistance tests ..... 56
19.4 Voltage tests ..... 57
19.5 Functional tests ..... 57
19.6 IP tests for HV equipment outside electrical operating areas ..... 57
19.7 Retesting ..... 57
Annex A (informative) Examples of machines covered by IEC 60204-11 ..... 58
Annex B (informative) Inquiry form for the HV equipment of machines ..... 59
~~Annex (informative) Method of calculation for the cross-sectional area of bare protective conductors in supply systems with direct earthing or low impedance earthing of the neutral~~ .....
Annex C (informative) Relationship between cable rated voltages and highest voltage for HV equipment ..... 65
~~Annex (informative) Rationalization of the use of terms relating to earthing and protective bonding~~ .....
~~Index~~ .....
Bibliography ..... 71

~~Figure – Explanation of the terms relating to earthing and protective bonding~~ .....
Figure 1 – Block diagram of a machine containing HV equipment ..... 9
Figure 2 – Example of equipotential bonding for electrical equipment of a machine ..... 37
Figure 3 – Symbol for protective earth (protective ground) ..... 40
Figure 4 – Warning sign “high voltage” ..... 54
Figure 5 – DANGER hazard severity panel ..... 55

~~Table – Cross-sectional area of bare protective conductors~~ .....
Table 1 – Maximum allowable conductor temperatures under normal and short-circuit conditions ..... 45
Table 2 – De-rating factors for cables wound on drums ..... 47
Table 3 – Selection of the pollution level depending on the degree of protection and insulator material ..... 49
Table 4 – Minimum creepage distance of conductor lines and slip ring assemblies ..... 49
Table B.1 – Overvoltage protection for HV equipment of machinery ..... 62
Table C.1 – Rated voltages of cable and highest voltage for HV equipment ..... 65

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# SAFETY OF MACHINERY – ELECTRICAL EQUIPMENT OF MACHINES –

## Part 11: Requirements for ~~HV~~ equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV

## FOREWORD

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International Standard IEC 60204-11 has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects.

This second edition cancels and replaces the first edition, published in 2000. This edition constitutes a technical revision.

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

– aspects of risk assessment, which are mirrored from ISO 12100;
– equipotential bonding and earthing;
– EMC and power quality;
– HV switchgear and controlgear;
– creepage distances for conductors and slip-ring assemblies;
– a list of machinery using HV equipment, in Annex A.

This second edition of IEC 60204-11 has been updated and improved to reflect the experience gained with the first edition and the evolution of high-voltage equipment reflected in the relevant standards.

Regarding formal requirements, IEC 60204-11 has been aligned with

– IEC 60204-1:2016,
– IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014,
– IEC 62271 (all parts).

This document is intended to be used in conjunction with IEC 60204-1.

The text of this International Standard is based on the following documents:

| FDIS | Report on voting |
|---|---|
| 44/819/FDIS | 44/828/RVD |

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

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

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

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# INTRODUCTION

This part of IEC 60204 provides requirements and recommendations relating to the high-voltage electrical equipment (HV equipment) of machines together with its associated low-voltage electrical equipment (LV equipment) so as to promote

– safety of persons and property,

– consistency of control response,

– ~~ease of maintenance~~ maintainability.

~~High performance is not to be obtained at the expense of the essential factors mentioned above.~~

~~An example of a possible application of these requirements is a machine or group of machines used for the processing of a material where a failure in such machinery can have serious economic consequences.~~

Figure 1 is a block diagram of a machine and associated equipment showing the various elements of the electrical equipment addressed in this document. Numbers in parentheses (…) refer to clauses and subclauses in this document. It is understood that all of the elements taken together including the safeguards, software and the documentation constitute the machine or group of machines working together with usually at least one level of supervisory control.

~~More guidance on the use of this standard is given in annex F of IEC 60204-1.~~

This document should be used in conjunction with IEC 60204-1. HV equipment can include LV control parts in the same general enclosure or in separate compartments.

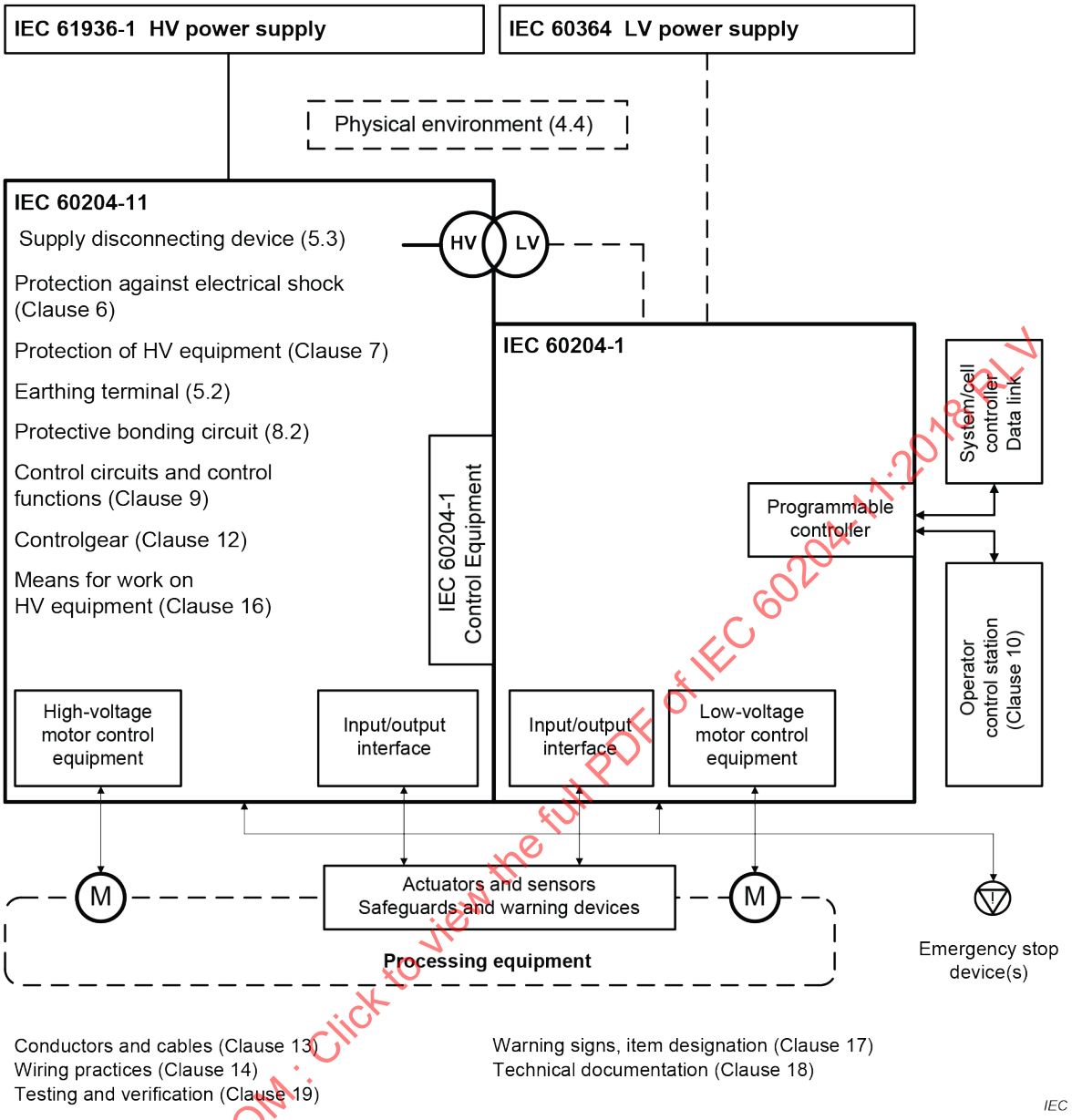



**Figure 1 – Block diagram of a machine containing HV equipment**

# SAFETY OF MACHINERY – ELECTRICAL EQUIPMENT OF MACHINES –

## Part 11: Requirements for ~~HV~~ equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV

## 1 Scope

This part of IEC 60204 applies to electrical and electronic equipment and systems to machines, including a group of machines working together in a co-ordinated manner, ~~but excluding higher level system aspects (i.e. communications between systems)~~ which operate at nominal voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV AC or DC with nominal frequencies not exceeding 60 Hz.

~~This part of IEC 60204 is applicable to equipment, or parts of equipment, which operate with nominal supply voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV a.c. or d.c. with nominal frequencies not exceeding 200 Hz. For higher voltages or frequencies, special requirements may be needed.~~

In this document, the term HV equipment also covers the LV equipment forming an integral part of the equipment operating at high voltage. The requirements in this document primarily cover the parts operating at high-voltage except where explicitly stated otherwise. ~~Reference is made to IEC 60204-1 for those requirements which also apply to HV equipment.~~

NOTE 1 ~~Other~~ LV equipment not forming part of the HV equipment ~~and defined as operating at voltages not exceeding 1 000 V a.c. or 1 500 V d.c. are~~ is covered by IEC 60204-1:2016.

NOTE 2 In this document, the term "electrical" includes both electrical and electronic matters (i.e. electrical equipment means both the electrical and the electronic equipment).

NOTE 3 This document does not apply to independent high-voltage power supply installations for which separate IEC standards exist.

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

~~NOTE For the requirements for power supply installations, see HD 637.~~

NOTE 4 For the requirements for high-voltage power supply installations, see IEC 61936-1.

This document is ~~an application~~ a generic safety standard ~~and is not intended to limit or inhibit technological advancement~~. It does not cover all the requirements (e.g. guarding, interlocking or control) which are needed or required by other standards or regulations in order to safeguard personnel from hazards other than electrical hazards. Each type of machine has unique requirements to be accommodated to provide adequate safety.

NOTE 5 In some machines the high-voltage power supply can be produced by a step-up transformer (autotransformer), supplied by a low-voltage system (e.g. by a LV generator).

NOTE 6 In the context of this document, the term "person" refers to any individual; "personnel" are those persons who are assigned and instructed by the user or his agent(s) in the use and care of the machine in question.

This part of IEC 60204 specifically includes, but is not limited to, machines as defined in 3.29 (Annex A lists examples of machines whose electrical equipment ~~may~~ can be covered by this document).

For protection against electric shock from high-voltage equipment, this document refers to IEC 61936-1. When it comes to low-voltage equipment, this document refers to IEC 60204-1:2016.

NOTE 7 High- and low-voltage standards use different terms regarding protection against electric shock. Whereas high-voltage standards use the terms “direct contact” and “indirect contact”, low-voltage standards correspondingly use “basic protection” and “fault protection”.

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

– are used in the open air (i.e. outside buildings or other protective structures);
– use, process or produce potentially explosive material (e.g. paint or sawdust);
– are used in potentially explosive and/or flammable atmospheres;
– have special risks when producing or using certain materials;
– are used in mines.

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

Hazards as a result of noise and vibration are excluded from the scope of this document.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~IEC 60034-1:1996, *Rotating electrical machines – Part 1: Rating and performance*~~

~~IEC 60050(191):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 191: Dependability and quality of service*~~

~~IEC 60050-195:1998, *International Electrotechnical Vocabulary (IEV) – Part 195: Earthing and protection against electric shock*~~

~~IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*~~

~~IEC 60050(826):1982, *International Electrotechnical Vocabulary (IEV) – Chapter 826: Electrical installations of buildings*~~

~~IEC 60050(826):1995, amendment No. 2~~

~~IEC 60071-1:1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*~~

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guide*

IEC 60076-5~~:1976~~, *Power transformers – Part 5: Ability to withstand short-circuit*

~~IEC 60129:1984, *Alternating current disconnectors and earthing switches*~~

~~IEC 60298:1990, *A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*~~

~~IEC 60364-4-41:1992, *Electrical installations of buildings – Part 4: Protection for safety – Chapter 41: Protection against electric shock*~~

~~IEC 60364-4-42:1980, *Electrical installations of buildings – Part 4: Protection for safety – Chapter 42: Protection against thermal effects*~~

IEC 60204-1:~~1997~~ 2016, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60364-5-54:~~1980~~ 2011, *Low-voltage electrical installations ~~of buildings~~ – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*

IEC 60417, *Graphical symbols for use on equipment* (available at http://www.graphical-symbols.info/equipment)

~~IEC 60420:1990, *High-voltage alternating current switch-fuse combinations*~~

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

~~IEC 60466:1987, *A.C. insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 38 kV*~~

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

~~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 60694:1996, *Common specifications for high-voltage switchgear and controlgear standards*~~

IEC 60865-1~~:1993~~, *Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods*

~~IEC 61230:1993, *Live working – Portable equipment for earthing or earthing and short-circuiting*~~

~~IEC 61243-1:1993, *Live working – Voltage detectors – Part 1: Capacitive type to be used for voltages exceeding 1 kV a.c.*~~

~~IEC 61310-1:1995, *Safety of machinery – Indication, marking and actuation – Part 1: Requirements for visual, auditory and tactile signals*~~

~~IEC 61310-3:1999, *Safety of machinery – Indication, marking and actuation – Part 3: Requirements for the location and operation of actuators*~~

IEC 61800 (all parts), *Adjustable speed electrical power drive systems*

IEC 61936-1:2010, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*
IEC 61936-1:2010/AMD1:2014

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

IEC 62271-102, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC 62271-103, *High-voltage switchgear and controlgear – Part 103: Switches for rated voltages above 1 kV up to and including 52 kV*

IEC 62271-105, *High-voltage switchgear and controlgear – Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kV up to and including 52 kV*

IEC 62271-107, *High-voltage switchgear and controlgear – Part 107: Alternating current fused circuit-switchers for rated voltages above 1 kV up to and including 52 kV*

IEC 62271-200:2011, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-201, *High-voltage switchgear and controlgear – Part 201: AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62745, *Safety of machinery – Requirements for cableless control systems of machinery*

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

ISO 3864-1:~~1984~~ 2011, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

ISO 3864-2:2016, *Graphical symbols –Safety colours and safety signs – Part 2: Design principles for product safety labels*

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

ISO 12100, *Safety of machinery –General principles for design – Risk assessment and risk reduction*

~~ISO/TR 12100-1:1992, *Safety of machinery – Basic concepts, general principles for design – Part 1: Basic terminology, methodology*~~

~~EN 50178:1997, *Electronic equipment for use in power stations*~~

~~HD 637:1999, *Power installations exceeding 1 kV a.c.*~~



## 3 Terms and definitions

~~NOTE The index lists, in alphabetical order, the terms defined in this clause and indicates where they are used in the text of this part of IEC 60204.~~

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

**3.1**
**ambient temperature**
temperature of the air or other medium where the equipment is to be used

~~[IEV 826-01-04]~~

**3.2**
**barrier**
part providing protection against ~~direct~~ contact with live parts from any usual direction of access

~~[IEV 826-03-13]~~

**3.3**
**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.]

**3.4**
**cable tray**
cable support consisting of a continuous base ~~and~~ with raised edges ~~and~~ but no covering

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

[SOURCE: ~~IEV 826-06-07, amendment 2~~ IEC 60050-826:2004, 826-15-08]

**3.5**
**conductor wire**
**conductor bar**
**conductor rail**
conductive wire, bar or rail of a feeder system with a sliding current collector

**3.6**
**control circuit**
<of a machine> circuit used for ~~the operational control of the machine and for protection of the power circuits~~ the control, including monitoring, of a machine and the electrical equipment

**3.7**
**control device**
device connected into the control circuit and used for controlling the operation of the machine

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

**3.8**
**controlgear**
general term covering 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 60050-441:2000, 441-11-03]

~~**3.7**~~
~~**direct contact**~~
~~electric contact of persons or animals with live parts~~

~~[IEV 195-06-03]~~

**3.9**
**duct**
enclosed channel designed expressly for holding and protecting electrical conductors, cables, and busbars

Note 1 to entry: Conduits, cable trunking systems and underfloor channels are types of duct.

**3.10**
**earthing system**
~~locally limited system of conductively connected earth electrodes or metal parts of equal effectiveness (for example tower footings, armourings, metal cable sheaths), of earthing conductors and of bonding conductors~~

~~[HD 637, 2.7.6]~~

all the electric connections and devices involved in the earthing of a system, an installation and equipment

[SOURCE: IEC 60050-826:2004, 826-13-04, modified – The preferred terms have been deleted and the deprecated term is used as a preferred term.]

**3.11**
**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

Note 1 to entry: An (electrically) instructed person is a person adequately advised or supervised by an electrically skilled person to enable him or her to perceive risks and to avoid hazards which electricity can create ~~[IEV 826-09-02, modified]~~ (see IEC 60050-826:2004, 826-18-02)

Note 2 to entry: An (electrically) skilled person is a person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create ~~[IEV 826-09-01, modified]~~ ~~[see also IEC 60204-1, 3.28 and 3.52]~~ (see IEC 60050-826:2004, 826-18-01)

**3.12**
**electronic equipment**
part of the electrical equipment containing circuitry mainly based on electronic devices and components

**3.13**
**~~enclosed~~ closed electrical operating area**
room or location for operation of electrical installations and equipment to which access is intended to be restricted to skilled or instructed persons or to lay personnel under the supervision of skilled or instructed persons, e.g. by opening of a door or removal of a protective barrier only by the use of a key or tool, and which is clearly marked by appropriate warning signs

Note 1 to entry: See also Notes to entry 1 and 2 of definition 3.11.

**3.14**
**enclosure**
part providing a specified degree of protection of equipment against ~~certain~~ external influences and, in any direction, a specified degree of protection against ~~direct contact [IEV 826-03-12]~~ approach to or contact with live parts and against contact with moving parts

Note 1 to entry: The definition ~~taken from the existing IEV~~ needs the following explanations within the scope of this document ~~(see IEC 60529, 3.1)~~:

Enclosures provide protection of persons or livestock against access to hazardous parts.

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.

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 60050-441:2000, 441-13-01, modified – "of an assembly" has been deleted and "in any direction" and the note have been added.]

**3.15**
**equipment**
~~general term including material, fittings, devices, appliances, fixtures, apparatus, and the like used as part of, or in connection with, an electrical installation~~
items used in connection with the utilisation of electricity by machines or parts of machines, for example material, fittings, devices, components, appliances, fixtures, apparatus, and similar

**3.15.1**
**high-voltage electrical equipment**
items as defined in IEC 60204-11:2018, 3.15 which are designed to operate at voltages above 1 000 V AC or 1 500 V DC

Note 1 to entry: For easier reading in this document "HV equipment" is used where the context is obvious.

**3.16**
**equipotential bonding**
provision of electric connections between conductive parts, intended to reduce the potential differences and achieve equipotentiality between these parts

[SOURCE: IEC 60050-195:1998, 195-01-10, modified – "reduce the potential differences" and "between these parts" have been added.]

~~**3.16**~~
~~**equipotential bonding conductor**~~
~~(protective bonding conductor)~~
~~protective conductor provided for protective equipotential bonding~~

~~[IEV 195-02-10]~~

**3.17**
**protective bonding conductor**
protective conductor provided for protective equipotential bonding

[SOURCE: IEC 60050-195:1998, 195-02-10]

**3.18**
**exposed conductive part**
conductive part of equipment which can be touched and which is not normally live, but which can become live when basic insulation fails

[SOURCE: IEC 60050-195:1998, 195-06-10]

**3.19**
**extraneous conductive part**
conductive part not forming part of the electrical installation and liable to introduce an electric potential, generally the electric potential of a local earth

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

**3.20**
**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: ~~IEV 191-04-01~~ IEC 60050-603:1986, 603-05-06, modified – The notes have been added.]

**3.21**
**fault**
state of an item characterized by the 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 ~~IEV 191-05-01~~ IEC 60050-192:2015, 192-04-01. 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.

**3.22**
**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]

**3.23**
**hazard**
potential source of ~~possible~~ 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, and 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 – "harm" has been replaced with "physical injury or damage to health" and Note 3 has been deleted.]

~~**3.22**~~
~~**indirect contact**~~
~~electric contact of persons or animals with exposed-conductive-parts which have become live under fault conditions~~

~~[IEV 195-06-04]~~

**3.24**
**Interlock**
**interlock ~~(~~for safeguarding~~)~~**
~~arrangement that interconnects guard(s) or device(s) with the control system and/or all or part of the electrical energy distributed to the machine~~
arrangement of devices operating together to:

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

**3.25**
**live part**
conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

[SOURCE: IEC 60050-195:1998, 195-02-19]

**3.26**
**machine bonding conductor**
conductor connecting the machine equipotential bonding to the earthing system

Note 1 to entry: This is an earthing conductor as defined in ~~IEV 826-04-07 and used in HD 637~~ IEC 60050-826:2004, 826-13-12 and used in IEC 61936-1.

Note 2 to entry: This corresponds to the term “earthing conductor” in IEC 61936-1.

**3.27**
**machine actuator**
power mechanism of the machine used to effect motion

EXAMPLE Motor, solenoid, pneumatic or hydraulic cylinder.

**3.28**
**neutral conductor**
conductor electrically connected to the neutral point and capable of contributing to the distribution of electric energy

[SOURCE: IEC 60050-195:1998, 195-02-06]

**3.29**
**machinery**
**machine**
assembly of linked parts or components, at least one of which moves, with the appropriate machine actuators, control and power circuits, etc., joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material

Note 1 to entry: The terms "machinery" and "machine" also cover:

– an assembly of machines which, in order to achieve one and the same end, are arranged and controlled so that they function as an integral whole;
– interchangeable equipment modifying the function of a machine, which is placed on the market (supplied) for the purpose of being assembled with a machine or a series of different machines or with a tractor by the operator himself insofar as this equipment is not a spare part or tool.

~~3.27~~
~~marking~~
~~signs or inscriptions for the identification of the type of a component or device attached by the manufacturer of the component or device~~

**3.30**
**obstacle**
part preventing unintentional direct contact, but not preventing direct contact by deliberate action

[SOURCE: ~~IEV 826-03-14~~ IEC 60050-826:2004, 826-12-24, modified – "electrically protective" has been deleted from the term.]

**3.31**
**overcurrent**
electric current exceeding the rated ~~value~~ electric current

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

[SOURCE: ~~IEV 826-05-06~~ IEC 60050-826:2004, 826-11-14]

**3.32**
**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.

**3.33**
**plug-socket combination**
~~plug and socket-outlet, cable coupler, or appliance coupler~~
component and suitable mating component, appropriate to terminate conductors, intended for connection or disconnection of two or more conductors

**3.34**
**power circuit**
circuit used for supplying power from the supply network to units of electrical equipment used for productive operation and to transformers supplying control circuits

**3.35**
**protective bonding circuit**
the whole of the protective conductors and conductive parts used for protection against electric shock in the event of an insulation failure

**3.36**
**protective conductor**
~~conductor required 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~~

~~[IEV 826-04-05, modified]~~

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

Note 1 to entry: The equivalent term in IEC 61936-1 is “protective bonding conductor”.

**3.37**
**reference designation**
distinctive code which serves to identify an item in a diagram, list or chart, and on the equipment

**3.38**
**risk**
combination of the probability ~~and the degree of possible injury or damage to health in a hazardous situation~~ of occurrence of harm (i.e. physical injury or damage to health) and the severity of that harm

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

**3.39**
**safe working procedure**
method of working that reduces risk

**3.40**
**safeguard**
guard or protective device used as a means to protect persons from a present or impending hazard

**3.41**
**safeguarding**
safety measures consisting of the use of specific means called safeguards to protect persons from hazards that cannot reasonably be removed or are not sufficiently limited by design

**3.42**
**servicing level**
level on which persons normally stand when operating or maintaining the electrical equipment

**3.43**
**short-circuit current**
overcurrent resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

[SOURCE: IEC 60050-441:2000, 441-11-07]

**3.44**
**supplier**
entity that provides equipment or services associated with the machine

EXAMPLE Manufacturer, contractor, installer, integrator.

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

**3.45**
**switching device**
device designed to make 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: ~~IEV 441-14-01~~ IEC 60050-441:2000, 441-14-01, modified – The note has been added.]

**3.46**
**terminal**
conductive part of a device provided for electrical connection to external circuits

**3.47**
**user**
entity who utilizes the machine and its associated electrical equipment

## 4 General requirements

### 4.1 General ~~considerations~~

~~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 coordinated manner.~~

This document focuses on high-voltage electrical equipment of machines.

The risks associated with the hazards relevant to the HV equipment shall be assessed as part of ~~the overall requirements for risk assessment of the machine~~ the risk assessment, for example in accordance with ISO 12100. This will:

– identify the need for risk reduction;
– determine adequate risk reductions; and
– determine ~~the acceptable level of risk, and~~ 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.

~~Hazards~~ 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 on sliding or rolling contacts~~, resulting in a failure of a safety function~~;
– electrical disturbances, for example electromagnetic, electrostatic ~~or radio interference~~ 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.

~~Design and development shall be the first consideration in the reduction of risks. Where this is not sufficient, safeguarding and safe working procedures shall be considered. Safeguarding includes the use of safeguards and awareness means.~~

~~The use of the inquiry form as shown in annex B of this standard is recommended in order to facilitate an appropriate agreement between the user and the supplier(s) on basic conditions and additional user requirements related to the HV equipment.~~

The design and development process shall identify hazards and the risks arising from them. Where the hazards cannot be removed and/or the risks cannot be sufficiently reduced by inherently safe design measures, protective measures (for example safeguarding) shall be provided to reduce the risk. Additional means (for example, awareness means) shall be

provided where further risk reduction is necessary. In addition, working procedures that reduce risk can be necessary.

It is recommended that, where the user is known, Annex B be used to facilitate an exchange of information between the user and the supplier(s) on basic conditions and additional user specifications related to the electrical equipment.

NOTE Those additional specifications ~~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
– ~~advance~~ improve the reliability and ease of operation.

### 4.2 Selection of electrical equipment

~~Electrical components and devices shall be suitable for their intended use and shall conform to relevant IEC standards where such exist. For example, where factory-built, type-tested HV switchgear is used, it shall be selected from those manufactured and tested in accordance with standards such as IEC 60298, IEC 60466 and IEC 60694.~~

Electrical components and devices shall

– be suitable for their intended use;
– conform to their relevant IEC standards; and
– be applied in accordance with the supplier's instructions.

Type-tested HV switchgear should be selected from those manufactured and tested in accordance with IEC 62271 (all parts).

HV Adjustable speed electrical power drive systems and their elements should be selected from those manufactured and tested in accordance with IEC 61800 (all parts).

### 4.3 Electrical power 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
– otherwise specified by the user (see Annex B), or
– specified by the supplier in the case of a special source of supply ~~such as an on-board generator~~ (see 4.3.3).

#### 4.3.2 ~~Supplies~~ Voltage characteristics

High-voltage equipment of machinery should be able to operate at supply conditions described by the requirements given by IEC TS 62749.

| | |
|---|---|
| Voltage | Steady-state voltage 0,9 to 1,1 of nominal voltage.<br>NOTE 1 In case of reduction of voltage below the nominal value, the performance of machine actuators can be affected. |
| Frequency | ~~0,99… 1,01 of nominal frequency continuously;~~<br>~~0,98… 1,02 short time.~~<br>~~NOTE The short time value may be specified by the user (see annex B).~~<br>±1 % of nominal frequency continuously;<br>±2 % short time. |

| | |
|---|---|
| Harmonics | ~~Harmonic distortion not to exceed 10 % of the total r.m.s. voltage between live conductors for the sum of the 2nd through 5th harmonic. An additional 2 % of the total r.m.s. voltage between live conductors for the sum of the 6th through 30th harmonic is permissible.~~<br>The total harmonic distortion (THD) of the voltage should not exceed 8 % of the total RMS voltage between live conductors for the sum of the 2nd through 50th harmonic. |
| Voltage unbalance | Neither the voltage of the negative sequence component nor the voltage of the zero sequence component in three-phase supplies shall exceed 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. There shall be more than 1 s between successive interruptions.~~ |
| ~~Voltage dips~~ | ~~Voltage dips shall not exceed 20 % of the peak voltage of the supply for more than 1 cycle. There shall be more than 1 s between successive dips.~~ |

NOTE 2 DC voltage characteristics of electrical power supply are under consideration.

### 4.3.3 On-board power supply

For special supply systems such as on-board generators, the limits given in 4.3.2 may be exceeded provided that the electrical equipment is designed to operate correctly with those conditions.

## 4.4 Physical environment and operating conditions

### 4.4.1 General

The HV equipment shall be suitable for use in the physical environment and operating conditions specified in 4.4.2 to 4.4.8 of IEC 60204-1:2016. There may be additional influences and environmental conditions which are to be taken into account. When the physical environment or the operating conditions are outside those specified, an agreement may be needed between the supplier and the user (see Annex B to specify the minimum requirements).

### 4.4.2 Electromagnetic compatibility (EMC)

High-voltage equipment of machinery shall not generate electromagnetic disturbances above levels that are appropriate for its intended operating environment. In addition, the HV 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 of IEC 60204-1:2016 if such instructions are not available.

For control systems of HV equipment the basic EMC rules of 9.6 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 apply. For electronic HV equipment (e.g. power converters, power drive systems) the EMC provisions of the relevant product standard apply.

### 4.5 Transportation and storage

~~Electrical equipment shall be designed to withstand, or suitable precautions shall be taken to protect against, the effects of transportation and storage temperatures within a range of –25 °C to +55 °C and for short periods not exceeding 24 h at up to +70 °C. Suitable means shall be provided to prevent damage from humidity, vibration, and shock.~~

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

Subclause 4.5 of IEC 60204-1:2016 is applicable.

### 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 by cranes or similar equipment (see also 14.5). Where appropriate, equipment shall be labelled to show the correct method of lifting and the maximum weight when fully equipped shall be indicated.

### 4.7 Installation

~~Electrical equipment shall be installed in accordance with the supplier's instructions, and ergonomic principles should be taken into account.~~

#### 4.7.1 General

High-voltage electrical equipment shall be installed in accordance with the requirements of Clause 8 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 and the supplier's instructions in order to:

– enable the safe access of personnel for operation and maintenance;

– facilitate fault clearing under safe working conditions.

Where lighting is installed for HV equipment, the relevant provisions of 7.2.6 and 15.2 of IEC 60204-1:2016 are applicable; refer to 18.2.

#### 4.7.2 Assembly and mounting

When the equipment is not fully assembled for transport, all transport units should be clearly marked. Detailed drawings showing assembly of these separated parts should be provided with the equipment included related wiring and provisions to maintain the integrity of the equipment in terms of safety.

## 5 Incoming supply conductor terminations and devices for disconnecting and switching off~~, and means for earthing~~

### 5.1 Incoming ~~supply~~ high-voltage conductor terminations

All terminations for the incoming supply connection shall be clearly identified in accordance with IEC 60445.

### 5.2 Earthing terminal of high-voltage equipment

High-voltage equipment shall be provided with an earthing terminal for connection of an earthing conductor suitable for specified fault conditions.

The connecting point shall be marked with the "protective earth" symbol IEC 60417-5019:2006-08.

### 5.3 Supply disconnecting ~~(isolating)~~ devices and means for earthing

#### 5.3.1 General

A supply disconnecting device shall be provided for

– each incoming source of supply to a machine;

Exception: In the case of on-board generation (for example diesel generator) as the only source of supply, the disconnector is not necessary if the voltage can be reduced to, and maintained at, zero by other means;

– the source of supply to a feeder system using conductor wires, conductor bars, slip-ring assemblies, flexible cable systems (reeled, festooned), to a machine or a number of machines;

– each on-board power supply if there are more than one generator for the same supply (for example common busbar).

The supply disconnecting device shall ~~disconnect (isolate) the electrical~~ isolate the high-voltage equipment of the machine from the supply when required (e.g. for work on the machine or its electrical equipment).

NOTE 1 Disconnectors are capable of opening and closing a circuit only at either negligible current (a current not exceeding 0,5 A) or if no significant change in the voltage across the terminals occurs. Therefore disconnecting devices always require associated switches or circuit-breakers for switching normal operating and fault currents; refer to Clause 7.

NOTE 2 HV disconnection implies physical separation (isolation).

When two or more supply ~~disconnecting devices~~ disconnectors are provided, protective interlocks for their correct operation shall be used ~~where a~~ so that no hazardous condition or damage to personnel or the machine ~~or to the work in progress~~ can occur.

For each incoming HV supply, means shall be provided to earth and short-circuit all live ~~conductors~~ parts by connecting them to the earthing system (e.g. for work on the HV equipment).

#### 5.3.2 Type

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

a) a switch-disconnector~~, with or without fuses~~;

NOTE 1 A switch-disconnector often is combined with HRC fuses.

b) a ~~disconnecting device that is interlocked~~ disconnector with interlocking to ensure that it can~~not~~ only be operated ~~until~~ if an associated switch~~ing device has opened~~ or circuit-breaker interrupted the load circuit;

c) a plug and socket~~-outlet or an appliance coupler~~ combination (see 3.33) for a flexible cable supply (e.g. reeled, festooned) to a mobile machine under the following conditions:

– it shall not be possible to connect or disconnect a ~~plug and socket-outlet or an appliance coupler~~ plug-socket combination during load conditions or when voltage is present. The effects of charging currents shall be taken into account;

– the ~~plug and socket-outlet or the appliance coupler~~ plug-socket combination shall be so connected that the part connected to the incoming power supply is that which is protected to at least IP 2XH or IP XXBH, when located inside an enclosed electrical operating area, or to at least IP 4XH or IP XXDH when located outside an enclosed electrical operating area.

NOTE 2 High-voltage plug-socket combinations are designed according to EN 50181.

~~When used, earthing switches shall be constructed and selected in accordance with IEC 60129. It is recommended that the supply disconnecting device and the associated earth-~~

~~ing switch be combined in a functional unit (see 3.104 of IEC 60298). When not assembled with the associated disconnecting device in accordance with IEC 60298 or IEC 60466, there shall be interlocks which ensure that~~

- ~~closing and opening of the earthing switch is only possible when the disconnecting device is in the open position, and~~
- ~~closing and opening of the disconnecting device is only possible when the earthing switch is in the open position.~~

When used, disconnectors shall be designed and selected in accordance with IEC 62271-102.

### 5.3.3 Requirements for disconnectors

~~**5.2.3.1 Disconnecting (isolating) device**~~

~~When the supply disconnecting device is one of the types specified in 5.2.2 a) or 5.2.2 b) it shall fulfil all of the following requirements:~~

- ~~isolate the electrical equipment from the HV supply and have one OFF (isolated) and one ON position only, clearly marked with "O" and "I" (symbols IEC 60417-5008 and IEC 60417-5007, see 10.2.2 of IEC 60204-1), with the actuating directions in accordance with IEC 61310-3;~~
- ~~have a visible gap or a position indicator which cannot indicate OFF (isolated) until all contacts are actually open and adequate isolating distances are ensured;~~
- ~~be provided with a means permitting it to be locked in the OFF (isolated) position (e.g. by padlocks). When so locked, local as well as remote closing shall be prevented;~~
- ~~disconnect all live conductors of its power supply circuit;~~
- ~~have a breaking capacity sufficient to interrupt the current of the largest motor when stalled together with the sum of the normal running currents of all other motors and/or loads. The calculated breaking capacity may be reduced by the use of a proven diversity factor.~~

~~Where an external operating means (e.g. handle) is provided it should be BLACK or GREY.~~

~~**Exception**: see 10.7.4 of IEC 60204-1.~~

When the supply disconnector is one of the types specified in 5.3.2 a) or 5.3.2 b) it shall comply with IEC 62271-102.

For instance, the disconnector shall

- have an external handle for the disconnecting function (this can be the handle also used for operating the earthing device);
- have a reliable position indicator;
- disconnect all live conductors from the power supply circuit.

The OFF (disconnected) and one ON positions shall be clearly marked with "O" and "I" (see symbols IEC 60417-5008:2002-10 and IEC 60417-5007:2002-10).

If a switch-disconnector (specified in 5.3.2 a)) is used, it shall comply with IEC 62271-102 and IEC 62271-103 and its breaking capacity shall be sufficient to interrupt the current of the largest motor under blocked rotor condition together with the sum of the normal operating currents of all other motors and/or loads. The calculated breaking capacity may be reduced by the use of a proven diversity (simultaneity) factor.

NOTE For motors supplied by converter(s) or similar devices the maximum operating current of the converter is relevant.

Unintended opening of disconnectors shall be prevented. Depending on the risk assessment, remote controlled locking systems shall have appropriate safety integrity level (SIL) or performance level (PL); according to IEC 62061 or ISO 13849-1.

Where a switch-disconnector is combined with HV fuses, the combination shall comply with IEC 62271-105.

Where fused circuit-switchers are used, the combination shall comply with IEC 62271-107.

Where an external operating means (e.g. handle) is provided it should be BLACK or GREY. Exception: If a switch-disconnector may be locally operated to serve the function of emergency stop, its actuator shall meet the colour requirements of 10.2.1 of IEC 60204-1:2016.

### 5.3.4 ~~Means~~ Requirements for earthing and short-circuiting

The means for earthing shall be capable of withstanding the prospective short-circuit current of the supply.

When used, an earthing switch shall comply with IEC 62271-102.

For instance, the earthing switch shall

– have a reliable position indicator;

– have an external handle for the earthing function (this can be the handle also used for operating the disconnecting device);

– earth and short-circuit all live conductors to the earthing system.

~~– be provided with means permitting it to be locked in the ON position and, if required (see annex B, question 16), in the OFF position, preferably by padlocks.~~

Mechanical locking in the ON position and the OFF position should be possible preferably by padlocks.

When an associated circuit-breaker is used for short-circuiting and for earthing and is locked in the closed (and earthed) position~~, local as well as remote opening~~, unintended manual and/or opening by the short-circuit current itself shall be prevented. Depending on the risk assessment, remote controlled locking systems shall have appropriate safety integrity level (SIL) or performance level (PL) according to IEC 62061 or ISO 13849-1.

~~**5.2.4 Operating handle**~~

~~When provided, the handle(s) of the supply disconnecting device and of the earthing switch shall be easily accessible and should be located between 0,6 m and 1,9 m above the servicing level.~~

### 5.3.5 Arrangement of disconnecting and earthing devices

It is recommended that the supply disconnecting device and the associated earthing switch are combined in a functional unit of prefabricated metal-enclosed switchgear complying with IEC 62271-200 or IEC 62271-201. If the earthing switch and disconnector are not assembled in a functional unit, interlocks shall ensure that

– the earthing switch can only be operated if the disconnecting device is in the open position, and

– the disconnecting device can only be operated if the earthing switch is in the open position.

The operating means of the supply disconnecting and earthing devices 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.

### 5.4 Devices for switching off for prevention of unexpected start-up

Devices for switching off for the prevention of unexpected start-up shall be provided (e.g. where, during maintenance, a start-up of the machine can create a hazard). Devices described in 5.3.2 may fulfil that function. Disconnectors, withdrawable fuse links or withdrawable links may also be used for that purpose, but only when located in ~~an enclosed~~ a closed electrical operating area (see 3.13).

Such devices shall be appropriate and convenient for the intended use, shall be suitably placed, and readily identifiable (e.g. by a durable marking where necessary).

Means shall be provided to prevent inadvertent, and/or mistaken ~~closure~~ closing of the ~~disconnecting device~~ disconnector (see also 5.6).

~~When means other than supply disconnecting devices in accordance with 5.2.2 are used (e.g. a contactor or circuit-breaker switched off by a control circuit), such means for switching off are intended to be employed only for situations that include~~

~~– no significant dismantling of the machine;~~

~~– adjustments requiring a relatively short time;~~

~~– no work being carried out on or near the HV parts of the electrical equipment.~~

Devices that do not fulfil the isolation function (for example a contactor switched off by a control circuit, or power drive system (PDS) with a safe torque off (STO) function in accordance with IEC 61800-5-2) may only be used for prevention of unexpected start-up during tasks such as:

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

The selection of a device will be dependent on the risk assessment, taking into account the intended use of the device, and the persons who are intended to operate them.

### 5.5 Devices for disconnecting and means for earthing HV equipment

Devices for disconnecting (isolating) and means for earthing HV equipment or part of it shall be provided to enable work to be carried out without a risk from electric shock or burn.

The supply disconnecting device together with a means for earthing the relevant circuit (see 5.3) may fulfil these functions. However, where it is necessary to work on individual HV part(s) of the electrical equipment of a machine, or on one of a number of machines fed by a common conductor bar or conductor wire system, a disconnecting device together with a means for earthing shall be provided for each part, or for each machine, requiring separate isolation and earthing. Where HV capacitors are part of the electrical equipment, discharging means shall be provided.

Devices described in 5.3 may fulfil these functions. Other means of isolation such as disconnectors, withdrawable fuse links or withdrawable links, together with a means for

earthing, may also be used for that purpose, but only when located in an enclosed electrical operating area.

Exception: If these means, for example a removable collector for crane-disconnection, are not located in an enclosed electrical operating area, they shall fulfil the following conditions:

– it shall not be possible to remove the disconnecting device during load conditions;
– it shall be so designed that the protective conductor circuit (earthing circuit) is interrupted only after the live conductors have been disconnected, and the continuity of the protective conductor circuit is re-established before any live conductor is reconnected;
– in open and in closed condition of the removable collector, the conductor bar has to be protected according to 13.8.1.

Such disconnecting devices and means for earthing shall be

– appropriate and convenient for the intended use;
– suitably located;
– readily identifiable as to which HV part or HV circuit(s) of the electrical equipment is served (e.g. by durable marking where necessary);
– provided with adequate means to prevent unauthorized, inadvertent, and/or mistaken closure of the disconnecting devices and opening of the means for earthing. Exception: see 5.6.

Electrical equipment such as HV transformers or HV capacitors shall be provided with additional means of earthing and short-circuiting ~~adjacent to that electrical equipment~~, except where it is located in the immediate vicinity of the associated switchgear.

NOTE Where the HV equipment (for example the main circuit-breaker) is part of ~~a power installation, 7.3 of HD 637~~ the distribution switchgear, 8.3 of IEC 61936-1:2010 can apply.

### 5.6 Protection against unauthorized, inadvertent and/or mistaken operation

The devices for disconnecting (isolating) and means for earthing described in 5.4 and 5.5 that are capable of being equipped with means to lock them in the OFF position or disconnected state or earthed condition (e.g. by padlocks) in order to achieve protection against unauthorized, inadvertent, and/or mistaken operation shall be equipped with such means. Other means of protection against such operation (e.g. warning labels) may be used where the non-lockable means are located in an enclosed electrical operating area.

However, when a device according to 5.3.2 c) (e.g. plug-socket combination) and/or a means for earthing is so positioned that it can be under the immediate supervision of the person carrying out the work, means for locking need not be provided.

## 6 Protection against electric shock

### 6.1 General

The HV ~~parts of the~~ electrical equipment shall provide protection of persons against electric shock ~~from~~ by

– basic protection against direct contact (6.2);
– fault protection against indirect contact (6.3).

The ~~recommended~~ measures for this protection ~~are~~ given in 6.2 and 6.3~~, which are derived from IEC 60364-4-41 and from HD 637~~, are a recommended selection from IEC 61936-1 (regarding high-voltage) and from IEC 60364-4-41 (regarding low-voltage). ~~Where those recommended measures are not practicable, other measures from HD 637 may be used.~~

### 6.2 Protection against direct contact

Basic protection against direct contact with live parts, parts with insulation for functional purposes only and with parts which can be considered to have a hazardous potential (for examples of such parts see ~~7.1.1 of HD 637~~ 8.2 of IEC 61936-1:2010) shall be provided as follows:

a) installations outside enclosed electrical operating areas

Protection against direct contact shall be provided by enclosures with a minimum degree of protection of IP 4X or IP XXDH, according to IEC 60529.

b) installations inside enclosed electrical operating areas

Protection against direct contact shall be provided by enclosures or doors or mesh-grids or barriers to a minimum degree of protection of IP 1X or IP XXAH, according to IEC 60529. Dimensions of doors, mesh-grids and barriers and clearances to live parts shall be in accordance with ~~6.3 of HD 637~~ 7.3 of IEC 61936-1:2010.

Access to HV parts of the electrical equipment shall only be possible by the use of a key or tool.

Where these measures are not practicable, other measures for protection against direct contact (e.g. by placing out of reach, using obstacles) as specified in ~~7.1 of HD 637~~ 8.2 of IEC 61936-1:2010 may be applied.

NOTE For protective measures for conductor wires, conductor bars and slip-ring assemblies, see 13.8.1.

### 6.3 Protection against indirect contact

#### 6.3.1 General

~~Protection against indirect contact (3.22) is intended to prevent hazardous conditions in the event of an insulation failure between live parts and exposed-conductive-parts.~~

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

~~Protection against indirect contact can be achieved~~

- ~~by measures to prevent the occurrence of a touch voltage which exceeds the tolerable touch voltage for an unlimited time of fault duration, or~~
- ~~for a higher touch voltage, which is not hazardous for a limited time of fault duration, by automatic disconnection of the supply within that time.~~

Fault protection against indirect contact is intended to prevent hazardous situations due to an insulation fault between live parts and exposed conductive parts.

For each HV circuit or HV part of the electrical equipment, protection against indirect contact can be achieved by automatic disconnection of the supply preventing the occurrence of a touch voltage which exceeds the tolerable limited time of fault duration.

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

These measures necessitate coordination between

- the type of ~~supply and~~ power system (e.g. neutral earthing) and exposed conductive parts to earth,
- the impedance values of the different elements of the protective bonding circuit, and
- the characteristics of the devices used to detect insulation failure.

### 6.3.2 Measures to prevent the occurrence of a hazardous touch voltage for an unlimited time of fault duration

Measures to prevent the occurrence of a hazardous touch voltage for an unlimited time of fault duration include the following:

– selection or design of the supply system and neutral earthing in accordance with ~~3.1 of HD 637~~ 4.2 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014, and

– design of the earthing system in accordance with ~~Clause 9 of HD 637~~ Clause 10 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

It is recommended that a supply system ~~which is isolated from earth, or is designed with its neutral point having a high impedance to earth,~~ is used whose neutral point is isolated from earth or is high impedance earthed. An earth fault detection device should be provided to initiate an alarm when an earth fault is detected.

NOTE Supply systems isolated from earth include systems without a neutral point such as single-phase systems, delta connected systems and DC systems.

### 6.3.3 Protection by automatic disconnection of supply within a limited time of fault duration

Automatic disconnection of the supply of any circuit affected by the occurrence of an insulation failure within a limited time is intended to prevent a hazardous condition resulting from a touch voltage higher than the tolerable touch voltage for an unlimited time of fault duration.

This protective measure comprises both

– the connection of exposed-conductive-parts to the protective bonding circuit (see Clause 8), and

– either

  a) the use of devices for the automatic disconnection of the supply in the event of an insulation failure in a supply system with low-impedance neutral earthing or direct neutral earthing, or

  b) the use of earth fault detection to initiate automatic disconnection of a supply system isolated from earth or ~~designed with its neutral point having a high impedance to earth~~ with high impedance earthed neutral point.

The selection/setting of the device(s) shall be such as to ensure that automatic disconnection of the supply takes place before the touch voltage, arising from an insulation failure, becomes hazardous.

NOTE For hazardous touch voltages, see ~~Clause 9 of HD 637~~ Clause 10 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

### 6.3.4 Protection for mobile machines

The measures described in 6.3.2 and 6.3.3 shall be selected by taking the following into consideration:

– system voltage;

– length of supply cable;

– number of machines connected to the point of supply;

over which there may be little influence, and

– type of supply cable;

– type of neutral earthing;

– value of earth-fault current in a supply system with low impedance neutral earthing.

General limitations depending upon the type of supply system are given below:

– direct neutral earthing is generally only appropriate for system voltages less than 2 kV. Automatic disconnection is always required;

– low impedance neutral earthing may be appropriate for system voltages up to 36 kV and a cable length up to 4 km. Automatic disconnection is normally necessary;

– isolated neutral ~~earthing~~ point or high impedance neutral point earthing is appropriate for system voltages up to 36 kV and a cable length up to 8 km (this length depends upon the capacitive reactance of all cables connected to the supply). Automatic disconnection is normally not necessary.

## 7 Protection of HV equipment

### 7.1 General

Clause 7 details the measures to be taken to protect HV parts of the electrical equipment against the effects of

– overcurrent;

– overheating of motors;

– abnormal temperature;

– overvoltage due to lightning and switching surges;

– other abnormal conditions;

~~IEC 60204-1 details measures to be taken to protect equipment against the effects of~~

– loss of or reduction in the supply voltage;

~~– overload current of motors;~~

– overspeed of machines/machine elements;

– earth fault;

– incorrect phase sequence;

– overvoltage;

– arc faults.

### 7.2 Overcurrent protection

#### 7.2.1 General

Overcurrent protection shall be provided where the current in a machine 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 used are detailed in 7.2.6.

#### 7.2.2 Supply conductors

Unless otherwise specified by the user, the supplier of the HV equipment shall not be responsible for providing the overcurrent protective device for the supply conductors to the HV equipment.

The supplier of the HV equipment shall state on the installation diagram the data necessary for selecting the overcurrent protective device (see 7.2.6 and ~~18.5 of IEC 60204-1~~ Annex B, question 15).

#### 7.2.3 Power circuits

Devices for detection and interruption of overcurrent, selected in accordance with 7.2.6, shall be applied to each live conductor.

### 7.2.4 Transformers

Transformers shall be protected against overcurrent in accordance with IEC 60076-5. Such protection shall (see also 7.2.6)

– 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.

For the provision of protection against other abnormal conditions, see 7.10.

### 7.2.5 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 (e.g. from motors, from power factor correction capacitors), those currents shall be taken into consideration.

Overcurrent protective devices for power circuits include fuses and circuit-breakers.

### 7.2.6 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 (e.g. during starting of motors or energizing of transformers). When selecting those protective devices, consideration should be given to the protection of switching devices against damage due to overcurrents (e.g. welding of the switching device contacts).

The rated current or setting of an overcurrent protective device is determined by the current carrying capacity of the conductors to be protected by that device in accordance with 13.4. That should take into account the needs of coordination with other electrical devices in the protected circuit. The recommendations of the supplier of those devices should be followed.

## 7.3 Protection of motors against overheating

Protection of motors against overheating shall be provided for each HV motor.

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

## 7.4 Protection against abnormal temperature

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

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

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

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

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

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

### 7.6 Motor overspeed protection

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

### 7.7 Earth fault protection

Earth fault protection shall be provided as described below when the earth-fault current can be lower than the setting of the overcurrent protective devices and unacceptable damage to the electrical equipment can occur.

An earth fault monitoring system that is appropriate to the type of HV supply system in use (e.g. system isolated from earth, earthed system) shall be provided. The electrical equipment or the appropriate section of the electrical equipment shall be switched off if the earth fault exceeds a given current/time value.

The setting of the earth fault protective devices shall be as low as possible and consistent with proper operation of the electrical equipment.

Unless otherwise specified by the user, the supplier of the HV equipment is not responsible for providing the earth fault protective device for the HV supply conductors. The supplier of the HV equipment shall state on the installation diagram the data necessary for selecting the earth fault protective device (see 7.2.6 and ~~18.5 of IEC 60204-1~~ Annex B, question 15).

### 7.8 Protection against overvoltage~~s~~ due to lightning and ~~to~~ switching surges

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

~~Devices for the suppression of overvoltages due to switching surges shall be connected across the HV terminals of all electrical equipment requiring such protection.~~

Equipment shall be protected against overvoltage resulting from switching operations or lightning that could exceed the withstand values. Since different protection methods are available, depending on the level of protection to be achieved and the reliability level required, the method to be used shall be agreed upon between the manufacturer and user; refer to Annex B.

For lightning protection refer to IEC 62305 (all parts).

### ~~7.5 Protection against other abnormal conditions~~

~~Protection against conditions such as abnormal temperature, overpressure and leakage shall be provided on liquid-filled HV equipment such as transformers, reactors and switchgear as necessary in accordance with HD 637, to prevent the occurrence of a hazardous situation.~~

~~NOTE See also HD 637, 7.6.~~

### 7.9 Protection against hazards due to arc faults

The high-voltage part of the electrical installation shall be designed and installed so that persons are protected against arc faults during normal operation as described by 8.5 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014. The degree of importance of the measures indicated in IEC 61936-1 shall be agreed upon between the supplier and user (for example, the IAC classification, according to IEC 62271-200).

### 7.10 Protection against overpressure and leakage

Protection against overpressure and/or leakage of liquid-filled high-voltage equipment such as transformers, reactors and switchgear shall be provided as applicable in accordance with 8.8 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

Where liquid-immersed equipment is used (e.g. oil insulated transformers), measures shall be taken to prevent environmental damage in the event of leakage.

### 7.11 Protection against fire

Protection against fire shall be provided in accordance with 8.7 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 to prevent the occurrence of a hazardous situation.

## 8 Equipotential bonding

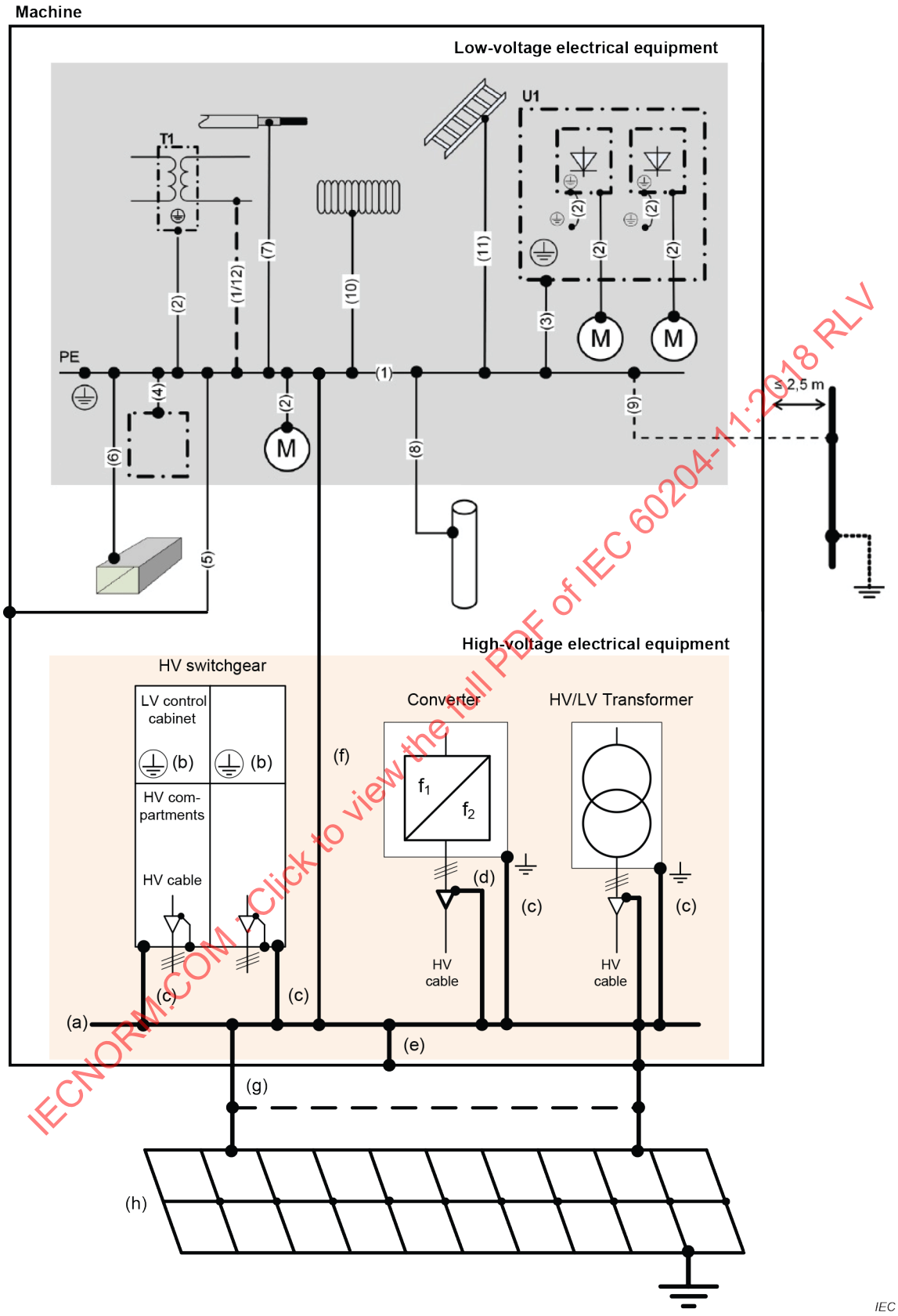
### 8.1 General

Clause 8 gives requirements for the protective (equipotential) bonding of

– the exposed-conductive-parts of the electrical equipment,
– the extraneous-conductive-parts of the machine, and
– the earthing system,

and for supplementary ~~equipotential~~ protective bonding (see 8.2.6) as required, in order to ensure fault protection (against indirect contact). Figure 2 illustrates these concepts.

~~The use of the terms related to earthing and protective bonding in this part of IEC 60204 is different in some respects to their use in HD 637 (see annex E).~~



**Key**

**Protective bonding circuit:**

(1) Interconnection of protective conductor(s) and the PE terminal

(2) Connection of exposed conductive parts

(3) Protective conductor connected to an electrical equipment mounting plate used as a protective conductor

(4) Connection of conductive structural parts of the electrical equipment

(5) Conductive structural parts of the machine

**Parts connected to the protective bonding circuit, which are not to be used as protective conductor:**

(6) Metal ducts of flexible or rigid construction

(7) Metallic cable sheaths or armouring

(8) Metallic pipes containing flammable materials

(9) Extraneous conductive parts, if earthed independently from the power supply of the machine and liable to introduce a potential, generally the earth potential, e.g.: metallic pipes, fences, ladders, handrails

(10) Flexible or pliable metal conduits

(11) Protective bonding of support wires, cable tray and cable ladders

**Connections to the protective bonding circuit for functional reasons:**

(12) Functional bonding

**Reference designations:**

T1 Auxiliary transformer

U1 Mounting plate of electrical equipment

**High-voltage equipment**

(a) Equipotential bonding of the high-voltage installation

(b) Protective earthing of low-voltage control equipment

(c) Earthing connection of high-voltage equipment

(d) HV cable screen bonding

(e) Connection to conductive structural parts of the machine

(f) Interconnection to low-voltage earthing system

(g) Machine bonding conductor

(h) Earthing system of installation (building)

NOTE The out-of-reach distance of 2,5 m refers to IEC 60364-4-41.

~~NOTE The protective conductors of the electrical equipment of the machine are not shown (see figure 3 of IEC 60204-1).~~

**Figure 2 – Example of equipotential bonding for electrical equipment of a machine**



## 8.2 Protective bonding circuit

### 8.2.1 General

The protective bonding circuit consists of (see Figure 2)

– the machine bonding conductor(s);

– the protective conductors of the electrical equipment of the machine, including sliding contacts where they are part of the circuit; and

– the ~~equipotential~~ protective bonding conductors connected to the structural parts of the electrical equipment and to the structural parts of the machine (equipotential bonding on the machine).

On mobile machines with on-board power supplies, the protective bonding circuits, the exposed-conductive-parts, and the extraneous-conductive-parts shall all be connected to a

protective bonding terminal to provide protection against electric shock. When a mobile machine is also capable of being connected to an external incoming supply, the protective bonding terminal shall be the connection point for the external protective conductor.

NOTE 1 When the supply of electrical energy is self-contained within stationary, mobile, or movable items of machinery, and when there is no external supply connected (e.g. when an on-board battery charger is not connected), there is no need to connect such electrical equipment to an external protective conductor.

All parts of the interconnected protective bonding circuits for the HV equipment and the LV equipment shall be so designed that they are capable of withstanding the highest thermal and mechanical stresses that can be caused by single or double earth-fault currents that could flow in any part of the protective bonding circuits.

NOTE 2 Details on how to fulfil this requirement are given in ~~9.4 of HD 637~~ 10.2.3 of IEC 61936-1:2010 or in 6.1.1 of EN 50522:2010.

The structural parts of the machine shall be individually connected to the protective bonding circuit.

Any structural part of the electrical equipment or of the machine may be used as part of the protective bonding circuit provided that it satisfies the requirements of IEC 60364-5-54.

NOTE 3 As guidance for the design of earthing or bonding conductors, the current density in the conductor, if of copper, does not exceed 200 A/mm$^2$ for a rated duration of short circuit of 1 s, and 125 A/mm$^2$ for a rated duration of short circuit of 3 s. A method of calculating cross-sectional areas of conductors is given in IEC 60724.

### 8.2.2 Protective conductors

Protective conductors shall be identified in accordance with 14.2.

Copper conductors ~~should be used~~ are preferred. Where a conductor material other than copper is used, its electrical resistance per unit length shall not exceed that of the allowable copper conductor and such conductors shall be not less than 16 mm$^2$ in cross-sectional area for reasons of mechanical durability. ~~The conductor material shall be selected taking into account the possible effects of corrosion.~~

~~The cross-sectional area *S* of a bare protective conductor shall be at least that given in table 1. Where the connection of the machine to an external installation earthing system using such a value is not sufficient to provide protection against indirect contact, the cross-sectional area *S* of the bare conductor shall be according to 9.2 of HD 637.~~

Due to mechanical strength and stability against corrosion, minimum cross-sections of protective conductors are:

– copper: 16 mm$^2$
– aluminium: 35 mm$^2$
– steel: 50 mm$^2$

NOTE Where the connection to an external installation earthing system using such a value is not sufficient to provide protection against indirect contact, the calculation of cross-sectional area of the bare conductor according to Annex D of EN 50522:2010 applies.

~~**Table 1 – Cross-sectional area of bare protective conductors**~~

| ~~Requirements~~ | ~~$S$ mm²~~ |
|---|---|
| ~~Mechanical strength~~ | ~~$S_{min}$ = 16 mm² for copper = 35 mm² for aluminium = 50 mm² for galvanized steel~~ |
| ~~Thermal stress due to continuous earth-fault current $I_E \leq 100$ A~~ | |
| ~~Thermal stress due to continuous earth-fault current $I_E > 100$ A~~ | ~~$S = S_{min} (I_E/100)^2$~~ |
| ~~Thermal stress due to short-time earth-fault current up to 5 s~~ | ~~For $S$ see annex C~~ |
| ~~NOTE $S_{min}$ for mechanical strength is also sufficient for a continuous earth-fault current up to 100 A for bare conductors, based on the maximum allowable touchable temperature of 80 °C in accordance with table 42A of IEC 60364-4-42.~~ | |

### 8.2.3 Continuity of the protective bonding circuit

All exposed-conductive-parts of the electrical equipment and the machine(s) shall be connected to the protective bonding circuit. Where a part is removed for any reason (e.g. routine maintenance), the protective bonding circuit for the remaining parts shall not be interrupted.

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

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

Doors, lids or cover plates on which devices (e.g. operator interface devices) are mounted shall be connected to the protective bonding circuit by a protective conductor.

For machines, for example mobile machines, where the connection to the earthing system (machine bonding conductor) is provided solely by flexible cables, the continuity of the protective conductor shall be ~~assured~~ ensured by appropriate design of the cable (see 13.7). Where there is a possibility that the cable and hence the machine bonding conductor could become damaged (e.g. a trailing cable dragged on the ground), the continuity of the protective bonding circuit shall be monitored (see question 13 in Annex B). The HV supply to the electrical equipment of the machine or to the relevant part of the machine shall be switched off

– when loss of continuity of the protective bonding circuit is detected, or
– when failure of the monitoring means occurs.

For requirements for the continuity of the protective bonding circuit using conductor wires, conductor bars and slip-ring assemblies, see 13.8.2.

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

The protective bonding circuit shall not incorporate a switching device, an overcurrent protective device (e.g. switch, fuse) ~~or a means for current detection for such devices~~ so that continuity of the earthing path is not interruptible and any metallic parts that may be touched during normal operation remain connected to the equipotential bonding and earthing system.

Exception: links that can only be opened with the use of tools (e.g. for measuring and testing purposes) and that are located in an enclosed electrical operating area may be provided for test or measurement purposes.

~~NOTE It is permissible to include devices that do not interrupt the protective bonding circuit, that have electrical characteristics that under all circumstances ensure prevention of a hazardous voltage rise in any part of the circuit, and that do not impair the performance of the circuit.~~

~~**8.2.5 Interruption of the protective bonding circuit**~~

### 8.2.4 Mobile machines

Where the continuity of the protective bonding circuit can be interrupted by means of removable current collectors or plug-socket combinations, the protective bonding circuit shall not be interrupted before the live conductors have been disconnected, and shall be re-established before any live conductor is reconnected. This also applies to removable or withdrawable plug-in units (see also 14.4).

Metallic housings of plug-socket combinations shall be connected to the protective bonding circuit.

### 8.2.5 Protective bonding circuit connecting points

All protective conductors shall be terminated in accordance with 14.1.1. The protective conductor connecting points shall have no other function and shall not be used, for example, to mechanically attach or connect ~~appliances~~ components or parts.

Each connecting point for

– protective conductors inside the electrical equipment of the machine,
– the ~~equipotential~~ protective bonding conductors on the machine (see Figure 2),
– the machine bonding conductor(s) (see Figure 2),

shall be identified as such using the symbol IEC 60417-5019:2006-08 (see Figure 3).

**Figure 3 – Symbol for protective earth (protective ground)**

### 8.2.6 Supplementary ~~equipotential~~ protective bonding conductors

Supplementary ~~equipotential~~ protective bonding conductors shall be used to connect the protective bonding circuit of the machine to the structural metalwork of the building when such metalwork is in close proximity (e.g. less than 2,5 m) to the machine. These conductors shall conform to Cause 544 of IEC 60364-5-54:2011 as appropriate. The cross-sectional area of a ~~supplementary equipotential~~ supplementary protective bonding conductor shall be not less than half the cross-sectional area of the associated machine bonding conductor and shall be not less than that specified in 8.2.2.

## 9 Control systems, control circuits and control functions

For control, protection and auxiliary systems of HV equipment the relevant subclauses of Clause 9 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 apply. Control, protection and auxiliary devices shall ensure the correct and safe functioning of the HV equipment; and

provide protection against the effects of unacceptable overload and any internal and external fault conditions.

Facilities shall be provided for isolating the control circuits in order to allow maintenance of high-voltage equipment to be performed safely. Provisions shall be made to allow for repair, maintenance, and/or testing to be carried out on control, protection and auxiliary devices without any danger to personnel or the equipment. Alarm and fault-indicating equipment shall clearly indicate danger and fault conditions.

For the control circuits the requirements of Clause 9 of IEC 60204-1:2016 apply except where the LV control circuits are covered by other standards. Control circuits directly connected to high-voltage circuits (e.g. thyristor gate circuits) shall be electrically separated from low-voltage circuits by the use of an interface technique such as optical coupling or transformer coupling.

Cableless control systems used in electrical equipment shall comply with IEC 62745.

## 10 Operator interface and machine-mounted control devices

The requirements of Clause 10 of IEC 60204-1:2016 apply, but the minimum degree of protection against direct contact shall be IP 4X or IP XXDH for operator interface and machine-mounted control devices (see also 6.2 for protection against direct contact).

## 11 Electronic equipment

~~The requirements of clause 11 of IEC 60204-1 apply.~~

~~NOTE Basic requirements for power electronic equipment are covered by EN 50178 and requirements for static converters are covered by 5.2.12 of HD 637.~~

HV electronic equipment, for example converters, power drive systems, shall comply with their relevant standards, for example, IEC 61800 (all parts) for power drive systems.

For static converters refer also to 6.2.14 of IEC 61936-1:2010. Where no specific standards for electronic power equipment exists, EN 50178 provides basic requirements.

## 12 Controlgear: location, mounting, and enclosures

### 12.1 General requirements

All controlgear shall be located and mounted so as to facilitate

– its accessibility and maintenance;
– its protection against the external influences or conditions under which it is intended to operate;
– operation and maintenance of the machine and its associated electrical equipment.

### 12.2 Location and mounting

#### 12.2.1 Accessibility and maintenance

All items of controlgear shall be so placed and oriented that they can be identified without moving them or the wiring. For items that require checking for correct operation or that are liable to need replacement, these actions should be possible without dismantling other electrical equipment or parts of the machine (except opening doors or removing covers). Terminals not associated with controlgear shall also conform to these requirements.

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

Only those devices necessary for operator interface purposes (for example operation, indication, measurement) and for cooling may be mounted on doors and on normally removable access covers of enclosures.

Where control devices are connected through plug-in arrangements, their association shall be made clear by type (shape), marking or reference designation, singly or in combination (see 13.4.5 of IEC 60204-1:2016).

Test points, where provided, shall be

– mounted so as to provide unobstructed access;
– clearly marked to correspond with the documentation (see 17.2 of IEC 60204-1:2016);
– adequately insulated;
– sufficiently spaced for connection of the test equipment or means.

### 12.2.2 Physical separation

Enclosures containing HV equipment shall not contain LV equipment and non-electrical parts except where they form an integral part of the HV equipment and are essential for its correct operation.

HV switchgear adjacent to LV equipment shall be:

– metal-enclosed and ~~capable of~~ designed to withstand~~ing~~ an internal arc-fault according to 7.9, and distinguishable from LV equipment by clear marking or
– segregated by earthed metallic partitions (tubes, walls) or by insulating partitions of protection category PB according to IEC 62271-201.

When arranging the location of devices (including interconnections), the clearances and creepage distances specified for them shall be maintained, taking into account the external influences or conditions of the physical environment (see ~~IEC 60071-1 and IEC 60071-2~~ IEC 61936-1).

### 12.3 Degrees of protection

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

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

Enclosures of controlgear shall provide a degree of protection of at least IP 22 (see IEC 60529).

Exception: Where an electrical operating area is used as a protective enclosure for an appropriate degree of protection against the ingress of solid bodies and liquids.

NOTE 2 Other degrees of protection ~~may~~ can be needed for protection against electric shock, see Clause 6.

~~NOTE 3 Some examples of applications, along with the degree of protection typically provided by their enclosures, are listed below:~~

~~– ventilated enclosure, containing only motor starter resistor and other large size electrical equipment: IP10;~~

~~– ventilated enclosure, containing other electrical equipment: IP32;~~

~~– enclosure used in general industry: IP32, IP43 and IP54;~~

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

~~– enclosure providing protection against fine dust: IP65;~~

~~– enclosure containing slip ring assemblies: IP2X.~~

~~Depending upon the installation conditions, another degree of protection may be appropriate.~~

### 12.4 Enclosures, doors and openings

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

Fasteners used to secure doors and covers should be of the captive type. Inspection windows shall be of a material suitable to withstand chemical attack and mechanical stress comparable to that of the enclosure. Precautions shall be taken to prevent the formation of a static charge on the windows, which may lead to a hazardous situation, either by adequate clearances or electrostatic shielding, for example wire mesh placed on the inside of the window and bonded to the enclosure.

It is recommended that enclosure doors should have vertical hinges, preferably of the lift-off type, with an angle of opening of at least 95°.

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

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

All openings in the enclosure, including those towards the floor or foundation or to other parts of the machine, shall be closed by the supplier(s) in a manner ensuring the degree of protection specified for the electrical equipment. Openings for cable entries shall be easily reopened on site. A suitable opening may be provided in the base of enclosures within the machine so that moisture due to condensation may drain away.

There shall be no opening between enclosures containing electrical equipment and compartments containing coolant, lubricating or hydraulic fluids, or those into which oil, other liquids, or dust can penetrate. This requirement does not apply to electrical devices specifically designed to operate in oil (e.g. electromagnetic clutches) or to electrical equipment in which coolants are used.

Where there are holes in an enclosure for mounting purposes, care shall be taken so that after mounting, the holes do not impair the required protection.

Electrical equipment that, in normal or abnormal operation, can attain a high surface temperature

– shall be located within an enclosure that will withstand such temperatures as may be generated, and

– shall be mounted and located at a sufficient distance from adjacent equipment so as to allow safe dissipation of heat (see 11.2.3 of IEC 60204-1:2016), or shall be otherwise screened by material that can withstand the heat emitted by the electrical equipment.

Accessible parts expected to be touched in normal operation shall not exceed 70 °C.

### 12.5 Access to HV equipment

Access to maintenance and operating areas of HV equipment shall be in accordance with ~~6.5 of HD 637~~ the relevant subclauses of 7.5 of IEC 61936-1:2010.

## 13 Conductors and cables

### 13.1 General requirements

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

In supply systems with direct or low impedance earthing of the neutral, all types of cable may be used if an earth fault is interrupted within 1 s.

NOTE 1 s is a standard value; other short-circuit durations are possible; refer to 4.2.4 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

In supply systems with the neutral point isolated or resonantly earthed, all types of radial field cable may be used when the estimated duration of any earth fault does not exceed 8 h. Where the estimated duration of any earth fault exceeds 8 h, a radial field cable of the next higher voltage rating shall be used (see Annex C). The recommendations of the cable supplier should be followed.

These requirements do not apply to the integral wiring of assemblies, which are manufactured and tested in accordance with relevant standards.

### 13.2 Conductors

In general, conductors should be of copper. Conductors of another material shall have a nominal cross-sectional area such that, when carrying the same current, the maximum conductor temperature shall not exceed the value given in Table 1.

**Table 1 – Maximum allowable conductor temperatures under normal and short-circuit conditions**

| Type of insulation | Maximum temperature under normal conditions<br>°C | Ultimate short-time temperature under short-circuit conditions[a]<br>°C |
|---|---|---|
| Polyvinyl chloride (PVC) | 70 | 160<br>(< 300 $mm^2$) |
| Cross-linked polyethylene (XLPE) | 90 | 250 |
| Ethylene-propylene compound (EPR/HEPR) | 80 to 90[b] | 250[b] |
| For ultimate short-time conductor temperatures greater than 200 °C, copper conductors shall be either silver-plated or nickel-plated because neither tinned nor bare conductors are suitable above 200 °C. | | |
| [a] These values are based on the assumption of adiabatic behaviour for a period of not more than 5 s.<br>[b] Consultation with the cable manufacturer is required. | | |

To withstand the electrodynamic and thermal effects of short-circuit currents, the dimensions of conductors shall be calculated according to IEC 60865-1.

### 13.3 Insulation and sheath materials

The types of insulation and sheath materials include (but are not limited to)

– polyvinyl chloride (PVC);
– cross-linked polyethylene (XLPE);
– ethylene propylene compound (EPR/HEPR).

Where the material of the insulation or the sheath of a cable (e.g. PVC) can constitute hazards due to the propagation of a fire or the emission of toxic or corrosive fumes, guidance should be sought from the cable supplier.

The mechanical strength and thickness of the materials shall be so selected that the insulation and the sheath cannot be damaged in operation or during laying, especially for cables pulled into ducts.

Where applicable, the requirements of ~~5.2.9 of HD 637~~ 6.2.9 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 apply.

### 13.4 Current-carrying capacity in normal service

The current-carrying capacity of conductors and cables is determined by both

– the maximum allowable conductor temperature under the highest possible steady-state current or the thermal equivalent RMS current for intermittent duty applications, and
– the ultimate allowable short-time conductor temperature under short-circuit conditions.

The cross-sectional area of a conductor shall be such that, under these conditions, the conductor temperature does not exceed the value given in Table 1, unless otherwise specified by the cable supplier.

The cable supplier shall be consulted for details of the current carrying capacities of cables for all continuous duty and intermittent duty applications.

### 13.5 Conductor and cable voltage drop

The voltage drop from the point of supply to the load shall be such that the correct operation of the electrical equipment is not affected by undervoltage. However, the overvoltage during no-load operation shall not damage the electrical equipment.

### 13.6 Minimum cross-sectional area

The cross-sectional area of the conductors shall be selected according to 13.1 and 8.2.2.

### 13.7 Flexible cables

#### 13.7.1 General

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

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

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

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

Each flexible cable for the HV power supply for the electrical equipment of a mobile machine shall contain a protective conductor; see also 8.2.3. The cross-sectional area of the protective conductor shall be determined in accordance with Clause 8. If the cross-sectional area is at least 25 $mm^2$, the protective conductor may be divided into several conductors of equal cross-sectional areas within the flexible cable.

#### 13.7.2 Mechanical rating

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

The allowed maximum stress of conductors of flexible cables with material other than copper should be agreed with the cable manufacturer.

~~NOTE The following conditions affect the tensile stress of the conductors:~~

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

#### 13.7.3 Current-carrying capacity of cables wound on drums

Cables to be wound on drums shall be selected with conductors of such cross-sectional area that, when fully wound on the drum and carrying the normal service load, the maximum allowable conductor temperature is not exceeded.

For cables of circular cross-sectional area installed on drums, the maximum current-carrying capacity in free air should be de-rated in accordance with Table 2 ~~(see also clause 44 of IEC 60621-3)~~.

NOTE The current-carrying capacity of cables in free air can be found in manufacturers' specifications or in relevant national standards.

**Table 2 – De-rating factors for cables wound on drums**

| Drum type | Number of layers of cable | | | | |
|---|---|---|---|---|---|
| | Any number | 1 | 2 | 3 | 4 |
| Cylindrical ventilated | - | 0,85 | 0,65 | 0,45 | 0,35 |
| Radial ventilated | 0,85 | - | - | - | - |
| Radial non-ventilated | 0,75 | - | - | - | - |

The use of de-rating factors should be discussed with the cable and the cable drum manufacturers. This may result in other factors being used.

NOTE 1 A radial type drum is one where spiral layers of cable are accommodated between closely spaced flanges; if fitted with solid flanges, the drum is described as non-ventilated and if the flanges have suitable apertures, as ventilated.

NOTE 2 A ventilated cylinder drum is one where the layers of cable are accommodated between widely spaced flanges and the drum and end flanges have ventilating apertures.

### 13.8 Conductor wires, conductor bars and slip-ring assemblies

#### 13.8.1 Protection against direct contact

Conductor wires, conductor bars and slip-ring assemblies shall be so installed or enclosed that, during normal access to the machine, protection against direct contact shall be achieved by the application of one or a combination of the following protective measures:

– protection by enclosures or barriers of at least IP 4X or IP XXDH according to IEC 60529 ~~(see also 412.2 of IEC 60364-4-41)~~;

– protection by placing out of reach (see ~~7.1.2 of HD 637, 412.4 of IEC 60364-4-41~~ 8.2.1 of IEC 61936-1:2010).

Where protection is achieved by placing live parts out of reach, emergency switching off in accordance with 9.2.3.4.3 of IEC 60204-1:2016 shall be applied.

Conductor wires and conductor bars shall be so placed and/or protected as to

– prevent contact, especially for unprotected conductor wires and conductor bars, with conductive items such as the cords of pull-cord switches, strain-relief devices and drive chains;

– prevent damage from a swinging load.

#### 13.8.2 Protective bonding circuit

Where conductor wires, conductor bars and slip-ring assemblies are installed as part of the protective bonding circuit, they shall not carry current in normal operation.

The continuity of the parts of the protective bonding circuit using sliding contacts shall be ensured by taking appropriate measures (e.g. by duplication of the current collector, continuity monitoring).

### 13.8.3 Protective conductor current collectors

Protective conductor current collectors shall have a shape or construction such that they are not interchangeable with the other current collectors. Such current collectors shall be of the sliding contact type.

### 13.8.4 Clearances in air

Clearances between the respective conductors, and between adjacent systems of conductor wires, conductor bars, slip-ring assemblies and their current collectors shall be suitable for ~~the rated short-duration power frequency withstand voltage and for the lower level of the rated lightning impulse withstand voltage shown in table 2 of IEC 60071-1 (identical with table 1 of HD 637)~~ the standard insulation levels shown in Table 1 of IEC 61936-1:2010. The clearances shall correspond to the following values assigned to a highest voltage for equipment:

– rated short-duration power-frequency withstand voltage;

– rated lightning impulse withstand voltage. Select the lowest value (formerly “list 1”) where the table lists several lightning impulse withstand voltages.

### 13.8.5 Creepage distances

~~Creepage distances between the respective conductors, and between adjacent systems of conductor wires, conductor bars, slip-ring assemblies and their current collectors shall be suitable for operation at pollution level II, III or IV of table 2 of IEC 60071-2, (see also 3.3.5.2, note 2 of HD 637).~~

The manufacturer's recommendations shall be followed regarding special measures to prevent a gradual reduction in the insulation values due to unfavourable ambient conditions (e.g. deposits of conductive dust, chemical attack). For this purpose one of the following pollution levels, listed in Table 3, shall be selected:

Pollution level 0: Pollution inside a fully encapsulated compartment or enclosure, which shall comply with a degree of protection of minimum IP 54; i.e. no contamination can occur. Pollution, for example caused by the wear of sliding contacts, shall be cleaned in the cycles established by the manufacturer. If condensation can occur with these systems, measures shall be taken against moisture.

Pollution levels 1 to 4: refer to definition in Table 1 of IEC 60071-2:1996.

Completely enclosed slip ring assemblies should meet at least the requirements for pollution level 0 in accordance with Table 4.

**Table 3 – Selection of the pollution level depending on the degree of protection and insulator material**

| Insulator type | Degree of protection for conductor wires, conductor bars and slip-ring assemblies | | | |
|---|---|---|---|---|
| | Indoor/Outdoor IP 54 or higher | Indoor/Outdoor IP 10 to IP53 | Indoor IP 00 | Outdoor IP 00 |
| glass or ceramic indoor/outdoor | pollution level 0 to 4 | pollution level 1 to 4 | pollution level 1 to 4 | pollution level 1 to 4 |
| polymer material designed for outdoor use | pollution level 0 to 4 | pollution level 1 to 4 | pollution level 1 to 4 | pollution level 1 to 4 |
| polymer material designed for indoor use | pollution level 0 to 4[a] | pollution level 0 to 3 shall be increased by one level (not permissible for pollution level 4) | pollution level 1 to 4 | not permissible |
| [a] For example, a slip ring of a cable drum protected IP 54 mounted outside a crane. | | | | |

Creepage distances for pollution level 0 shall be not less than the values given in Table 4 unless the insulator is designed according to IEC 60273 and tested according to IEC 60660.

**Table 4 – Minimum creepage distance of conductor lines and slip ring assemblies**

| Nominal voltage of supply $U_n$ (RMS) | Highest voltage for equipment $U_m$ (RMS) | Minimum creepage distance for pollution level | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | | 1 | | 2 | | 3 | | 4 | |
| kV | kV | mm | | mm | | mm | | mm | | mm | |
| | | L-L | L-E | L-L | L-E | L-L | L-E | L-L | L-E | L-L | L-E |
| 3 | 3,6 | 60 | 60 | 100* | 60* | 125 | 73* | 156 | 91* | 193 | 112* |
| 6 | 7,2 | 87 | 60 | 200 | 116* | 249 | 144 | 312 | 181 | 387 | 224 |
| 10 | 12 | 144 | 90 | 333 | 193 | 416 | 241 | 520 | 301 | 644 | 372 |
| 15 | 17,5 | 210 | 122 | 485 | 281 | 606 | 350 | 758 | 438 | 940 | 543 |
| 20 | 24 | 288 | 167 | 665 | 384 | 831 | 480 | 1 039 | 600 | 1 289 | 745 |
| 30 | 36 | 432 | 250 | 998 | 577 | 1 247 | 720 | 1 559 | 901 | 1 933 | 1 117 |
| 36 | 41,5 | 498 | 288 | 1 150 | 664 | 1 438 | 831 | 1 797 | 1 038 | 2 228 | 1 287 |
| Creepage distances of pollution levels 1 to 4 are used for indoor and outdoor applications. Values marked with "*" are for indoor use only and have to be increased to 120 mm in case of outdoor use.<br><br>NOTE Columns "L-L" means line-line values (between phases), "L-E" means values for line-earth. . | | | | | | | | | | | |



### 13.8.6 Conductor system sectioning

Where conductor wires or conductor bars are arranged so that they can be divided into isolated sections, suitable design measures shall be employed to prevent the energization of adjacent sections by the current collectors themselves.

### 13.8.7 Construction and installation of conductor wire, conductor bar systems and slip-ring assemblies

Conductor wires, conductor bars and slip-ring assemblies used for HV power circuits shall be grouped separately from those used for LV circuits.

Conductor wires, conductor bars and slip-ring assemblies shall be capable of withstanding, without damage, the mechanical forces and thermal effects of short-circuit currents.

Removable covers for conductor wire and conductor bar systems laid underground or underfloor shall be so designed that they cannot be opened without the aid of a tool.

Where conductor bars are installed in a common metal enclosure, the individual sections of the enclosure shall be bonded together and earthed at several points depending upon their length. Metal covers of conductor bars laid underground or underfloor shall also be bonded together and earthed.

NOTE For equipotential bonding or protective conductor connection to covers or cover plates of metal enclosures or underfloor ducts, the usual metal hinges are considered sufficient to ensure continuity.

Underground and underfloor conductor bar ducts shall have drainage facilities.

## 14 Wiring practices

### 14.1 Connections and routing

#### 14.1.1 General requirements

The means of introduction of a HV cable with its glands, bushings, etc., into an enclosure shall ensure that the degree of protection of the enclosure is not reduced (see 12.3).

All connections shall be secured against accidental loosening. The means of connection shall be suitable for the cross-sectional area and nature of the conductor being terminated. In the case of aluminium or aluminium alloy conductors, particular consideration shall be given to the problems of intrinsic plasticity (flowing) and electrolytic corrosion. Screw and compression joints of conductors and connections to electrical equipment shall be designed to maintain the required contact pressure under load and short-circuit conditions. The recommendations of the cable supplier shall be followed regarding types of gland, box and methods of termination.

Identification tags shall be fixed on the cable at the cable terminations, and shall be legible, permanent, and appropriate for the physical environment.

#### 14.1.2 Cable runs

Cables shall be so installed or protected as to minimize the possibility of mechanical damage that may arise due to the use of the machine or by foreseeable misuse.

The bending radius of the cables and the conditions of laying shall be in accordance with the advice of the cable supplier.

Where it is necessary to disconnect and reconnect cables (e.g. for replacement of a motor), sufficient extra length shall be provided for this purpose.

Conductors and cables shall be adequately supported. In particular the terminations of cables shall be adequately supported to prevent mechanical stresses at the terminations of the conductors.

Cables shall be run from termination to termination without splices or joints. Where this is impracticable (e.g. on mobile machines, on machines having long flexible cables), splices or joints may be used.

High-voltage cables should be physically separated from low-voltage cables.

### 14.2 Identification of conductors

Conductors shall be identifiable at each termination in accordance with the technical documentation (see Clause 18). Annex B, question 29 may be used for agreement between supplier and user regarding a preferred method of identification.

Where the protective conductor cannot be easily identified by its shape, position, or construction, it shall be clearly identified at accessible positions by the graphical symbol IEC 60417-5019:2006-08 or by the bicolour combination GREEN-and-YELLOW.

NOTE National deviations can apply regarding the colour to identify the protective conductor.

### 14.3 Flexible cables

Flexible cables subject to movement shall be supported in such a way that there is no mechanical strain on the anchorage points or any sharp flexing. Where this is achieved by the use of a loop, it shall have sufficient length to provide for a bending radius of the cable of at least 10 times the diameter of the cable unless otherwise specified.

The connecting ends of the cables shall be relieved from stress and thrust. Cable sheaths shall be secured against stripping and the cable ends protected against torsion.

The points of connection shall be arranged in such a manner that the cables cannot be kinked.

Flexible cables of machines shall be installed or protected so as to minimize the possibility of external damage due to factors that include the following cable uses or foreseeable misuse:

– being run over by the machine itself;
– being run over by vehicles or other machines;
– coming into contact with the machine structure during movements;
– running in and out on cable baskets, or on or off cable drums;
– acceleration forces and wind forces on festoon systems or suspended cables;
– excessive rubbing by cable collectors;
– exposure to excessive radiated heat.

The cable sheath shall be resistant to

– the normal wear which can be expected from movement, and
– the effects of atmospheric contaminants (e.g. oil, water, coolants, dust).

The cable handling system shall be so designed that lateral cable angles do not exceed 5°, avoiding torsion in the cable when

– being wound on and off cable drums, and
– approaching and leaving cable guidance devices.

Measures shall be taken to ensure that at least two turns of flexible cable remain on a drum.

The allowable cable bending radius shall be ensured, unless otherwise agreed with the cable manufacturer, as follows:

– Cable drums and rollers shall be used which ensure that the operative winding diameter is at least 25 times the cable diameter. The minimum radius at the guide and deflector pulleys as well as towards the stationary cable termination point shall not be, in any direction, less than 15 times the cable diameter. The straight distance between two bends of an S-shaped deflection or a deflection to another level shall be at least 20 times the

cable diameter. The minimum bending radius at the feeding points which are within the travel way shall be at least 15 times the cable diameter.

– For roller conveyors, the distance between the individual rollers shall be so set as to avoid excessive bending at a roller. This applies especially under conditions of high travel speeds, frequent reversed bending and usage at the maximum permissible tensile stress of the conductors.

These requirements also apply to similar devices, for example mobile cable supports, cable carriages.

### 14.4 Plug-socket combinations

Plug-socket combinations which remain connected during normal service shall be

– of the retaining type requiring the use of a key or tool to prevent unintended disconnection, or

– of a type interlocked with a switch to prevent disconnection under load.

In cases where plug-socket combinations are required, for example to extend a flexible power supply cable, they shall be retained in a way requiring the use of a key or tool and it is recommended that, in addition, they be interlocked with a switch.

The plug-socket combination shall meet the requirements of 5.3.2 c). Appropriate warning signs in accordance with 17.2 shall be affixed to the plug-socket combination. Appropriate instructions for safe use shall be provided in accordance with Clause 18.

### 14.5 Dismantling for shipment

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

### 14.6 Cable trays

Cable trays shall be rigidly supported and positioned at a sufficient distance from moving parts and in such a manner as to minimize the possibility of damage or wear. In areas where human passage is required, the cable trays shall be mounted at least 2 m above the working surface.

## 15 Electric motors and associated equipment

### 15.1 General

Electric motors should conform to the relevant parts of the IEC 60034 series. In all other respects the requirements of Clause 14 of IEC 60204-1:2016 apply.

NOTE Motors in supply systems with isolated neutral point or resonant earthing sometimes need a higher insulation level; see 7.4 of IEC 60034-1:2017.

### 15.2 Motor connection boxes

Motor-mounted devices, for example brakes, temperature sensors, plugging switches, tachometer generators, shall be terminated either

– in a connection box separate from the motor connection box, or

– in a compartment of the motor connection box separate from the high-voltage terminations.

~~16 Accessories~~

~~16.1 Accessories for earthing and short-circuiting live parts~~

~~Accessories for earthing and short-circuiting all live parts to the earthing system (see 5.5) which are appropriate for the HV equipment shall be provided in sufficient quantity to facilitate work being carried out in safety on the live parts of the HV equipment of the machine (see annex B). These accessories shall comply with the requirements of IEC 61230.~~

~~16.2 Voltage detectors~~

~~Voltage detectors complying with IEC 61243-1, suitable for verifying that live parts on the machine are de-energized shall be provided. These voltage detectors shall include means of verifying that they are in working order (see annex B). See also 7.3.3 of HD 637.~~

~~16.3 Accessories for safe working~~

~~Accessories for safe working in the vicinity of live HV equipment (e.g. mobile screens, insertable insulated partitions) shall be provided in accordance with 7.3.5 of HD 637 (see annex B).~~

## 16 Means to protect persons working on electrical installations

### 16.1 General

Accessories for earthing and short-circuiting all live parts to the earthing system (see 5.5) which are appropriate for the HV equipment shall be provided in sufficient quantity to facilitate work being carried out in safety on the live parts of the HV equipment of the machine (see Annex B).

It is recommended that the working procedures are agreed upon between the manufacturer and the user. Means for safe working in the vicinity of live HV equipment shall be appropriate and adequate for the present risk and shall be in accordance with 8.4 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

### 16.2 Equipment for isolating installations or apparatus

Refer to 8.4.1 of IEC 61936-1:2010.

### 16.3 Devices to prevent reclosing of isolating devices

Refer to 8.4.2 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

### 16.4 Devices for determining the de-energized state

Refer to 8.4.3 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

### 16.5 Devices for earthing and short-circuiting

Refer to 8.4.4 of IEC 61936-1:2010.

### 16.6 Equipment acting as protective barriers against adjacent live parts

Refer to 8.4.5 of IEC 61936-1:2010.

### 16.7 Storage of personal protection equipment

Refer to 8.4.6 of IEC 61936-1:2010.

## 17 Marking, warning signs and reference designations

### 17.1 General

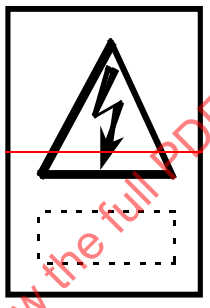
The electrical equipment shall be marked with the supplier's name, trade mark, or other identifying symbol.

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

Marking and reference designations shall be in accordance with Clause 16 of IEC 60204-1:2016.

### 17.2 Warning signs

~~Enclosures that do not otherwise clearly show that they contain electrical devices shall be marked with a combined sign according to figure 10 of IEC 61310-1. This shall show a black lightning flash on a yellow background within a black triangle, shaped in accordance with the graphical symbol IEC-60417-5036, the whole in accordance with symbol 13 of ISO 3864 and shall be marked in the supplementary label with the relevant voltage:~~



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

Enclosures that do not otherwise clearly show that they contain electrical devices shall be marked with a combined sign according to Figure 8 or Figure 9 of ISO 3864-1:2011. This shall show the graphical symbol ISO 7010-W012:2011-06 and shall be marked in the supplementary label with the capital letters "HV" (see Figure 4).

NOTE 1 The relevant voltage can be added optionally below or beside the letters "HV"


**Figure 4 – Warning sign "high voltage"**

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

In addition a DANGER hazard severity panel to identify a high level of risk according to Table 2, ISO 3864-2:2016 (refer to Figure 5) shall be placed next to the warning sign "high voltage".


**Figure 5 – DANGER hazard severity panel**

NOTE 2 The DANGER hazard severity panel can be in local language.

## 18 Technical documentation

~~The requirements of clause 18 of IEC 60204-1 apply. In addition the documentation, especially the operating manual, shall include the proper procedures for the use of the accessories specified in clause 16 of this standard.~~

### 18.1 General

The requirements of Clause 17 of IEC 60204-1:2016 apply.

### 18.2 Instructions for use

#### 18.2.1 General

The documentation, especially the operating manual, shall include the proper procedures for the use of the accessories specified in Clause 16.

#### 18.2.2 Provisions for handling

Special lifting devices shall be capable of lifting the mass of each transport unit and special precautions shall be detailed in the installation manual (for example lifting brackets/bolts that are not intended to be left outdoors shall be removed at site). Required information for unpacking should be given (see 4.6).

#### 18.2.3 Assembly and mounting

Instructions for mounting of equipment, operating device and auxiliary equipment shall include sufficient details of locations and foundations to enable site preparation to be completed. These instructions shall also indicate the total mass of the apparatus and the mass of the parts of the apparatus to be lifted separately if they exceed 100 kg.

#### 18.2.4 Connections

Instructions shall include information on connection of high-voltage conductors; auxiliary circuits and earthing circuits.

#### 18.2.5 Final installation inspection

Instructions shall be provided for inspection and tests which should be made after the equipment has been installed and all connections have been completed. These instructions shall include

– a schedule of recommended site tests to establish correct operation;
– procedures for carrying out any adjustment that may be necessary to obtain correct operation;
– recommendations for any relevant measurements that should be made and recorded for maintenance;

– instructions for final inspection and putting into service.

#### 18.2.6 Warning sign

The meaning of the warning signs and hazard severity panels should be explained in the user documentation.

## 19 Testing and verification

### 19.1 General

This document gives general requirements for the HV equipment of machines. The relevant tests for a particular machine type will be given in the dedicated product standard. Where there is no dedicated product standard for the machine, ~~the appropriate tests may include one or more of the following but shall always include the earthing system tests (see 19.2)~~ the verifications shall always include the following items a), b), and e) and may include one or more of the following items d) to f):

a) verification that the HV equipment is in compliance with the technical documentation;

b) earthing system tests (see 19.2);

c) insulation resistance tests (see 19.3);

d) voltage tests (see 19.4);

e) functional tests (see 19.5);

f) IP tests for HV equipment outside electrical operating areas (see 19.6).

When these tests are performed, it is recommended that they follow the sequence listed.

### 19.2 Earthing system tests

Tests shall be carried out on

a) the machine installation,

b) the connections between the machine installation and the external installation (machine bonding conductors),

c) any earthing system provided as part of the electrical installation of the machine,

to verify that the earthing system satisfies the requirements for protection against indirect contact according to 6.3.

~~The tests shall be carried out in accordance with 9.6 of HD 637.~~

NOTE 1 Guidance on tests and measurements is given in 10.5 of IEC 61936-1:2010 and Clause 8 of EN 50522:2010.

NOTE 2 National deviations due to European regulations for earthing systems are defined in Annex Q of EN 50522:2010.

### 19.3 Insulation resistance tests

The insulation resistance, between the power circuit conductors and the protective bonding circuit, measured at a voltage equal to the rated voltage of the HV equipment or 5 kV, whichever is the lower value, shall be not less than 1 MΩ. The test may be made on individual sections of the complete HV installation.

Exception: For certain parts of HV equipment, incorporating for example busbars, conductor wire or conductor bar systems or slip-ring assemblies, a lower minimum value of insulation resistance is permitted in agreement with the manufacturer.

### 19.4 Voltage tests

Details of the voltage tests shall be agreed between the supplier and user.

Guidance for voltage tests after installation on site is given ~~in appendix DD of IEC 60298~~, for example, in 7.105 of IEC 62271-200:2011.

### 19.5 Functional tests

The functions of electrical equipment shall be tested, particularly those related to safety and safeguarding.

### 19.6 IP tests for HV equipment outside electrical operating areas

IP tests are not necessary for type-tested HV equipment ~~that provides a minimum degree of protection against direct contact of IPXXDH~~ if it is installed according to the manufacturer's instructions and the requirements of IEC 61936-1.

For other electrical equipment, the appropriate tests specified in IEC 60529 shall be carried out.

### 19.7 Retesting

Where a portion of the machine and its associated electrical equipment is changed or modified, that portion shall be re-verified and re-tested as is appropriate (see 19.1).

# Annex A
(informative)

## Examples of machines covered by IEC 60204-11

The following list shows examples of machines whose HV equipment should conform to this document:

- compressors;
- conveyors;
- cranes;
- extruders;
- hoisting machines;
- internal mixers (rubber and plastics);
- material (e.g. coal) stocking-out and reclaiming machines;
- mills;
- mining and quarrying machines;
- paper and board making machines;
- pumps;
- rolling mills for metals;
- ship loaders~~/unloaders~~;
- tunnelling machines;
- ventilators.

# Annex B
(informative)

## Inquiry form for the HV equipment of machines

It is recommended that the following information be provided by the intended user of the HV equipment. It facilitates an agreement between the user and supplier on basic conditions and additional user requirements to ensure proper design, application and utilisation of the HV equipment of the machine (see 4.1).

NOTE There is a separate inquiry form for the LV equipment of machines in Annex B of IEC 60204-1:2016.

Name of manufacturer/supplier _____

Name of end user _____

Tender/order No. _____ Date _____

Type of machine/serial number _____

1. Are there to be modifications as allowed for within this standard?

   YES_____ NO_____

   NOTE Check network codes for the direct connection of machinery to the distribution network.

   ***Operating conditions – Special requirements (see 4.4)***

2. Ambient temperature range _____
3. Humidity range _____
4. Altitude _____
5. Environmental (e.g. corrosive atmospheres, particulate matter, EMC) _____

   NOTE Certain environments may be prone to abet microflora or microfauna.

6. Radiation _____
7. Vibration, shock _____
8. Special installation and operation requirements (e.g. flame retardant requirements for cables and conductors)

   _____

***Power supply (supplies) and related conditions (see 4.3)***

9. Anticipated voltage fluctuations (if more than ±10 %)

10. Anticipated frequency fluctuations (if more than in 4.3.2) _____

    Specification of short-term value _____

11. Indicate possible future changes in HV equipment that will require an increase in the electrical HV supply requirements _____

12. Indicate for each source of electrical supply required:

    Nominal voltage (V) _____ AC _____ DC _____

    If AC, number of phases _____ Frequency _____ Hz

    Prospective short-circuit current at the point of supply to the machine _____ kA RMS (see also question 15)

    Fluctuations outside values given in 4.3.2 _____

13. What size and type of cable will be used to connect the supply to the machine?

    – cable cross-sectional area _____
    – conductor material _____
    – cable type _____

    Is monitoring of the protective conductor required? YES_____ NO_____

14. Expected single earth-fault current of the HV supply system

    Value: _____ Duration: _____

    Type of earthing

    – isolated neutral point
    – resonant earthing
    – low impedance neutral earthing
    – resonant earthing and temporary low impedance neutral earthing ~~?~~

    Expected double earth-fault current in systems with isolated neutral point or resonant earthing ~~?~~

    Value: _____ Duration: _____

15. Does the user or the supplier provide the overcurrent and earth fault protection of the supply conductors? (See 7.2)

    _____

    Type and setting of

    – overcurrent protective devices _____

– earth fault protective devices _____

16. Supply disconnecting and earthing devices

Type of ~~disconnecting device~~ disconnector to be provided ~~?~~ _____

Are locking facilities to lock in the OFF position required for earthing switches?

YES _____ NO _____

17. Limit of power up to which three-phase AC motors may be started directly across the incoming supply lines ~~?~~ _____ kW

18. Motors

With reference to 7.3 of IEC 60204-1:2016 (overload protection of motors):

– May the number of motor overload detection devices be reduced?

YES _____ NO _____

– Is protection under loss of phase condition required?

YES _____ NO _____

– Is protection under stalled rotor condition required?

YES _____ NO _____

19. Overvoltage protection

Table B.1 indicates applications where the installation of overvoltage protection devices is recommendable to ensure reliable and secure service. Type and ratings of the protection devices shall be individually configured to the installation conditions.

**Table B.1 – Overvoltage protection for HV equipment of machinery**

| Equipment | Recommendation |
|---|---|
| Outdoor installation | Lightning protection (requires customised engineering) |
| Distribution and/or power transformer<br><br>NOTE For unit transformers see:<br>– motor<br>– generator<br>– converter | No surge protection for normal distribution transformer which is installed in HV cable networks.<br>Surge arresters to be fitted in case of:<br>– connection to overhead line<br>– insulation level is lowest level (“list 1”) to IEC 60071-1<br>– insulation is aged or its level is unknown<br>– switching rate in normal service is high |
| Motor | Surge arresters if starting current < 600 A;<br>additional RC circuits if<br>– insulation is not in line with IEC 60034-15,<br>– insulation is aged or its level is unknown,<br>– intended switching rate is high,<br>– starting is controlled by auto-transformer |
| Generator | Surge arresters if generator short-circuit current is < 600 A;<br>(see table line “Motor” regarding additional RC circuits) |
| Converter transformer | Surge arresters |
| Capacitive circuits<br>(filter circuit, capacitor bank) | If breaker corresponds with class 2 to IEC 62271-100,<br>no surge protection is required. |

***Other considerations***

20. Identification (see 17.1) _____

21. Inscriptions/special markings

    – mark of certification YES _____ NO _____ If YES, which one? _____
    – on HV-equipment? _____ In which language? _____

22. Technical documentation ~~(see 18.1 of IEC 60204-1)~~

    On what media? _____ In which language? _____

23. Size, location, and purpose of ducts, open cable trays, or cable supports to be provided by the user ~~? (see 18.5 of IEC 60204-1)~~ (additional sheets to be provided where necessary)

24. If 'two-hand control' is to be provided, state the type: _____

    Where it is type III, state the time limit (0,5 s maximum) within which each pair of pushbuttons is to be operated _____

25. Indicate if special limitations on the size or weight affect the transport of a particular machine or the controlgear assemblies to the installation site:

    – maximum dimensions _____
    – maximum weight _____

26. In the case of machines with frequent repetitive cycles of operation dependent on manual control, how frequently will cycles of operation be repeated?

_____ per hour

For what length of time is it expected that the machine will be operated at this rate without subsequent pause? _____ min

27. In the case of specially built machines, is a certificate of operating tests with the loaded machine to be supplied? YES_____ NO_____

    In the case of other machines, is a certificate of operating type tests on a loaded prototype machine to be supplied? YES_____ NO_____

28. For cable-less control systems, specify the time delay before automatic machine shutdown is initiated in the absence of a valid signal~~? (see 9.2.7.3 of IEC 60204-1)~~ ____ s

29. Do you need a specific method of conductor identification to be used for the conductors referred to in 14.2?

    YES_____ NO_____ Type _____

30. Type and quantity of accessories for:

    – earthing and short-circuiting (see 16.1) Type _____ No. _____
    – voltage detectors (see 16.2) Type _____ No _____
    – safe working (see 16.3) Type _____ No _____

# Annex C
(informative)

## Method of calculation for the cross-sectional area of bare protective conductors in supply systems with direct earthing or low impedance earthing of the neutral

Because the probability of receiving a burn from touching the protective conductor during the time when a short-time earth fault occurs is very low, the cross-sectional area is dimensioned for a temperature of 200 °C. The formula below can be used to calculate the required cross-sectional area of bare conductors that will carry the earth-fault current for a period of up to 5 s without exceeding a conductor temperature of 200 °C, assuming adiabatic behaviour:

$$S = (I_E/k)t^{1/2}$$

where

$S$ is the required cross-sectional area in square millimetres ($mm^2$);

$I_E$ is the effective earth-fault current in amperes (A), expressed for a.c. as the r.m.s. value;

$t$ is the time in seconds (s) of fault current flow;

$k$ is the factor in $As^{1/2}\ mm^{-2}$ for bare conductors with an allowable maximum temperature of 200 °C, based on an initial temperature of 40 °C:

153 for copper,

99 for aluminium,

56 for galvanized steel.

# Annex C
(informative)

## Relationship between cable rated voltages and highest voltage for HV equipment

The voltage designation of a cable is given in terms of $U_0 / U$ ($U_m$)

where

$U_0$ is the rated power frequency voltage between conductor and earth or metallic screen for which a cable is designed;

$U$ is the rated power frequency voltage between conductors for which the cable is designed (also used as the "nominal system voltage");

$U_m$ is the maximum value of the "highest system voltage" for which the HV equipment may be used (see IEC 60038).

**Table C.1 – Rated voltages of cable and highest voltage for HV equipment**

| Rated voltages of cables and related fittings | | Highest voltage for HV equipment |
|---|---|---|
| $U_0$<br>kV | $U$<br>kV | $U_m$<br>kV |
| 1,8 | 3 | 3,6 |
| 3,6 | 6 | 7,2 |
| 6 | 10 | 12 |
| 8,7 | 15 | 17,5 |
| 12 | 20 | 24 |
| 18 | 30 | 36 |

# Annex E
(informative)

# Rationalization of the use of terms relating to earthing and protective bonding

| IEC 60204-11 | HD 637 |
|---|---|
| **Earth electrode**<br>Not defined<br>No specific requirements<br>Used in 3.9 | **Earth electrode**<br>Defined in 2.7.3 as follows:<br>a conductor which is in conductive contact with the earth, or a conductor, which is embedded in concrete, which is in contact with the earth via a large surface (for example a foundation earth electrode) |
| **Earthing system**<br>Defined in 3.9 as follows:<br>locally limited system of conductively connected earth electrodes or metal parts of equal effectiveness (for example tower footings, armourings, metal cable sheaths), of earthing conductors and of bonding conductors<br>[HD 637, 2.7.6]<br>No specific requirements<br>Used in 3.25, 5.2.1, 5.2.3.2, 6.3.2, 8.1, 8.2.2, 8.2.3, 16.1, 19.1, 19.2 | **Earthing system**<br>Defined in 2.7.6 as follows:<br>A locally limited system of conductively connected earth electrodes or metal parts of equal effectiveness (for example tower footings, armourings, metal cable sheaths), of earthing conductors and of bonding conductors |
| **Earthing conductor**<br>Not defined<br>No specific requirements<br>Used in 3.9, 3.25 | **Earthing conductor**<br>Defined in 2.7.4 as follows:<br>a conductor which connects a part of the installation that has to be earthed to an earth electrode or which connects earth electrodes and is laid outside of the soil or is buried in the soil and insulated from it<br>NOTE Where the connection between part of the installation and the earth electrode is made via a disconnecting link, disconnecting switch, surge arrester counter, surge arrester control gap etc., then only that part of the connection permanently attached to the earth electrode is an earthing conductor. |
| **Machine bonding conductor**<br>Defined in 3.25 as follows:<br>conductor connecting the machine equipotential bonding to the earthing system<br>NOTE This is an earthing conductor as defined in IEV 826-04-07 and used in HD 637.<br>No specific requirements<br>Used in 8.2.1, 8.2.3, 8.2.6, 8.2.7, 19.2 | **Machine bonding conductor**<br>Not used |

| IEC 60204-11 | HD 637 |
|---|---|
| **Protective conductor**<br>Defined in 3.35 as follows:<br>conductor required by some measures for protection against electric shock for electrically connecting any of the following parts:<br>– exposed conductive parts;<br>– extraneous conductive parts;<br>– main earthing terminal<br>[IEV 826-04-05, modified]<br>Requirements in 8.2.2, 13.7.1<br>Used in 3.16, 3.34, 8.2.1, 8.2.3, 8.2.6, 13.8.3, 13.8.7, 14.2, annex C | **Protective conductor**<br>Not defined<br>Used only for connections between LV equipment and HV earthing systems |
| **Equipotential bonding**<br>Defined in 3.15 as follows:<br>provision of electric connections between conductive parts, intended to achieve equipotentiality<br>[IEV 195-01-10]<br>Requirements in clause 8<br>Used in 3.16, 3.25, 8.1, 8.2.1, 13.8.7 | **Equipotential bonding**<br>Defined in 2.7.14.1 as follows:<br>the conductive connection between conductive parts, to reduce the potential differences between these parts |
| **Equipotential bonding conductor**<br>Defined in 3.16 as follows:<br>protective conductor provided for protective equipotential bonding<br>[IEV 195-02-10]<br>No specific requirements<br>Used in 8.2.1, 8.2.6 | **Bonding conductor**<br>Defined in 2.7.5 as follows:<br>a conductor providing equipotential bonding |
| **Supplementary equipotential bonding conductor**<br>Not defined<br>Requirements in 8.2.7<br>Used in 8.2.7 | **Supplementary equipotential bonding conductor**<br>Not used |
| **Protective bonding circuit**<br>Defined in 3.34 as follows:<br>the whole of the protective conductors and conductive parts used for protection against electric shock in the event of an insulation failure<br>No specific requirements<br>Used in 6.3.1, 6.3.3, 8.2.1, 8.2.3, 8.2.4, 8.2.5, 8.2.6, 8.2.7, 13.8.2, 19.3 | **Protective bonding circuit**<br>Not used |

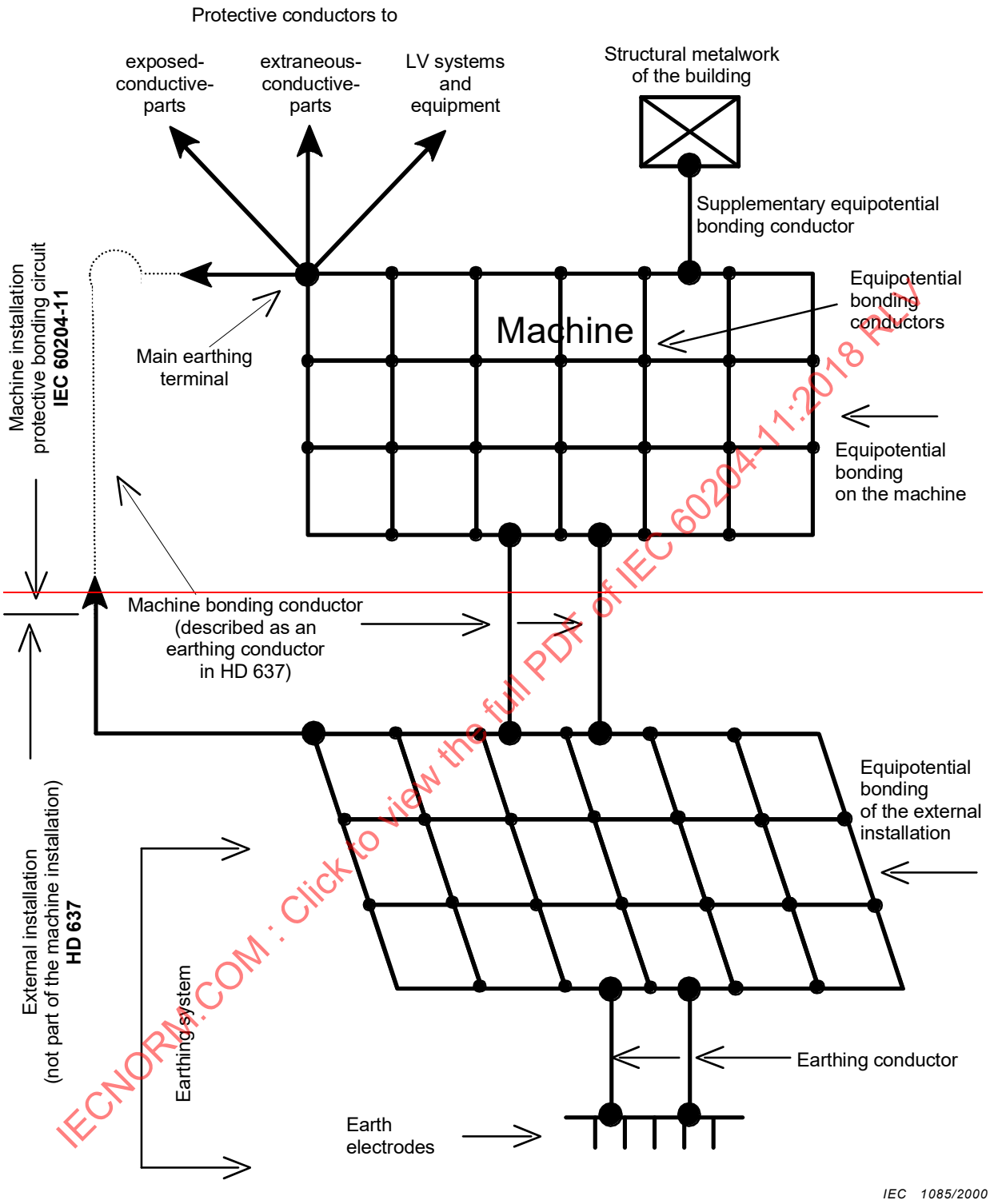





**Figure E.1 – Explanation of the terms relating to earthing and protective bonding**

# Index

This index lists, in alphabetical order, the terms defined in clause 3 and indicates where they are used in the text of this standard.


**A**

ambient temperature — **3.1**, 13.1, annex B

**B**

barrier — **3.2**, 3.10, 3.12, 6.2, 13.8.1

**C**

cable tray — **3.3**, 14.6, annex B
control circuit (of a machine) — **3.4**, 3.5, 3.26, 3.33, 4.1, 5.3, 9
control device — **3.5**,10, 12.2.1
controlgear — **3.6**, 12.1, 12.2.1, 12.3, annex B

**D**

direct contact — **3.7**, 3.2, 3.13, 3.29, 6.1, 6.2, 10, 13.8.1, 19.6
duct — **3.8**, 8.2.3, 13.3, 13.8.7, annex B

**E**

earthing system — **3.9**, 3.25, 5.2.1, 5.2.3.2, 6.3.2, 8.1, 8.2.2, 8.2.3, 16.1, 19.1, 19.2
electrical operating area — **3.10**, 12.3, 19.1, 19.6
electronic equipment — **3.11**, 1, 11
enclosed electrical operating area — **3.12**, 5.2.2, 5.3, 5.4, 5.5, 6.2
enclosure — **3.13**, 3.6, 6.2, 8.2.3, 12.2.1, 12.2.2, 12.3, 12.4, 13.8.1, 13.8.7, 14.1.1, 17.2
equipment — **3.14**
equipotential bonding — **3.15**, 3.16, 3.25, 8.1, 8.2.1, 13.8.7
equipotential bonding conductor — **3.16**, 8.2.1, 8.2.6, 8.2.7
exposed conductive part — **3.17**, 3.22, 3.35, 6.3.1, 6.3.3, 8.1, 8.2.1, 8.2.3
extraneous conductive part — **3.18**, 3.35, 8.1, 8.2.1

**F**

failure — **3.19**, 3.20, 3.34, 4.1, 6.3.1, 6.3.3, 8.2.3
fault — **3.20**, 3.19, 3.22, 3.31, 3.42, 4.1, 6.3.1, 6.3.2, 6.3.3, 6.3.4, 7.1, 7.2.5, 7.3, 8.2.1, table 1, 12.2.2, 13.1, annex B, annex C

**H**

hazard — **3.21**, 1, 3.39, 3.40, 4.1, 5.2.1, 5.3, 6.2, 6.3.1, 13.1, 13.3

**I**

indirect contact — **3.22**, 6.1, 6.3.1, 8.1, 8.2.2, 19.2
interlock — **3.23**, 5.2.1, 5.2.2

**L**

live part — **3.24**, 3.7, 6.2, 6.3.1, 13.8.1, 16.1, 16.2

**M**

machine bonding conductor — **3.25**, 8.2.1, 8.2.3, 8.2.6, 8.2.7, 19.2
machinery — **3.26**
marking — **3.27**, 5.3, 5.4, 12.2.1, 12.2.2, 17.1, annex B

**N**

neutral conductor (symbol N) — **3.28**, 3.24

**O**

obstacle — **3.29**, 6.2
overcurrent — **3.30**, 3.31, 3.42, 7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4, 7.2.5, 7.2.6, 7.3, 8.2.4, annex B
overload (of a circuit) — **3.31**, 7.1, annex B

**P**
plug/socket combination **3.32**, 5.5, 8.2.5, 14.4, 14.5
power circuit **3.33**, 1, 3.4, 3.26, 4.1, 7.2.3, 7.2.5, 13.8.7, 19.3
protective bonding circuit **3.34**, 6.3.1, 6.3.3, 8.2.1, 8.2.3, 8.2.4, 8.2.5, 8.2.6, 8.2.7, 13.8.2, 19.3
protective conductor **3.35**, 3.16, 3.34, 8.2.1, 8.2.3, 8.2.6, 13.7.1, 13.8.3, 13.8.7, 14.2, annex C

**R**
reference designation **3.36**, 12.2.1, 17.1
risk **3.37**, 1, 3.24, 3.38, 4.1

**S**
safe working procedure **3.38**, 4.1
safeguard **3.39**, 1, 3.40, 4.1
safeguarding **3.40**, 3.23, 4.1, 19.5
servicing level **3.41**, 5.2.4, 12.2.1

short-circuit current **3.42**, 5.2.3.2, 7.2.5, 13.2, 13.8.7, annex B
supplier **3.43**, 4.1, 4.3.1, 4.4, 4.7, 7.2.2, 7.2.4, 7.2.6, 7.3, 13.4, 13.1, 13.3, 13.4, 14.1.1, 14.2, 17.1, 19.4, annex B
switching device **3.44**, 3.6, 5.2.2, 7.2.6, 8.2.4

**T**
terminal **3.45**, 3.35, 7.2.4, 7.4, 8.2.1, 12.2.1

**U**
user **3.46**, 1, 3.43, 4.1, 4.3.1, 4.3.2, 4.4, 7.2.2, 7.3, 14.2, 19.4, annex B

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IEC 60204-11

Edition 2.0 2018-07

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

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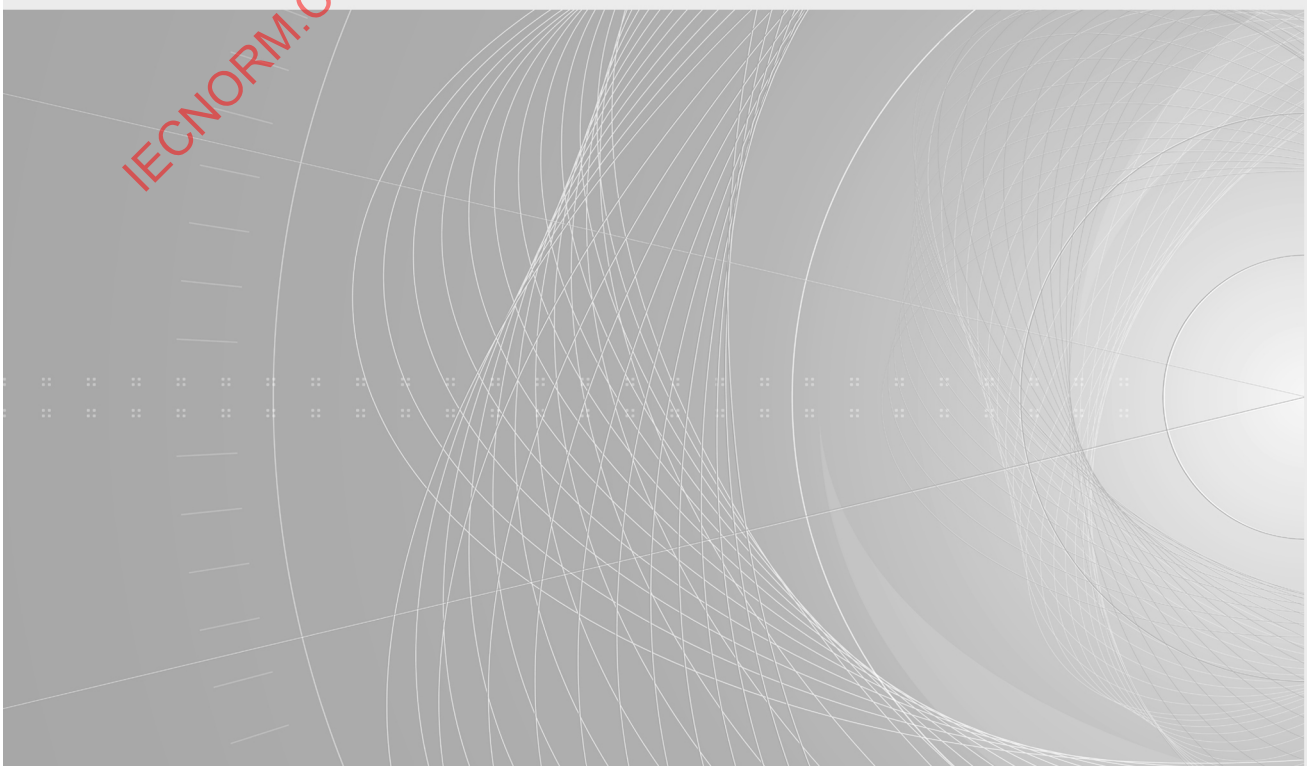
## Safety of machinery – Electrical equipment of machines – Part 11: Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV

## Sécurité des machines – Équipement électrique des machines – Partie 11: Exigences pour les équipements fonctionnant à des tensions supérieures à 1 000 V en courant alternatif ou 1 500 V en courant continu et ne dépassant pas 36 kV



IEC 60204-11:2018-07(en-fr)

CONTENTS

FOREWORD....6
INTRODUCTION....8
1 Scope....10
2 Normative references....11
3 Terms and definitions....12
4 General requirements....18
4.1 General....18
4.2 Selection of electrical equipment....19
4.3 Electrical power supply....20
4.3.1 General....20
4.3.2 Voltage characteristics....20
4.3.3 On-board power supply....20
4.4 Physical environment and operating conditions....20
4.4.1 General....20
4.4.2 Electromagnetic compatibility (EMC)....20
4.5 Transportation and storage....21
4.6 Provisions for handling....21
4.7 Installation....21
4.7.1 General....21
4.7.2 Assembly and mounting....21
5 Incoming supply conductor terminations and devices for disconnecting and switching off....21
5.1 Incoming high-voltage conductor terminations....21
5.2 Earthing terminal of high-voltage equipment....21
5.3 Supply disconnecting devices and means for earthing....22
5.3.1 General....22
5.3.2 Type....22
5.3.3 Requirements for disconnectors....23
5.3.4 Requirements for earthing and short-circuiting....23
5.3.5 Arrangement of disconnecting and earthing devices....24
5.4 Devices for switching off for prevention of unexpected start-up....24
5.5 Devices for disconnecting and means for earthing HV equipment....24
5.6 Protection against unauthorized, inadvertent and/or mistaken operation....25
6 Protection against electric shock....25
6.1 General....25
6.2 Protection against direct contact....26
6.3 Protection against indirect contact....26
6.3.1 General....26
6.3.2 Measures to prevent the occurrence of a hazardous touch voltage for an unlimited time of fault duration....26
6.3.3 Protection by automatic disconnection of supply within a limited time of fault duration....27
6.3.4 Protection for mobile machines....27
7 Protection of HV equipment....28
7.1 General....28
7.2 Overcurrent protection....28

7.2.1 General ..... 28
7.2.2 Supply conductors ..... 28
7.2.3 Power circuits ..... 28
7.2.4 Transformers ..... 28
7.2.5 Overcurrent protective devices ..... 29
7.2.6 Rating and setting of overcurrent protective devices ..... 29
7.3 Protection of motors against overheating ..... 29
7.4 Protection against abnormal temperature ..... 29
7.5 Protection against the effects of supply interruption or voltage reduction and subsequent restoration ..... 29
7.6 Motor overspeed protection ..... 29
7.7 Earth fault protection ..... 30
7.8 Protection against overvoltage due to lightning and switching surges ..... 30
7.9 Protection against hazards due to arc faults ..... 30
7.10 Protection against overpressure and leakage ..... 30
7.11 Protection against fire ..... 30
8 Equipotential bonding ..... 30
8.1 General ..... 30
8.2 Protective bonding circuit ..... 33
8.2.1 General ..... 33
8.2.2 Protective conductors ..... 34
8.2.3 Continuity of the protective bonding circuit ..... 34
8.2.4 Mobile machines ..... 35
8.2.5 Protective bonding circuit connecting points ..... 35
8.2.6 Supplementary protective bonding conductors ..... 36
9 Control systems, control circuits and control functions ..... 36
10 Operator interface and machine-mounted control devices ..... 36
11 Electronic equipment ..... 36
12 Controlgear: location, mounting, and enclosures ..... 36
12.1 General requirements ..... 36
12.2 Location and mounting ..... 37
12.2.1 Accessibility and maintenance ..... 37
12.2.2 Physical separation ..... 37
12.3 Degrees of protection ..... 37
12.4 Enclosures, doors and openings ..... 38
12.5 Access to HV equipment ..... 39
13 Conductors and cables ..... 39
13.1 General requirements ..... 39
13.2 Conductors ..... 39
13.3 Insulation and sheath materials ..... 40
13.4 Current-carrying capacity in normal service ..... 40
13.5 Conductor and cable voltage drop ..... 40
13.6 Minimum cross-sectional area ..... 40
13.7 Flexible cables ..... 40
13.7.1 General ..... 40
13.7.2 Mechanical rating ..... 41
13.7.3 Current-carrying capacity of cables wound on drums ..... 41
13.8 Conductor wires, conductor bars and slip-ring assemblies ..... 41

13.8.1 Protection against direct contact ..... 41
13.8.2 Protective bonding circuit ..... 42
13.8.3 Protective conductor current collectors ..... 42
13.8.4 Clearances in air ..... 42
13.8.5 Creepage distances ..... 42
13.8.6 Conductor system sectioning ..... 43
13.8.7 Construction and installation of conductor wire, conductor bar systems and slip-ring assemblies ..... 43
14 Wiring practices ..... 44
14.1 Connections and routing ..... 44
14.1.1 General requirements ..... 44
14.1.2 Cable runs ..... 44
14.2 Identification of conductors ..... 45
14.3 Flexible cables ..... 45
14.4 Plug-socket combinations ..... 46
14.5 Dismantling for shipment ..... 46
14.6 Cable trays ..... 46
15 Electric motors and associated equipment ..... 46
15.1 General ..... 46
15.2 Motor connection boxes ..... 46
16 Means to protect persons working on electrical installations ..... 47
16.1 General ..... 47
16.2 Equipment for isolating installations or apparatus ..... 47
16.3 Devices to prevent reclosing of isolating devices ..... 47
16.4 Devices for determining the de-energized state ..... 47
16.5 Devices for earthing and short-circuiting ..... 47
16.6 Equipment acting as protective barriers against adjacent live parts ..... 47
16.7 Storage of personal protection equipment ..... 47
17 Marking, warning signs and reference designations ..... 47
17.1 General ..... 47
17.2 Warning signs ..... 47
18 Technical documentation ..... 48
18.1 General ..... 48
18.2 Instructions for use ..... 48
18.2.1 General ..... 48
18.2.2 Provisions for handling ..... 48
18.2.3 Assembly and mounting ..... 48
18.2.4 Connections ..... 49
18.2.5 Final installation inspection ..... 49
18.2.6 Warning sign ..... 49
19 Testing and verification ..... 49
19.1 General ..... 49
19.2 Earthing system tests ..... 49
19.3 Insulation resistance tests ..... 50
19.4 Voltage tests ..... 50
19.5 Functional tests ..... 50
19.6 IP tests for HV equipment outside electrical operating areas ..... 50
19.7 Retesting ..... 50

Annex A (informative) Examples of machines covered by IEC 60204-11 ..... 51
Annex B (informative) Inquiry form for the HV equipment of machines ..... 52
Annex C (informative) Relationship between cable rated voltages and highest voltage for HV equipment ..... 56
Bibliography ..... 57

Figure 1 – Block diagram of a machine containing HV equipment ..... 9
Figure 2 – Example of equipotential bonding for electrical equipment of a machine ..... 33
Figure 3 – Symbol for protective earth (protective ground) ..... 35
Figure 4 – Warning sign “high voltage” ..... 48
Figure 5 – DANGER hazard severity panel ..... 48

Table 1 – Maximum allowable conductor temperatures under normal and short-circuit conditions ..... 39
Table 2 – De-rating factors for cables wound on drums ..... 41
Table 3 – Selection of the pollution level depending on the degree of protection and insulator material ..... 43
Table 4 – Minimum creepage distance of conductor lines and slip ring assemblies ..... 43
Table B.1 – Overvoltage protection for HV equipment of machinery ..... 54
Table C.1 – Rated voltages of cable and highest voltage for HV equipment ..... 56

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# SAFETY OF MACHINERY – ELECTRICAL EQUIPMENT OF MACHINES –

## Part 11: Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV

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International Standard IEC 60204-11 has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects.

This second edition cancels and replaces the first edition, published in 2000. This edition constitutes a technical revision.

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

– aspects of risk assessment, which are mirrored from ISO 12100;
– equipotential bonding and earthing;
– EMC and power quality;
– HV switchgear and controlgear;

– creepage distances for conductors and slip-ring assemblies;
– a list of machinery using HV equipment, in Annex A.

This second edition of IEC 60204-11 has been updated and improved to reflect the experience gained with the first edition and the evolution of high-voltage equipment reflected in the relevant standards.

Regarding formal requirements, IEC 60204-11 has been aligned with

– IEC 60204-1:2016,
– IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014,
– IEC 62271 (all parts).

This document is intended to be used in conjunction with IEC 60204-1.

The text of this International Standard is based on the following documents:

| FDIS | Report on voting |
|---|---|
| 44/819/FDIS | 44/828/RVD |

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

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

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

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

# INTRODUCTION

This part of IEC 60204 provides requirements and recommendations relating to the high-voltage electrical equipment (HV equipment) of machines together with its associated low-voltage electrical equipment (LV equipment) so as to promote

– safety of persons and property,

– consistency of control response,

– maintainability.

Figure 1 is a block diagram of a machine and associated equipment showing the various elements of the electrical equipment addressed in this document. Numbers in parentheses (…) refer to clauses and subclauses in this document. It is understood that all of the elements taken together including the safeguards, software and the documentation constitute the machine or group of machines working together with usually at least one level of supervisory control.

This document should be used in conjunction with IEC 60204-1. HV equipment can include LV control parts in the same general enclosure or in separate compartments.

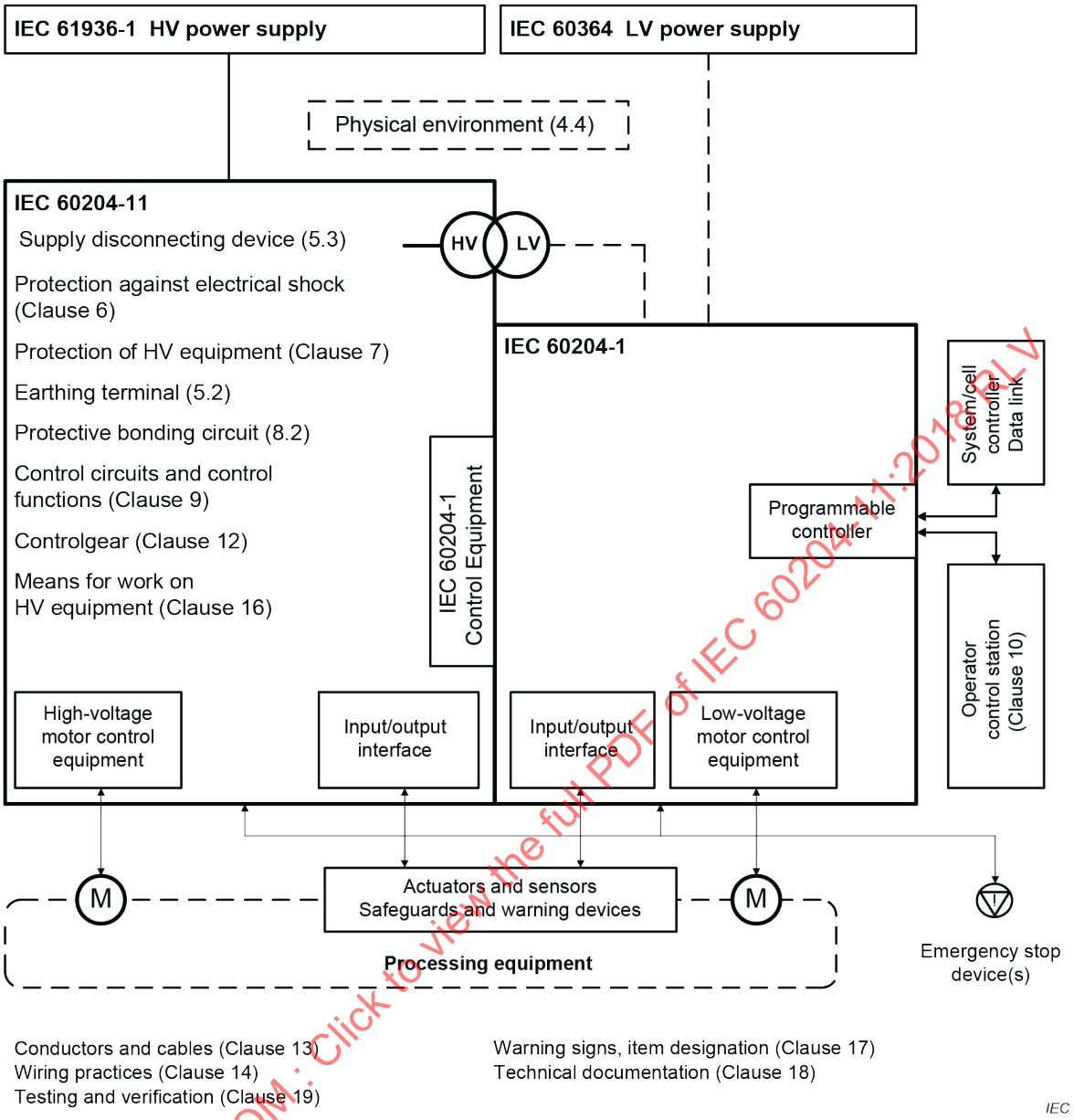



**Figure 1 – Block diagram of a machine containing HV equipment**

# SAFETY OF MACHINERY – ELECTRICAL EQUIPMENT OF MACHINES –

## Part 11: Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV

## 1 Scope

This part of IEC 60204 applies to electrical and electronic equipment and systems to machines, including a group of machines working together in a co-ordinated manner, which operate at nominal voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV AC or DC with nominal frequencies not exceeding 60 Hz.

In this document, the term HV equipment also covers the LV equipment forming an integral part of the equipment operating at high voltage. The requirements in this document primarily cover the parts operating at high-voltage except where explicitly stated otherwise.

NOTE 1 LV equipment not forming part of the HV equipment is covered by IEC 60204-1:2016.

NOTE 2 In this document, the term "electrical" includes both electrical and electronic matters (i.e. electrical equipment means both the electrical and the electronic equipment).

NOTE 3 This document does not apply to independent high-voltage power supply installations for which separate IEC standards exist.

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

NOTE 4 For the requirements for high-voltage power supply installations, see IEC 61936-1.

This document is a generic safety standard. It does not cover all the requirements (e.g. guarding, interlocking or control) which are needed or required by other standards or regulations in order to safeguard personnel from hazards other than electrical hazards. Each type of machine has unique requirements to be accommodated to provide adequate safety.

NOTE 5 In some machines the high-voltage power supply can be produced by a step-up transformer (autotransformer), supplied by a low-voltage system (e.g. by a LV generator).

NOTE 6 In the context of this document, the term "person" refers to any individual; "personnel" are those persons who are assigned and instructed by the user or his agent(s) in the use and care of the machine in question.

This part of IEC 60204 specifically includes, but is not limited to, machines as defined in 3.29 (Annex A lists examples of machines whose electrical equipment can be covered by this document).

For protection against electric shock from high-voltage equipment, this document refers to IEC 61936-1. When it comes to low-voltage equipment, this document refers to IEC 60204-1:2016.

NOTE 7 High- and low-voltage standards use different terms regarding protection against electric shock. Whereas high-voltage standards use the terms “direct contact” and “indirect contact”, low-voltage standards correspondingly use “basic protection” and “fault protection”.

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

– are used in the open air (i.e. outside buildings or other protective structures);
– use, process or produce potentially explosive material (e.g. paint or sawdust);
– are used in potentially explosive and/or flammable atmospheres;

– have special risks when producing or using certain materials;
– are used in mines.

Hazards as a result of noise and vibration are excluded from the scope of this document.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guide*

IEC 60076-5, *Power transformers – Part 5: Ability to withstand short-circuit*

IEC 60204-1:2016, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

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

IEC 60417, *Graphical symbols for use on equipment* (available at http://www.graphical-symbols.info/equipment)

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

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

IEC 60865-1, *Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods*

IEC 61800 (all parts), *Adjustable speed electrical power drive systems*

IEC 61936-1:2010, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*
IEC 61936-1:2010/AMD1:2014

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

IEC 62271-102, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC 62271-103, *High-voltage switchgear and controlgear – Part 103: Switches for rated voltages above 1 kV up to and including 52 kV*

IEC 62271-105, *High-voltage switchgear and controlgear – Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kV up to and including 52 kV*

IEC 62271-107, *High-voltage switchgear and controlgear – Part 107: Alternating current fused circuit-switchers for rated voltages above 1 kV up to and including 52 kV*

IEC 62271-200:2011, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-201, *High-voltage switchgear and controlgear – Part 201: AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62745, *Safety of machinery – Requirements for cableless control systems of machinery*

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

ISO 3864-1:2011, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

ISO 3864-2:2016, *Graphical symbols –Safety colours and safety signs – Part 2: Design principles for product safety labels*

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

ISO 12100, *Safety of machinery –General principles for design – Risk assessment and risk reduction*

## 3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

**3.1**
**ambient temperature**
temperature of the air or other medium where the equipment is to be used

**3.2**
**barrier**
part providing protection against contact with live parts from any usual direction of access

**3.3**
**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.]

**3.4**
**cable tray**
cable support consisting of a continuous base with raised edges but no covering

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

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

**3.5**
**conductor wire**
**conductor bar**
**conductor rail**
conductive wire, bar or rail of a feeder system with a sliding current collector

**3.6**
**control circuit**
<of a machine> circuit used for the control, including monitoring, of a machine and the electrical equipment

**3.7**
**control device**
device connected into the control circuit and used for controlling the operation of the machine

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

**3.8**
**controlgear**
general term covering 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 60050-441:2000, 441-11-03]

**3.9**
**duct**
enclosed channel designed expressly for holding and protecting electrical conductors, cables, and busbars

Note 1 to entry: Conduits, cable trunking systems and underfloor channels are types of duct.

**3.10**
**earthing system**
all the electric connections and devices involved in the earthing of a system, an installation and equipment

[SOURCE: IEC 60050-826:2004, 826-13-04, modified – The preferred terms have been deleted and the deprecated term is used as a preferred term.]

**3.11**
**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

Note 1 to entry: An (electrically) instructed person is a 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 (see IEC 60050-826:2004, 826-18-02.

Note 2 to entry: An (electrically) skilled person is a person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create (see IEC 60050-826:2004, 826-18-01)

**3.12**
**electronic equipment**
part of the electrical equipment containing circuitry mainly based on electronic devices and components

**3.13**
**closed electrical operating area**
room or location for operation of electrical installations and equipment to which access is intended to be restricted to skilled or instructed persons or to lay personnel under the supervision of skilled or instructed persons, e.g. by opening of a door or removal of a protective barrier only by the use of a key or tool, and which is clearly marked by appropriate warning signs

Note 1 to entry: See also Notes to entry 1 and 2 of definition 3.11.

**3.14**
**enclosure**
part providing a specified degree of protection of equipment against external influences and, in any direction, a specified degree of protection against approach to or contact with live parts and against contact with moving parts

Note 1 to entry: The definition needs the following explanations within the scope of this document:

Enclosures provide protection of persons or livestock against access to hazardous parts.

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.

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 60050-441:2000, 441-13-01, modified – "of an assembly" has been deleted and "in any direction" and the note have been added.]

**3.15**
**equipment**
items used in connection with the utilisation of electricity by machines or parts of machines, for example material, fittings, devices, components, appliances, fixtures, apparatus, and similar

**3.15.1**
**high-voltage electrical equipment**
items as defined in IEC 60204-11:2018, 3.15 which are designed to operate at voltages above 1 000 V AC or 1 500 V DC

Note 1 to entry: For easier reading in this document “HV equipment” is used where the context is obvious.

**3.16**
**equipotential bonding**
provision of electric connections between conductive parts, intended to reduce the potential differences and achieve equipotentiality between these parts

[SOURCE: IEC 60050-195:1998, 195-01-10, modified – “reduce the potential differences” and "between these parts" have been added.]

**3.17**
**protective bonding conductor**
protective conductor provided for protective equipotential bonding

[SOURCE: IEC 60050-195:1998, 195-02-10]

**3.18**
**exposed conductive part**
conductive part of equipment which can be touched and which is not normally live, but which can become live when basic insulation fails

[SOURCE: IEC 60050-195:1998, 195-06-10]

**3.19**
**extraneous conductive part**
conductive part not forming part of the electrical installation and liable to introduce an electric potential, generally the electric potential of a local earth

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

**3.20**
**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 60050-603:1986, 603-05-06, modified – The notes have been added.]

**3.21**
**fault**
state of an item characterized by the 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 60050-192:2015, 192-04-01. 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.

**3.22**
**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]

**3.23**
**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, and 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 – "harm" has been replaced with "physical injury or damage to health" and Note 3 has been deleted.]

**3.24**
**interlock**
**interlock for safeguarding**
arrangement of devices operating together to:

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

**3.25**
**live part**
conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

[SOURCE: IEC 60050-195:1998, 195-02-19]

**3.26**
**machine bonding conductor**
conductor connecting the machine equipotential bonding to the earthing system

Note 1 to entry: This is an earthing conductor as defined in IEC 60050-826:2004, 826-13-12 and used in IEC 61936-1.

Note 2 to entry: This corresponds to the term “earthing conductor” in IEC 61936-1.

**3.27**
**machine actuator**
power mechanism of the machine used to effect motion

EXAMPLE Motor, solenoid, pneumatic or hydraulic cylinder.

**3.28**
**neutral conductor**
conductor electrically connected to the neutral point and capable of contributing to the distribution of electric energy

[SOURCE: IEC 60050-195:1998, 195-02-06]

**3.29**
**machinery**
**machine**
assembly of linked parts or components, at least one of which moves, with the appropriate machine actuators, control and power circuits, etc., joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material

Note 1 to entry: The terms "machinery" and "machine" also cover:

– an assembly of machines which, in order to achieve one and the same end, are arranged and controlled so that they function as an integral whole;
– interchangeable equipment modifying the function of a machine, which is placed on the market (supplied) for the purpose of being assembled with a machine or a series of different machines or with a tractor by the operator himself insofar as this equipment is not a spare part or tool.

**3.30**
**obstacle**
part preventing unintentional direct contact, but not preventing direct contact by deliberate action

[SOURCE: IEC 60050-826:2004, 826-12-24, modified – "electrically protective" has been deleted from the term.]

**3.31**
**overcurrent**
electric current exceeding the rated electric current

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]

**3.32**
**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.

**3.33**
**plug-socket combination**
component and suitable mating component, appropriate to terminate conductors, intended for connection or disconnection of two or more conductors

**3.34**
**power circuit**
circuit used for supplying power from the supply network to units of electrical equipment used for productive operation and to transformers supplying control circuits

**3.35**
**protective bonding circuit**
the whole of the protective conductors and conductive parts used for protection against electric shock in the event of an insulation failure

**3.36**
**protective conductor**
conductor providing a primary fault current path from the exposed conductive parts of the electrical equipment to a protective earthing (PE) terminal

Note 1 to entry: The equivalent term in IEC 61936-1 is “protective bonding conductor”.

**3.37**
**reference designation**
distinctive code which serves to identify an item in a diagram, list or chart, and on the equipment

**3.38**
**risk**
combination of the probability of occurrence of harm (i.e. physical injury or damage to health) and the severity of that harm

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

**3.39**
**safe working procedure**
method of working that reduces risk

**3.40**
**safeguard**
guard or protective device used as a means to protect persons from a present or impending hazard

**3.41**
**safeguarding**
safety measures consisting of the use of specific means called safeguards to protect persons from hazards that cannot reasonably be removed or are not sufficiently limited by design

**3.42**
**servicing level**
level on which persons normally stand when operating or maintaining the electrical equipment

**3.43**
**short-circuit current**
overcurrent resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

[SOURCE: IEC 60050-441:2000, 441-11-07]

**3.44**
**supplier**
entity that provides equipment or services associated with the machine

EXAMPLE Manufacturer, contractor, installer, integrator.

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

**3.45**
**switching device**
device designed to make 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 60050-441:2000, 441-14-01, modified – The note has been added.]

**3.46**
**terminal**
conductive part of a device provided for electrical connection to external circuits

**3.47**
**user**
entity who utilizes the machine and its associated electrical equipment

## 4 General requirements

### 4.1 General

This document focuses on high-voltage electrical equipment of machines.

The risks associated with the hazards relevant to the HV equipment shall be assessed as part of the risk assessment, for example in accordance with ISO 12100. This will:

– identify the need for risk reduction;
– determine adequate risk reductions; and
– determine the necessary protective measures for persons who can be exposed to those hazards, while still maintaining an appropriate performance of the machine and its equipment.

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

– failures or faults in the electrical equipment resulting in the possibility of electric shock, arc or fire;
– failures or faults in control circuits (or components and devices associated with those circuits) resulting in the malfunctioning of the machine;
– disturbances or disruptions in power sources as well as failures or faults in the power circuits resulting in the malfunctioning of the machine;
– loss of continuity of circuits that can result in a failure of a safety function, for example those that depend on sliding or rolling contacts;
– electrical disturbances, for example electromagnetic, electrostatic either from outside the electrical equipment or internally generated, resulting in the malfunctioning of the machine;
– release of stored energy (either electrical or mechanical) resulting in, for example, electric shock, unexpected movement that can cause injury;
– acoustic noise and mechanical vibration at levels that cause health problems to persons;
– surface temperatures that can cause injury.

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

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

It is recommended that, where the user is known, Annex B be used to facilitate an exchange of information between the user and the supplier(s) on basic conditions and additional user specifications related to the electrical equipment.

NOTE Those additional specifications can

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

### 4.2 Selection of electrical equipment

Electrical components and devices shall

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

Type-tested HV switchgear should be selected from those manufactured and tested in accordance with IEC 62271 (all parts).

HV Adjustable speed electrical power drive systems and their elements should be selected from those manufactured and tested in accordance with IEC 61800 (all parts).

### 4.3 Electrical power 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
– otherwise specified by the user (see Annex B), or
– specified by the supplier in the case of a special source of supply (see 4.3.3).

#### 4.3.2 Voltage characteristics

High-voltage equipment of machinery should be able to operate at supply conditions described by the requirements given by IEC TS 62749.

| | |
|---|---|
| Voltage | Steady-state voltage 0,9 to 1,1 of nominal voltage.<br><br>NOTE 1 In case of reduction of voltage below the nominal value, the performance of machine actuators can be affected. |
| Frequency | ±1 % of nominal frequency continuously;<br>±2 % short time. |
| Harmonics | The total harmonic distortion (THD) of the voltage should not exceed 8 % of the total RMS voltage between live conductors for the sum of the 2nd through 50th harmonic. |
| Voltage unbalance | Neither the voltage of the negative sequence component nor the voltage of the zero sequence component in three-phase supplies shall exceed 2 % of the positive sequence component. |

NOTE 2 DC voltage characteristics of electrical power supply are under consideration.

#### 4.3.3 On-board power supply

For special supply systems such as on-board generators, the limits given in 4.3.2 may be exceeded provided that the electrical equipment is designed to operate correctly with those conditions.

### 4.4 Physical environment and operating conditions

#### 4.4.1 General

The HV equipment shall be suitable for use in the physical environment and operating conditions specified in 4.4.2 to 4.4.8 of IEC 60204-1:2016. There may be additional influences and environmental conditions which are to be taken into account. When the physical environment or the operating conditions are outside those specified, an agreement may be needed between the supplier and the user (see Annex B to specify the minimum requirements).

#### 4.4.2 Electromagnetic compatibility (EMC)

High-voltage equipment of machinery shall not generate electromagnetic disturbances above levels that are appropriate for its intended operating environment. In addition, the HV 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 of IEC 60204-1:2016 if such instructions are not available.

For control systems of HV equipment the basic EMC rules of 9.6 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 apply. For electronic HV equipment (e.g. power converters, power drive systems) the EMC provisions of the relevant product standard apply.

### 4.5 Transportation and storage

Subclause 4.5 of IEC 60204-1:2016 is applicable.

### 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 by cranes or similar equipment (see also 14.5). Where appropriate, equipment shall be labelled to show the correct method of lifting and the maximum weight when fully equipped shall be indicated.

### 4.7 Installation

#### 4.7.1 General

High-voltage electrical equipment shall be installed in accordance with the requirements of Clause 8 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 and the supplier's instructions in order to:

– enable the safe access of personnel for operation and maintenance;
– facilitate fault clearing under safe working conditions.

Where lighting is installed for HV equipment, the relevant provisions of 7.2.6 and 15.2 of IEC 60204-1:2016 are applicable; refer to 18.2.

#### 4.7.2 Assembly and mounting

When the equipment is not fully assembled for transport, all transport units should be clearly marked. Detailed drawings showing assembly of these separated parts should be provided with the equipment included related wiring and provisions to maintain the integrity of the equipment in terms of safety.

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

### 5.1 Incoming high-voltage conductor terminations

All terminations for the incoming supply connection shall be clearly identified in accordance with IEC 60445.

### 5.2 Earthing terminal of high-voltage equipment

High-voltage equipment shall be provided with an earthing terminal for connection of an earthing conductor suitable for specified fault conditions.

The connecting point shall be marked with the "protective earth" symbol IEC 60417-5019:2006-08.

### 5.3 Supply disconnecting devices and means for earthing

#### 5.3.1 General

A supply disconnecting device shall be provided for

– each incoming source of supply to a machine;

  Exception: In the case of on-board generation (for example diesel generator) as the only source of supply, the disconnector is not necessary if the voltage can be reduced to, and maintained at, zero by other means;

– the source of supply to a feeder system using conductor wires, conductor bars, slip-ring assemblies, flexible cable systems (reeled, festooned), to a machine or a number of machines;

– each on-board power supply if there are more than one generator for the same supply (for example common busbar).

The supply disconnecting device shall isolate the high-voltage equipment of the machine from the supply when required (e.g. for work on the machine or its electrical equipment).

NOTE 1 Disconnectors are capable of opening and closing a circuit only at either negligible current (a current not exceeding 0,5 A) or if no significant change in the voltage across the terminals occurs. Therefore disconnecting devices always require associated switches or circuit-breakers for switching normal operating and fault currents; refer to Clause 7.

NOTE 2 HV disconnection implies physical separation (isolation).

When two or more supply disconnectors are provided, protective interlocks for their correct operation shall be used so that no hazardous condition or damage to personnel or the machine can occur.

For each incoming HV supply, means shall be provided to earth and short-circuit all live parts by connecting them to the earthing system (e.g. for work on the HV equipment).

#### 5.3.2 Type

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

a) a switch-disconnector;

  NOTE 1 A switch-disconnector often is combined with HRC fuses.

b) a disconnector with interlocking to ensure that it can only be operated if an associated switch or circuit-breaker interrupted the load circuit;

c) a plug and socket combination (see 3.33) for a flexible cable supply (e.g. reeled, festooned) to a mobile machine under the following conditions:

  – It shall not be possible to connect or disconnect a plug-socket combination during load conditions or when voltage is present. The effects of charging currents shall be taken into account.

  – The plug-socket combination shall be so connected that the part connected to the incoming power supply is that which is protected to at least IP 2XH or IP XXBH, when located inside an enclosed electrical operating area, or to at least IP 4XH or IP XXDH when located outside an enclosed electrical operating area.

  NOTE 2 High-voltage plug-socket combinations are designed according to EN 50181.

When used, disconnectors shall be designed and selected in accordance with IEC 62271-102.

### 5.3.3 Requirements for disconnectors

When the supply disconnector is one of the types specified in 5.3.2 a) or 5.3.2 b) it shall comply with IEC 62271-102.

For instance, the disconnector shall

– have an external handle for the disconnecting function (this can be the handle also used for operating the earthing device);
– have a reliable position indicator;
– disconnect all live conductors from the power supply circuit.

The OFF (disconnected) and one ON positions shall be clearly marked with "O" and "I" (see symbols IEC 60417-5008:2002-10 and IEC 60417-5007:2002-10).

If a switch-disconnector (specified in 5.3.2 a)) is used, it shall comply with IEC 62271-102 and IEC 62271-103 and its breaking capacity shall be sufficient to interrupt the current of the largest motor under blocked rotor condition together with the sum of the normal operating currents of all other motors and/or loads. The calculated breaking capacity may be reduced by the use of a proven diversity (simultaneity) factor.

NOTE For motors supplied by converter(s) or similar devices the maximum operating current of the converter is relevant.

Unintended opening of disconnectors shall be prevented. Depending on the risk assessment, remote controlled locking systems shall have appropriate safety integrity level (SIL) or performance level (PL); according to IEC 62061 or ISO 13849-1.

Where a switch-disconnector is combined with HV fuses, the combination shall comply with IEC 62271-105.

Where fused circuit-switchers are used the combination shall comply with IEC 62271-107.

Where an external operating means (e.g. handle) is provided it should be BLACK or GREY. Exception: If a switch-disconnector may be locally operated to serve the function of emergency stop, its actuator shall meet the colour requirements of 10.2.1 of IEC 60204-1:2016.

### 5.3.4 Requirements for earthing and short-circuiting

The means for earthing shall be capable of withstanding the prospective short-circuit current of the supply.

When used, an earthing switch shall comply with IEC 62271-102.

For instance, the earthing switch shall

– have a reliable position indicator;
– have an external handle for the earthing function (this can be the handle also used for operating the disconnecting device);
– earth and short-circuit all live conductors to the earthing system.

Mechanical locking in the ON position and the OFF position should be possible preferably by padlocks.

When an associated circuit-breaker is used for short-circuiting and for earthing and is locked in the closed (and earthed) position, unintended manual and/or opening by the short-circuit current itself shall be prevented. Depending on the risk assessment, remote controlled locking

systems shall have appropriate safety integrity level (SIL) or performance level (PL) according to IEC 62061 or ISO 13849-1.

### 5.3.5 Arrangement of disconnecting and earthing devices

It is recommended that the supply disconnecting device and the associated earthing switch are combined in a functional unit of prefabricated metal-enclosed switchgear complying with IEC 62271-200 or IEC 62271-201. If the earthing switch and disconnector are not assembled in a functional unit, interlocks shall ensure that

– the earthing switch can only be operated if the disconnecting device is in the open position, and
– the disconnecting device can only be operated if the earthing switch is in the open position.

The operating means of the supply disconnecting and earthing devices 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.

## 5.4 Devices for switching off for prevention of unexpected start-up

Devices for switching off for the prevention of unexpected start-up shall be provided (e.g. where, during maintenance, a start-up of the machine can create a hazard). Devices described in 5.3.2 may fulfil that function. Disconnectors, withdrawable fuse links or withdrawable links may also be used for that purpose, but only when located in a closed electrical operating area (see 3.13).

Such devices shall be appropriate and convenient for the intended use, shall be suitably placed, and readily identifiable (e.g. by a durable marking where necessary).

Means shall be provided to prevent inadvertent, and/or mistaken closing of the disconnector (see also 5.6).

Devices that do not fulfil the isolation function (for example a contactor switched off by a control circuit, or power drive system (PDS) with a safe torque off (STO) function in accordance with IEC 61800-5-2) may only be used for prevention of unexpected start-up during tasks such as:

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

The selection of a device will be dependent on the risk assessment, taking into account the intended use of the device, and the persons who are intended to operate them.

## 5.5 Devices for disconnecting and means for earthing HV equipment

Devices for disconnecting (isolating) and means for earthing HV equipment or part of it shall be provided to enable work to be carried out without a risk from electric shock or burn.

The supply disconnecting device together with a means for earthing the relevant circuit (see 5.3) may fulfil these functions. However, where it is necessary to work on individual HV part(s) of the electrical equipment of a machine, or on one of a number of machines fed by a common conductor bar or conductor wire system, a disconnecting device together with a means for

earthing shall be provided for each part, or for each machine, requiring separate isolation and earthing. Where HV capacitors are part of the electrical equipment, discharging means shall be provided.

Devices described in 5.3 may fulfil these functions. Other means of isolation such as disconnectors, withdrawable fuse links or withdrawable links, together with a means for earthing, may also be used for that purpose, but only when located in an enclosed electrical operating area.

Exception: If these means, for example a removable collector for crane-disconnection, are not located in an enclosed electrical operating area, they shall fulfil the following conditions:

– it shall not be possible to remove the disconnecting device during load conditions;
– it shall be so designed that the protective conductor circuit (earthing circuit) is interrupted only after the live conductors have been disconnected, and the continuity of the protective conductor circuit is re-established before any live conductor is reconnected;
– in open and in closed condition of the removable collector, the conductor bar has to be protected according to 13.8.1.

Such disconnecting devices and means for earthing shall be

– appropriate and convenient for the intended use;
– suitably located;
– readily identifiable as to which HV part or HV circuit(s) of the electrical equipment is served (e.g. by durable marking where necessary);
– provided with adequate means to prevent unauthorized, inadvertent, and/or mistaken closure of the disconnecting devices and opening of the means for earthing. Exception: see 5.6.

Electrical equipment such as HV transformers or HV capacitors shall be provided with additional means of earthing and short-circuiting, except where it is located in the immediate vicinity of the associated switchgear.

NOTE Where the HV equipment (for example the main circuit-breaker) is part of the distribution switchgear, 8.3 of IEC 61936-1:2010 can apply.

### 5.6 Protection against unauthorized, inadvertent and/or mistaken operation

The devices for disconnecting (isolating) and means for earthing described in 5.4 and 5.5 that are capable of being equipped with means to lock them in the OFF position or disconnected state or earthed condition (e.g. by padlocks) in order to achieve protection against unauthorized, inadvertent, and/or mistaken operation shall be equipped with such means. Other means of protection against such operation (e.g. warning labels) may be used where the non-lockable means are located in an enclosed electrical operating area.

However, when a device according to 5.3.2 c) (e.g. plug-socket combination) and/or a means for earthing is so positioned that it can be under the immediate supervision of the person carrying out the work, means for locking need not be provided.

## 6 Protection against electric shock

### 6.1 General

The HV electrical equipment shall provide protection of persons against electric shock by

– basic protection against direct contact (6.2);
– fault protection against indirect contact (6.3).

The measures for this protection given in 6.2 and 6.3, are a recommended selection from IEC 61936-1 (regarding high-voltage) and from IEC 60364-4-41 (regarding low-voltage).

### 6.2 Protection against direct contact

Basic protection against direct contact with live parts, parts with insulation for functional purposes only and with parts which can be considered to have a hazardous potential (for examples of such parts see 8.2 of IEC 61936-1:2010) shall be provided as follows:

a) installations outside enclosed electrical operating areas

   Protection against direct contact shall be provided by enclosures with a minimum degree of protection of IP 4X or IP XXDH, according to IEC 60529.

b) installations inside enclosed electrical operating areas

   Protection against direct contact shall be provided by enclosures or doors or mesh-grids or barriers to a minimum degree of protection of IP 1X or IP XXAH, according to IEC 60529. Dimensions of doors, mesh-grids and barriers and clearances to live parts shall be in accordance with 7.3 of IEC 61936-1:2010.

Access to HV parts of the electrical equipment shall only be possible by the use of a key or tool.

Where these measures are not practicable, other measures for protection against direct contact (e.g. by placing out of reach, using obstacles) as specified in 8.2 of IEC 61936-1:2010 may be applied.

NOTE For protective measures for conductor wires, conductor bars and slip-ring assemblies, see 13.8.1.

### 6.3 Protection against indirect contact

#### 6.3.1 General

Fault protection against indirect contact is intended to prevent hazardous situations due to an insulation fault between live parts and exposed conductive parts.

For each HV circuit or HV part of the electrical equipment, protection against indirect contact can be achieved by automatic disconnection of the supply preventing the occurrence of a touch voltage which exceeds the tolerable limited time of fault duration.

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

These measures necessitate coordination between

– the type of power system (e.g. neutral earthing) and exposed conductive parts to earth,
– the impedance values of the different elements of the protective bonding circuit, and
– the characteristics of the devices used to detect insulation failure.

#### 6.3.2 Measures to prevent the occurrence of a hazardous touch voltage for an unlimited time of fault duration

Measures to prevent the occurrence of a hazardous touch voltage for an unlimited time of fault duration include the following:

– selection or design of the supply system and neutral earthing in accordance with 4.2 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014, and
– design of the earthing system in accordance with Clause 10 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

It is recommended that a supply system is used whose neutral point is isolated from earth or is high impedance earthed. An earth fault detection device should be provided to initiate an alarm when an earth fault is detected.

NOTE Supply systems isolated from earth include systems without a neutral point such as single-phase systems, delta connected systems and DC systems.

### 6.3.3 Protection by automatic disconnection of supply within a limited time of fault duration

Automatic disconnection of the supply of any circuit affected by the occurrence of an insulation failure within a limited time is intended to prevent a hazardous condition resulting from a touch voltage higher than the tolerable touch voltage for an unlimited time of fault duration.

This protective measure comprises both

– the connection of exposed-conductive-parts to the protective bonding circuit (see Clause 8), and
– either
  a) the use of devices for the automatic disconnection of the supply in the event of an insulation failure in a supply system with low-impedance neutral earthing or direct neutral earthing, or
  b) the use of earth fault detection to initiate automatic disconnection of a supply system isolated from earth or with high impedance earthed neutral point.

The selection/setting of the device(s) shall be such as to ensure that automatic disconnection of the supply takes place before the touch voltage, arising from an insulation failure, becomes hazardous.

NOTE For hazardous touch voltages, see Clause 10 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

### 6.3.4 Protection for mobile machines

The measures described in 6.3.2 and 6.3.3 shall be selected by taking the following into consideration:

– system voltage;
– length of supply cable;
– number of machines connected to the point of supply;

over which there may be little influence, and

– type of supply cable;
– type of neutral earthing;
– value of earth-fault current in a supply system with low impedance neutral earthing.

General limitations depending upon the type of supply system are given below:

– direct neutral earthing is generally only appropriate for system voltages less than 2 kV. Automatic disconnection is always required;
– low impedance neutral earthing may be appropriate for system voltages up to 36 kV and a cable length up to 4 km. Automatic disconnection is normally necessary;
– isolated neutral point or high impedance neutral point earthing is appropriate for system voltages up to 36 kV and a cable length up to 8 km (this length depends upon the capacitive reactance of all cables connected to the supply). Automatic disconnection is normally not necessary.

# 7 Protection of HV equipment

## 7.1 General

Clause 7 details the measures to be taken to protect HV parts of the electrical equipment against the effects of

– overcurrent;
– overheating of motors;
– abnormal temperature;
– overvoltage due to lightning and switching surges;
– other abnormal conditions;
– loss of or reduction in the supply voltage;
– overspeed of machines/machine elements;
– earth fault;
– incorrect phase sequence;
– overvoltage;
– arc faults.

## 7.2 Overcurrent protection

### 7.2.1 General

Overcurrent protection shall be provided where the current in a machine 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 used are detailed in 7.2.6.

### 7.2.2 Supply conductors

Unless otherwise specified by the user, the supplier of the HV equipment shall not be responsible for providing the overcurrent protective device for the supply conductors to the HV equipment.

The supplier of the HV equipment shall state on the installation diagram the data necessary for selecting the overcurrent protective device (see 7.2.6, and Annex B, question 15).

### 7.2.3 Power circuits

Devices for detection and interruption of overcurrent, selected in accordance with 7.2.6, shall be applied to each live conductor.

### 7.2.4 Transformers

Transformers shall be protected against overcurrent in accordance with IEC 60076-5. Such protection shall (see also 7.2.6)

– 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.

For the provision of protection against other abnormal conditions, see 7.10.

### 7.2.5 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 (e.g. from motors, from power factor correction capacitors), those currents shall be taken into consideration.

Overcurrent protective devices for power circuits include fuses and circuit-breakers.

### 7.2.6 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 (e.g. during starting of motors or energizing of transformers). When selecting those protective devices, consideration should be given to the protection of switching devices against damage due to overcurrents (e.g. welding of the switching device contacts).

The rated current or setting of an overcurrent protective device is determined by the current carrying capacity of the conductors to be protected by that device in accordance with 13.4. That should take into account the needs of coordination with other electrical devices in the protected circuit. The recommendations of the supplier of those devices should be followed.

## 7.3 Protection of motors against overheating

Protection of motors against overheating shall be provided for each HV motor.

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

## 7.4 Protection against abnormal temperature

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

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

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

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

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

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

## 7.6 Motor overspeed protection

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

### 7.7 Earth fault protection

Earth fault protection shall be provided as described below when the earth-fault current can be lower than the setting of the overcurrent protective devices and unacceptable damage to the electrical equipment can occur.

An earth fault monitoring system that is appropriate to the type of HV supply system in use (e.g. system isolated from earth, earthed system) shall be provided. The electrical equipment or the appropriate section of the electrical equipment shall be switched off if the earth fault exceeds a given current/time value.

The setting of the earth fault protective devices shall be as low as possible and consistent with proper operation of the electrical equipment.

Unless otherwise specified by the user, the supplier of the HV equipment is not responsible for providing the earth fault protective device for the HV supply conductors. The supplier of the HV equipment shall state on the installation diagram the data necessary for selecting the earth fault protective device (see 7.2.6 and, Annex B, question 15).

### 7.8 Protection against overvoltage due to lightning and switching surges

Equipment shall be protected against overvoltage resulting from switching operations or lightning that could exceed the withstand values. Since different protection methods are available, depending on the level of protection to be achieved and the reliability level required, the method to be used shall be agreed upon between the manufacturer and user; refer to Annex B.

For lightning protection refer to IEC 62305 (all parts).

### 7.9 Protection against hazards due to arc faults

The high-voltage part of the electrical installation shall be designed and installed so that persons are protected against arc faults during normal operation as described by 8.5 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014. The degree of importance of the measures indicated in IEC 61936-1 shall be agreed upon between the supplier and user (for example, the IAC classification, according to IEC 62271-200).

### 7.10 Protection against overpressure and leakage

Protection against overpressure and/or leakage of liquid-filled high-voltage equipment such as transformers, reactors and switchgear shall be provided as applicable in accordance with 8.8 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

Where liquid-immersed equipment is used (e.g. oil insulated transformers), measures shall be taken to prevent environmental damage in the event of leakage.

### 7.11 Protection against fire

Protection against fire shall be provided in accordance with 8.7 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 to prevent the occurrence of a hazardous situation.

## 8 Equipotential bonding

### 8.1 General

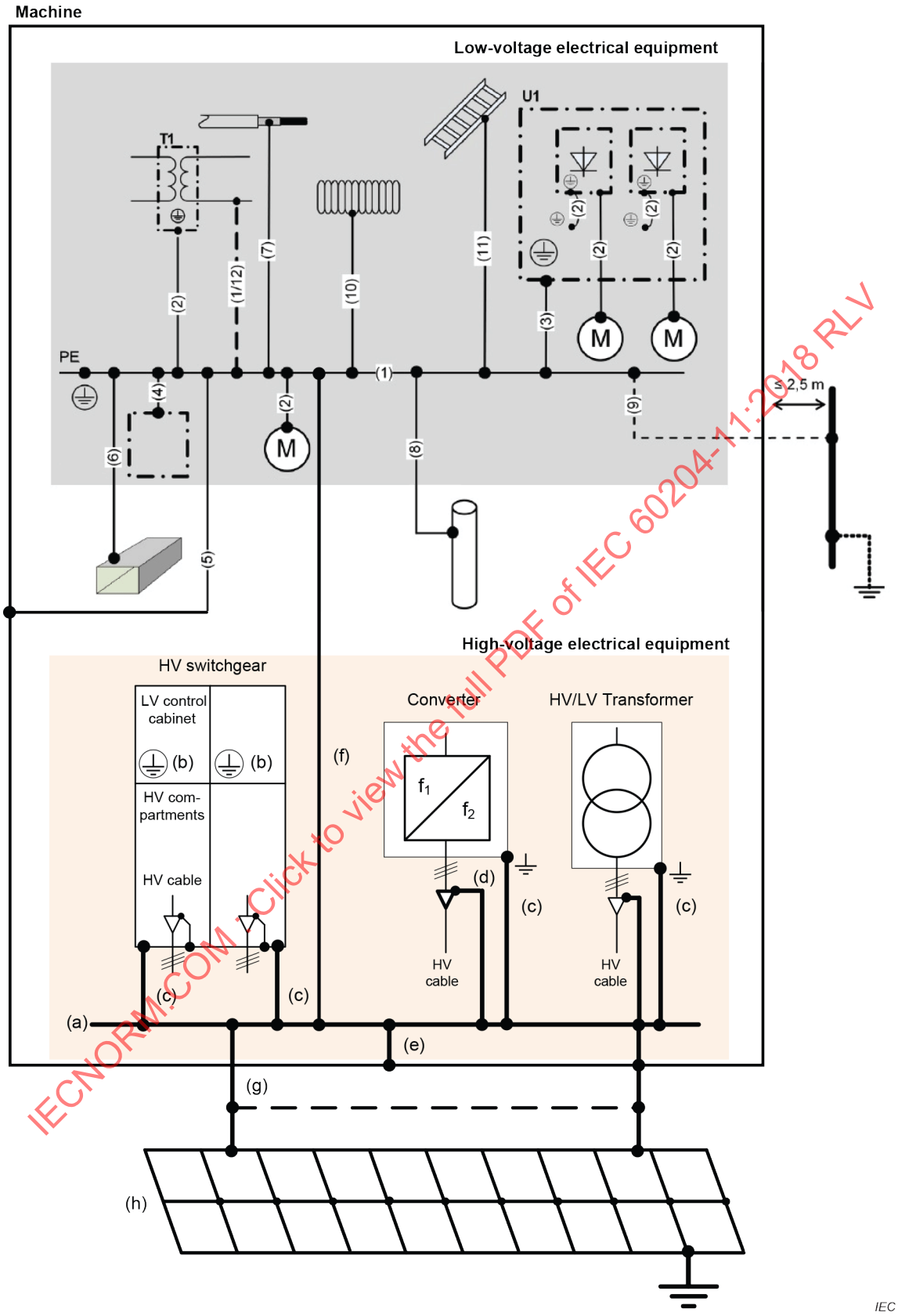
Clause 8 gives requirements for the protective (equipotential) bonding of

– the exposed-conductive-parts of the electrical equipment,

– the extraneous-conductive-parts of the machine, and

– the earthing system,

and for supplementary protective bonding (see 8.2.6) as required, in order to ensure fault protection (against indirect contact). Figure 2 illustrates these concepts.



**Key**

**Protective bonding circuit:**

(1) Interconnection of protective conductor(s) and the PE terminal

(2) Connection of exposed conductive parts

(3) Protective conductor connected to an electrical equipment mounting plate used as a protective conductor

(4) Connection of conductive structural parts of the electrical equipment

(5) Conductive structural parts of the machine

**Parts connected to the protective bonding circuit, which are not to be used as protective conductor:**

(6) Metal ducts of flexible or rigid construction

(7) Metallic cable sheaths or armouring

(8) Metallic pipes containing flammable materials

(9) Extraneous conductive parts, if earthed independently from the power supply of the machine and liable to introduce a potential, generally the earth potential, e.g.: metallic pipes, fences, ladders, handrails

(10) Flexible or pliable metal conduits

(11) Protective bonding of support wires, cable tray and cable ladders

**Connections to the protective bonding circuit for functional reasons:**

(12) Functional bonding

**Reference designations:**

T1 Auxiliary transformer

U1 Mounting plate of electrical equipment

**High-voltage equipment**

(a) Equipotential bonding of the high-voltage installation

(b) Protective earthing of low-voltage control equipment

(c) Earthing connection of high-voltage equipment

(d) HV cable screen bonding

(e) Connection to conductive structural parts of the machine

(f) Interconnection to low-voltage earthing system

(g) Machine bonding conductor

(h) Earthing system of installation (building)

NOTE The out-of-reach distance of 2,5 m refers to IEC 60364-4-41.

**Figure 2 – Example of equipotential bonding for electrical equipment of a machine**



## 8.2 Protective bonding circuit

### 8.2.1 General

The protective bonding circuit consists of (see Figure 2)

– the machine bonding conductor(s);

– the protective conductors of the electrical equipment of the machine, including sliding contacts where they are part of the circuit; and

– the protective bonding conductors connected to the structural parts of the electrical equipment and to the structural parts of the machine (equipotential bonding on the machine).

On mobile machines with on-board power supplies, the protective bonding circuits, the exposed-conductive-parts, and the extraneous-conductive-parts shall all be connected to a protective bonding terminal to provide protection against electric shock. When a mobile

machine is also capable of being connected to an external incoming supply, the protective bonding terminal shall be the connection point for the external protective conductor.

NOTE 1 When the supply of electrical energy is self-contained within stationary, mobile, or movable items of machinery, and when there is no external supply connected (e.g. when an on-board battery charger is not connected), there is no need to connect such electrical equipment to an external protective conductor.

All parts of the interconnected protective bonding circuits for the HV equipment and the LV equipment shall be so designed that they are capable of withstanding the highest thermal and mechanical stresses that can be caused by single or double earth-fault currents that could flow in any part of the protective bonding circuits.

NOTE 2 Details on how to fulfil this requirement are given in 10.2.3 of IEC 61936-1:2010 or in 6.1.1 of EN 50522:2010.

The structural parts of the machine shall be individually connected to the protective bonding circuit.

Any structural part of the electrical equipment or of the machine may be used as part of the protective bonding circuit provided that it satisfies the requirements of IEC 60364-5-54.

NOTE 3 As guidance for the design of earthing or bonding conductors, the current density in the conductor, if of copper, does not exceed 200 A/mm$^2$ for a rated duration of short circuit of 1 s, and 125 A/mm$^2$ for a rated duration of short circuit of 3 s. A method of calculating cross-sectional areas of conductors is given in IEC 60724.

### 8.2.2 Protective conductors

Protective conductors shall be identified in accordance with 14.2.

Copper conductors are preferred. Where a conductor material other than copper is used, its electrical resistance per unit length shall not exceed that of the allowable copper conductor and such conductors shall be not less than 16 mm$^2$ in cross-sectional area for reasons of mechanical durability.

Due to mechanical strength and stability against corrosion, minimum cross-sections of protective conductors are:

– copper: 16 mm$^2$
– aluminium: 35 mm$^2$
– steel: 50 mm$^2$

NOTE Where the connection to an external installation earthing system using such a value is not sufficient to provide protection against indirect contact, the calculation of cross-sectional area of the bare conductor according to Annex D of EN 50522:2010 applies.

### 8.2.3 Continuity of the protective bonding circuit

All exposed-conductive-parts of the electrical equipment and the machine(s) shall be connected to the protective bonding circuit. Where a part is removed for any reason (e.g. routine maintenance), the protective bonding circuit for the remaining parts shall not be interrupted.

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

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

Doors, lids or cover plates on which devices (e.g. operator interface devices) are mounted shall be connected to the protective bonding circuit by a protective conductor.

For machines, for example mobile machines, where the connection to the earthing system (machine bonding conductor) is provided solely by flexible cables, the continuity of the protective conductor shall be ensured by appropriate design of the cable (see 13.7). Where there is a possibility that the cable and hence the machine bonding conductor could become damaged (e.g. a trailing cable dragged on the ground), the continuity of the protective bonding circuit shall be monitored (see question 13 in Annex B). The HV supply to the electrical equipment of the machine or to the relevant part of the machine shall be switched off

– when loss of continuity of the protective bonding circuit is detected, or
– when failure of the monitoring means occurs.

For requirements for the continuity of the protective bonding circuit using conductor wires, conductor bars and slip-ring assemblies, see 13.8.2.

The protective bonding circuit shall not incorporate a switching device, an overcurrent protective device (e.g. switch, fuse) so that continuity of the earthing path is not interruptible and any metallic parts that may be touched during normal operation remain connected to the equipotential bonding and earthing system.

Exception: links that can only be opened with the use of tools (e.g. for measuring and testing purposes) and that are located in an enclosed electrical operating area may be provided for test or measurement purposes.

### 8.2.4 Mobile machines

Where the continuity of the protective bonding circuit can be interrupted by means of removable current collectors or plug-socket combinations, the protective bonding circuit shall not be interrupted before the live conductors have been disconnected, and shall be re-established before any live conductor is reconnected. This also applies to removable or withdrawable plug-in units (see also 14.4).

Metallic housings of plug-socket combinations shall be connected to the protective bonding circuit.

### 8.2.5 Protective bonding circuit connecting points

All protective conductors shall be terminated in accordance with 14.1.1. The protective conductor connecting points shall have no other function and shall not be used, for example, to mechanically attach or connect components or parts.

Each connecting point for

– protective conductors inside the electrical equipment of the machine,
– the protective bonding conductors on the machine (see Figure 2),
– the machine bonding conductor(s) (see Figure 2),

shall be identified as such using the symbol IEC 60417-5019:2006-08 (see Figure 3).

**Figure 3 – Symbol for protective earth (protective ground)**

### 8.2.6 Supplementary protective bonding conductors

Supplementary protective bonding conductors shall be used to connect the protective bonding circuit of the machine to the structural metalwork of the building when such metalwork is in close proximity (e.g. less than 2,5 m) to the machine. These conductors shall conform to Cause 544 of IEC 60364-5-54:2011 as appropriate. The cross-sectional area of a supplementary protective bonding conductor shall be not less than half the cross-sectional area of the associated machine bonding conductor and shall be not less than that specified in 8.2.2.

## 9 Control systems, control circuits and control functions

For control, protection and auxiliary systems of HV equipment the relevant subclauses of Clause 9 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 apply. Control, protection and auxiliary devices shall ensure the correct and safe functioning of the HV equipment; and provide protection against the effects of unacceptable overload and any internal and external fault conditions.

Facilities shall be provided for isolating the control circuits in order to allow maintenance of high-voltage equipment to be performed safely. Provisions shall be made to allow for repair, maintenance, and/or testing to be carried out on control, protection and auxiliary devices without any danger to personnel or the equipment. Alarm and fault-indicating equipment shall clearly indicate danger and fault conditions.

For the control circuits the requirements of Clause 9 of IEC 60204-1:2016 apply except where the LV control circuits are covered by other standards. Control circuits directly connected to high-voltage circuits (e.g. thyristor gate circuits) shall be electrically separated from low-voltage circuits by the use of an interface technique such as optical coupling or transformer coupling.

Cableless control systems used in electrical equipment shall comply with IEC 62745.

## 10 Operator interface and machine-mounted control devices

The requirements of Clause 10 of IEC 60204-1:2016 apply, but the minimum degree of protection against direct contact shall be IP 4X or IP XXDH for operator interface and machine-mounted control devices (see also 6.2 for protection against direct contact).

## 11 Electronic equipment

HV electronic equipment, for example converters, power drive systems, shall comply with their relevant standards, for example, IEC 61800 (all parts) for power drive systems.

For static converters refer also to 6.2.14 of IEC 61936-1:2010. Where no specific standards for electronic power equipment exists, EN 50178 provides basic requirements.

## 12 Controlgear: location, mounting, and enclosures

### 12.1 General requirements

All controlgear shall be located and mounted so as to facilitate

– its accessibility and maintenance;

– its protection against the external influences or conditions under which it is intended to operate;

– operation and maintenance of the machine and its associated electrical equipment.

### 12.2 Location and mounting

#### 12.2.1 Accessibility and maintenance

All items of controlgear shall be so placed and oriented that they can be identified without moving them or the wiring. For items that require checking for correct operation or that are liable to need replacement, these actions should be possible without dismantling other electrical equipment or parts of the machine (except opening doors or removing covers). Terminals not associated with controlgear shall also conform to these requirements.

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

Only those devices necessary for operator interface purposes (for example operation, indication, measurement) and for cooling may be mounted on doors and on normally removable access covers of enclosures.

Where control devices are connected through plug-in arrangements, their association shall be made clear by type (shape), marking or reference designation, singly or in combination (see 13.4.5 of IEC 60204-1:2016).

Test points, where provided, shall be

– mounted so as to provide unobstructed access;
– clearly marked to correspond with the documentation (see 17.2 of IEC 60204-1:2016);
– adequately insulated;
– sufficiently spaced for connection of the test equipment or means.

#### 12.2.2 Physical separation

Enclosures containing HV equipment shall not contain LV equipment and non-electrical parts except where they form an integral part of the HV equipment and are essential for its correct operation.

HV switchgear adjacent to LV equipment shall be:

– metal-enclosed and designed to withstand an internal arc-fault according to 7.9, and distinguishable from LV equipment by clear marking or
– segregated by earthed metallic partitions (tubes, walls) or by insulating partitions of protection category PB according to IEC 62271-201.

When arranging the location of devices (including interconnections), the clearances and creepage distances specified for them shall be maintained, taking into account the external influences or conditions of the physical environment (see IEC 61936-1).

### 12.3 Degrees of protection

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

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

Enclosures of controlgear shall provide a degree of protection of at least IP 22 (see IEC 60529).

Exception: Where an electrical operating area is used as a protective enclosure for an appropriate degree of protection against the ingress of solid bodies and liquids.

NOTE 2 Other degrees of protection can be needed for protection against electric shock, see Clause 6.

### 12.4 Enclosures, doors and openings

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

Fasteners used to secure doors and covers should be of the captive type. Inspection windows shall be of a material suitable to withstand chemical attack and mechanical stress comparable to that of the enclosure. Precautions shall be taken to prevent the formation of a static charge on the windows, which may lead to a hazardous situation, either by adequate clearances or electrostatic shielding, for example wire mesh placed on the inside of the window and bonded to the enclosure.

It is recommended that enclosure doors should have vertical hinges, preferably of the lift-off type, with an angle of opening of at least 95°.

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

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

All openings in the enclosure, including those towards the floor or foundation or to other parts of the machine, shall be closed by the supplier(s) in a manner ensuring the degree of protection specified for the electrical equipment. Openings for cable entries shall be easily reopened on site. A suitable opening may be provided in the base of enclosures within the machine so that moisture due to condensation may drain away.

There shall be no opening between enclosures containing electrical equipment and compartments containing coolant, lubricating or hydraulic fluids, or those into which oil, other liquids, or dust can penetrate. This requirement does not apply to electrical devices specifically designed to operate in oil (e.g. electromagnetic clutches) or to electrical equipment in which coolants are used.

Where there are holes in an enclosure for mounting purposes, care shall be taken so that after mounting, the holes do not impair the required protection.

Electrical equipment that, in normal or abnormal operation, can attain a high surface temperature

– shall be located within an enclosure that will withstand such temperatures as may be generated, and
– shall be mounted and located at a sufficient distance from adjacent equipment so as to allow safe dissipation of heat (see 11.2.3 of IEC 60204-1:2016), or shall be otherwise screened by material that can withstand the heat emitted by the electrical equipment.

Accessible parts expected to be touched in normal operation shall not exceed 70 °C.

### 12.5 Access to HV equipment

Access to maintenance and operating areas of HV equipment shall be in accordance with the relevant subclauses of 7.5 of IEC 61936-1:2010.

## 13 Conductors and cables

### 13.1 General requirements

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

In supply systems with direct or low impedance earthing of the neutral, all types of cable may be used if an earth fault is interrupted within 1 s.

NOTE 1 s is a standard value; other short-circuit durations are possible; refer to 4.2.4 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

In supply systems with the neutral point isolated or resonantly earthed, all types of radial field cable may be used when the estimated duration of any earth fault does not exceed 8 h. Where the estimated duration of any earth fault exceeds 8 h, a radial field cable of the next higher voltage rating shall be used (see Annex C). The recommendations of the cable supplier should be followed.

These requirements do not apply to the integral wiring of assemblies, which are manufactured and tested in accordance with relevant standards.

### 13.2 Conductors

In general, conductors should be of copper. Conductors of another material shall have a nominal cross-sectional area such that, when carrying the same current, the maximum conductor temperature shall not exceed the value given in Table 1.

**Table 1 – Maximum allowable conductor temperatures under normal and short-circuit conditions**

| Type of insulation | Maximum temperature under normal conditions<br>°C | Ultimate short-time temperature under short-circuit conditions[a]<br>°C |
|---|---|---|
| Polyvinyl chloride (PVC) | 70 | 160<br>(< 300 mm$^2$) |
| Cross-linked polyethylene (XLPE) | 90 | 250 |
| Ethylene-propylene compound (EPR/HEPR) | 80 to 90[b] | 250[b] |
| For ultimate short-time conductor temperatures greater than 200 °C, copper conductors shall be either silver-plated or nickel-plated because neither tinned nor bare conductors are suitable above 200 °C. | | |
| [a] These values are based on the assumption of adiabatic behaviour for a period of not more than 5 s.<br>[b] Consultation with the cable manufacturer is required. | | |

To withstand the electrodynamic and thermal effects of short-circuit currents, the dimensions of conductors shall be calculated according to IEC 60865-1.

### 13.3 Insulation and sheath materials

The types of insulation and sheath materials include (but are not limited to)

– polyvinyl chloride (PVC);
– cross-linked polyethylene (XLPE);
– ethylene propylene compound (EPR/HEPR).

Where the material of the insulation or the sheath of a cable (e.g. PVC) can constitute hazards due to the propagation of a fire or the emission of toxic or corrosive fumes, guidance should be sought from the cable supplier.

The mechanical strength and thickness of the materials shall be so selected that the insulation and the sheath cannot be damaged in operation or during laying, especially for cables pulled into ducts.

Where applicable, the requirements of 6.2.9 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 apply.

### 13.4 Current-carrying capacity in normal service

The current-carrying capacity of conductors and cables is determined by both

– the maximum allowable conductor temperature under the highest possible steady-state current or the thermal equivalent RMS current for intermittent duty applications, and
– the ultimate allowable short-time conductor temperature under short-circuit conditions.

The cross-sectional area of a conductor shall be such that, under these conditions, the conductor temperature does not exceed the value given in Table 1, unless otherwise specified by the cable supplier.

The cable supplier shall be consulted for details of the current carrying capacities of cables for all continuous duty and intermittent duty applications.

### 13.5 Conductor and cable voltage drop

The voltage drop from the point of supply to the load shall be such that the correct operation of the electrical equipment is not affected by undervoltage. However, the overvoltage during no-load operation shall not damage the electrical equipment.

### 13.6 Minimum cross-sectional area

The cross-sectional area of the conductors shall be selected according to 13.1 and 8.2.2.

### 13.7 Flexible cables

#### 13.7.1 General

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

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

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

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

Each flexible cable for the HV power supply for the electrical equipment of a mobile machine shall contain a protective conductor; see also 8.2.3. The cross-sectional area of the protective conductor shall be determined in accordance with Clause 8. If the cross-sectional area is at least 25 $mm^2$, the protective conductor may be divided into several conductors of equal cross-sectional areas within the flexible cable.

### 13.7.2 Mechanical rating

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

The allowed maximum stress of conductors of flexible cables with material other than copper should be agreed with the cable manufacturer.

### 13.7.3 Current-carrying capacity of cables wound on drums

Cables to be wound on drums shall be selected with conductors of such cross-sectional area that, when fully wound on the drum and carrying the normal service load, the maximum allowable conductor temperature is not exceeded.

For cables of circular cross-sectional area installed on drums, the maximum current-carrying capacity in free air should be de-rated in accordance with Table 2.

NOTE The current-carrying capacity of cables in free air can be found in manufacturers' specifications or in relevant national standards.

**Table 2 – De-rating factors for cables wound on drums**

| Drum type | Number of layers of cable | | | | |
|---|---|---|---|---|---|
| | Any number | 1 | 2 | 3 | 4 |
| Cylindrical ventilated | - | 0,85 | 0,65 | 0,45 | 0,35 |
| Radial ventilated | 0,85 | - | - | - | - |
| Radial non-ventilated | 0,75 | - | - | - | - |
| The use of de-rating factors should be discussed with the cable and the cable drum manufacturers. This may result in other factors being used.<br><br>NOTE 1 A radial type drum is one where spiral layers of cable are accommodated between closely spaced flanges; if fitted with solid flanges, the drum is described as non-ventilated and if the flanges have suitable apertures, as ventilated.<br><br>NOTE 2 A ventilated cylinder drum is one where the layers of cable are accommodated between widely spaced flanges and the drum and end flanges have ventilating apertures. | | | | | |



## 13.8 Conductor wires, conductor bars and slip-ring assemblies

### 13.8.1 Protection against direct contact

Conductor wires, conductor bars and slip-ring assemblies shall be so installed or enclosed that, during normal access to the machine, protection against direct contact shall be achieved by the application of one or a combination of the following protective measures:

– protection by enclosures or barriers of at least IP 4X or IP XXDH according to IEC 60529;

– protection by placing out of reach (see 8.2.1 of IEC 61936-1:2010).

Where protection is achieved by placing live parts out of reach, emergency switching off in accordance with 9.2.3.4.3 of IEC 60204-1:2016 shall be applied.

Conductor wires and conductor bars shall be so placed and/or protected as to

– prevent contact, especially for unprotected conductor wires and conductor bars, with conductive items such as the cords of pull-cord switches, strain-relief devices and drive chains;

– prevent damage from a swinging load.

### 13.8.2 Protective bonding circuit

Where conductor wires, conductor bars and slip-ring assemblies are installed as part of the protective bonding circuit, they shall not carry current in normal operation.

The continuity of the parts of the protective bonding circuit using sliding contacts shall be ensured by taking appropriate measures (e.g. by duplication of the current collector, continuity monitoring).

### 13.8.3 Protective conductor current collectors

Protective conductor current collectors shall have a shape or construction such that they are not interchangeable with the other current collectors. Such current collectors shall be of the sliding contact type.

### 13.8.4 Clearances in air

Clearances between the respective conductors, and between adjacent systems of conductor wires, conductor bars, slip-ring assemblies and their current collectors shall be suitable for the standard insulation levels shown in Table 1 of IEC 61936-1:2010. The clearances shall correspond to the following values assigned to a highest voltage for equipment:

– rated short-duration power-frequency withstand voltage;

– rated lightning impulse withstand voltage. Select the lowest value (formerly “list 1”) where the table lists several lightning impulse withstand voltages.

### 13.8.5 Creepage distances

The manufacturer's recommendations shall be followed regarding special measures to prevent a gradual reduction in the insulation values due to unfavourable ambient conditions (e.g. deposits of conductive dust, chemical attack). For this purpose one of the following pollution levels, listed in Table 3, shall be selected:

Pollution level 0: Pollution inside a fully encapsulated compartment or enclosure, which shall comply with a degree of protection of minimum IP 54; i.e. no contamination can occur. Pollution, for example caused by the wear of sliding contacts, shall be cleaned in the cycles established by the manufacturer. If condensation can occur with these systems, measures shall be taken against moisture.

Pollution levels 1 to 4: refer to definition in Table 1 of IEC 60071-2:1996.

Completely enclosed slip ring assemblies should meet at least the requirements for pollution level 0 in accordance with Table 4.

**Table 3 – Selection of the pollution level depending on the degree of protection and insulator material**

| Insulator type | Degree of protection for conductor wires, conductor bars and slip-ring assemblies | | | |
|---|---|---|---|---|
| | Indoor/Outdoor IP 54 or higher | Indoor/Outdoor IP 10 to IP53 | Indoor IP 00 | Outdoor IP 00 |
| glass or ceramic indoor/outdoor | pollution level 0 to 4 | pollution level 1 to 4 | pollution level 1 to 4 | pollution level 1 to 4 |
| polymer material designed for outdoor use | pollution level 0 to 4 | pollution level 1 to 4 | pollution level 1 to 4 | pollution level 1 to 4 |
| polymer material designed for indoor use | pollution level 0 to 4[a] | pollution level 0 to 3 shall be increased by one level (not permissible for pollution level 4) | pollution level 1 to 4 | not permissible |
| [a] For example, a slip ring of a cable drum protected IP 54 mounted outside a crane. | | | | |

Creepage distances for pollution level 0 shall be not less than the values given in Table 4 unless the insulator is designed according to IEC 60273 and tested according to IEC 60660.

**Table 4 – Minimum creepage distance of conductor lines and slip ring assemblies**

| Nominal voltage of supply $U_n$ (RMS) | Highest voltage for equipment $U_m$ (RMS) | Minimum creepage distance for pollution level | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | | 1 | | 2 | | 3 | | 4 | |
| kV | kV | mm | | mm | | mm | | mm | | mm | |
| | | L-L | L-E | L-L | L-E | L-L | L-E | L-L | L-E | L-L | L-E |
| 3 | 3,6 | 60 | 60 | 100* | 60* | 125 | 73* | 156 | 91* | 193 | 112* |
| 6 | 7,2 | 87 | 60 | 200 | 116* | 249 | 144 | 312 | 181 | 387 | 224 |
| 10 | 12 | 144 | 90 | 333 | 193 | 416 | 241 | 520 | 301 | 644 | 372 |
| 15 | 17,5 | 210 | 122 | 485 | 281 | 606 | 350 | 758 | 438 | 940 | 543 |
| 20 | 24 | 288 | 167 | 665 | 384 | 831 | 480 | 1 039 | 600 | 1 289 | 745 |
| 30 | 36 | 432 | 250 | 998 | 577 | 1 247 | 720 | 1 559 | 901 | 1 933 | 1 117 |
| 36 | 41,5 | 498 | 288 | 1 150 | 664 | 1 438 | 831 | 1 797 | 1 038 | 2 228 | 1 287 |
| Creepage distances of pollution levels 1 to 4 are used for indoor and outdoor applications. Values marked with "*" are for indoor use only and have to be increased to 120 mm in case of outdoor use.<br>NOTE Columns "L-L" means line-line values (between phases), "L-E" means values for line-earth. . | | | | | | | | | | | |



### 13.8.6 Conductor system sectioning

Where conductor wires or conductor bars are arranged so that they can be divided into isolated sections, suitable design measures shall be employed to prevent the energization of adjacent sections by the current collectors themselves.

### 13.8.7 Construction and installation of conductor wire, conductor bar systems and slip-ring assemblies

Conductor wires, conductor bars and slip-ring assemblies used for HV power circuits shall be grouped separately from those used for LV circuits.

Conductor wires, conductor bars and slip-ring assemblies shall be capable of withstanding, without damage, the mechanical forces and thermal effects of short-circuit currents.

Removable covers for conductor wire and conductor bar systems laid underground or underfloor shall be so designed that they cannot be opened without the aid of a tool.

Where conductor bars are installed in a common metal enclosure, the individual sections of the enclosure shall be bonded together and earthed at several points depending upon their length. Metal covers of conductor bars laid underground or underfloor shall also be bonded together and earthed.

NOTE For equipotential bonding or protective conductor connection to covers or cover plates of metal enclosures or underfloor ducts, the usual metal hinges are considered sufficient to ensure continuity.

Underground and underfloor conductor bar ducts shall have drainage facilities.

## 14 Wiring practices

### 14.1 Connections and routing

#### 14.1.1 General requirements

The means of introduction of a HV cable with its glands, bushings, etc., into an enclosure shall ensure that the degree of protection of the enclosure is not reduced (see 12.3).

All connections shall be secured against accidental loosening. The means of connection shall be suitable for the cross-sectional area and nature of the conductor being terminated. In the case of aluminium or aluminium alloy conductors, particular consideration shall be given to the problems of intrinsic plasticity (flowing) and electrolytic corrosion. Screw and compression joints of conductors and connections to electrical equipment shall be designed to maintain the required contact pressure under load and short-circuit conditions. The recommendations of the cable supplier shall be followed regarding types of gland, box and methods of termination.

Identification tags shall be fixed on the cable at the cable terminations, and shall be legible, permanent, and appropriate for the physical environment.

#### 14.1.2 Cable runs

Cables shall be so installed or protected as to minimize the possibility of mechanical damage that may arise due to the use of the machine or by foreseeable misuse.

The bending radius of the cables and the conditions of laying shall be in accordance with the advice of the cable supplier.

Where it is necessary to disconnect and reconnect cables (e.g. for replacement of a motor), sufficient extra length shall be provided for this purpose.

Conductors and cables shall be adequately supported. In particular the terminations of cables shall be adequately supported to prevent mechanical stresses at the terminations of the conductors.

Cables shall be run from termination to termination without splices or joints. Where this is impracticable (e.g. on mobile machines, on machines having long flexible cables), splices or joints may be used.

High-voltage cables should be physically separated from low-voltage cables.

### 14.2 Identification of conductors

Conductors shall be identifiable at each termination in accordance with the technical documentation (see Clause 18). Annex B, question 29 may be used for agreement between supplier and user regarding a preferred method of identification.

Where the protective conductor cannot be easily identified by its shape, position, or construction, it shall be clearly identified at accessible positions by the graphical symbol IEC 60417-5019:2006-08 or by the bicolour combination GREEN-and-YELLOW.

NOTE National deviations can apply regarding the colour to identify the protective conductor.

### 14.3 Flexible cables

Flexible cables subject to movement shall be supported in such a way that there is no mechanical strain on the anchorage points or any sharp flexing. Where this is achieved by the use of a loop, it shall have sufficient length to provide for a bending radius of the cable of at least 10 times the diameter of the cable unless otherwise specified.

The connecting ends of the cables shall be relieved from stress and thrust. Cable sheaths shall be secured against stripping and the cable ends protected against torsion.

The points of connection shall be arranged in such a manner that the cables cannot be kinked.

Flexible cables of machines shall be installed or protected so as to minimize the possibility of external damage due to factors that include the following cable uses or foreseeable misuse:

– being run over by the machine itself;
– being run over by vehicles or other machines;
– coming into contact with the machine structure during movements;
– running in and out on cable baskets, or on or off cable drums;
– acceleration forces and wind forces on festoon systems or suspended cables;
– excessive rubbing by cable collectors;
– exposure to excessive radiated heat.

The cable sheath shall be resistant to

– the normal wear which can be expected from movement, and
– the effects of atmospheric contaminants (e.g. oil, water, coolants, dust).

The cable handling system shall be so designed that lateral cable angles do not exceed 5°, avoiding torsion in the cable when

– being wound on and off cable drums, and
– approaching and leaving cable guidance devices.

Measures shall be taken to ensure that at least two turns of flexible cable remain on a drum.

The allowable cable bending radius shall be ensured, unless otherwise agreed with the cable manufacturer, as follows:

– Cable drums and rollers shall be used which ensure that the operative winding diameter is at least 25 times the cable diameter. The minimum radius at the guide and deflector pulleys as well as towards the stationary cable termination point shall not be, in any direction, less than 15 times the cable diameter. The straight distance between two bends of an S-shaped deflection or a deflection to another level shall be at least 20 times the

cable diameter. The minimum bending radius at the feeding points which are within the travel way shall be at least 15 times the cable diameter.

– For roller conveyors, the distance between the individual rollers shall be so set as to avoid excessive bending at a roller. This applies especially under conditions of high travel speeds, frequent reversed bending and usage at the maximum permissible tensile stress of the conductors.

These requirements also apply to similar devices, for example mobile cable supports, cable carriages.

### 14.4 Plug-socket combinations

Plug-socket combinations which remain connected during normal service shall be

– of the retaining type requiring the use of a key or tool to prevent unintended disconnection, or

– of a type interlocked with a switch to prevent disconnection under load.

In cases where plug-socket combinations are required, for example to extend a flexible power supply cable, they shall be retained in a way requiring the use of a key or tool and it is recommended that, in addition, they be interlocked with a switch.

The plug-socket combination shall meet the requirements of 5.3.2 c). Appropriate warning signs in accordance with 17.2 shall be affixed to the plug-socket combination. Appropriate instructions for safe use shall be provided in accordance with Clause 18.

### 14.5 Dismantling for shipment

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

### 14.6 Cable trays

Cable trays shall be rigidly supported and positioned at a sufficient distance from moving parts and in such a manner as to minimize the possibility of damage or wear. In areas where human passage is required, the cable trays shall be mounted at least 2 m above the working surface.

## 15 Electric motors and associated equipment

### 15.1 General

Electric motors should conform to the relevant parts of the IEC 60034 series. In all other respects the requirements of Clause 14 of IEC 60204-1:2016 apply.

NOTE Motors in supply systems with isolated neutral point or resonant earthing sometimes need a higher insulation level; see 7.4 of IEC 60034-1:2017.

### 15.2 Motor connection boxes

Motor-mounted devices, for example brakes, temperature sensors, plugging switches, tachometer generators, shall be terminated either

– in a connection box separate from the motor connection box, or

– in a compartment of the motor connection box separate from the high-voltage terminations.

## 16 Means to protect persons working on electrical installations

### 16.1 General

Accessories for earthing and short-circuiting all live parts to the earthing system (see 5.5) which are appropriate for the HV equipment shall be provided in sufficient quantity to facilitate work being carried out in safety on the live parts of the HV equipment of the machine (see Annex B).

It is recommended that the working procedures are agreed upon between the manufacturer and the user. Means for safe working in the vicinity of live HV equipment shall be appropriate and adequate for the present risk and shall be in accordance with 8.4 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

### 16.2 Equipment for isolating installations or apparatus

Refer to 8.4.1 of IEC 61936-1:2010.

### 16.3 Devices to prevent reclosing of isolating devices

Refer to 8.4.2 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

### 16.4 Devices for determining the de-energized state

Refer to 8.4.3 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

### 16.5 Devices for earthing and short-circuiting

Refer to 8.4.4 of IEC 61936-1:2010.

### 16.6 Equipment acting as protective barriers against adjacent live parts

Refer to 8.4.5 of IEC 61936-1:2010.

### 16.7 Storage of personal protection equipment

Refer to 8.4.6 of IEC 61936-1:2010.

## 17 Marking, warning signs and reference designations

### 17.1 General

The electrical equipment shall be marked with the supplier's name, trade mark, or other identifying symbol.

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

Marking and reference designations shall be in accordance with Clause 16 of IEC 60204-1:2016.

### 17.2 Warning signs

Enclosures that do not otherwise clearly show that they contain electrical devices shall be marked with a combined sign according to Figure 8 or Figure 9 of ISO 3864-1:2011. This shall show the graphical symbol ISO 7010-W012:2011-06 and shall be marked in the supplementary label with the capital letters "HV" (see Figure 4).

NOTE 1 The relevant voltage can be added optionally below or beside the letters “HV”


**Figure 4 – Warning sign “high voltage”**

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

In addition a DANGER hazard severity panel to identify a high level of risk according to Table 2, ISO 3864-2:2016 (refer to Figure 5) shall be placed next to the warning sign “high voltage”.


**Figure 5 – DANGER hazard severity panel**

NOTE 2 The DANGER hazard severity panel can be in local language.

## 18 Technical documentation

### 18.1 General

The requirements of Clause 17 of IEC 60204-1:2016 apply.

### 18.2 Instructions for use

#### 18.2.1 General

The documentation, especially the operating manual, shall include the proper procedures for the use of the accessories specified in Clause 16.

#### 18.2.2 Provisions for handling

Special lifting devices shall be capable of lifting the mass of each transport unit and special precautions shall be detailed in the installation manual (for example lifting brackets/bolts that are not intended to be left outdoors shall be removed at site). Required information for unpacking should be given (see 4.6).

#### 18.2.3 Assembly and mounting

Instructions for mounting of equipment, operating device and auxiliary equipment shall include sufficient details of locations and foundations to enable site preparation to be completed. These instructions shall also indicate the total mass of the apparatus and the mass of the parts of the apparatus to be lifted separately if they exceed 100 kg.

#### 18.2.4 Connections

Instructions shall include information on connection of high-voltage conductors; auxiliary circuits and earthing circuits.

#### 18.2.5 Final installation inspection

Instructions shall be provided for inspection and tests which should be made after the equipment has been installed and all connections have been completed. These instructions shall include

– a schedule of recommended site tests to establish correct operation;
– procedures for carrying out any adjustment that may be necessary to obtain correct operation;
– recommendations for any relevant measurements that should be made and recorded for maintenance;
– instructions for final inspection and putting into service.

#### 18.2.6 Warning sign

The meaning of the warning signs and hazard severity panels should be explained in the user documentation.

## 19 Testing and verification

### 19.1 General

This document gives general requirements for the HV equipment of machines. The relevant tests for a particular machine type will be given in the dedicated product standard. Where there is no dedicated product standard for the machine, the verifications shall always include the following items a), b), and e) and may include one or more of the following items d) to f):

a) verification that the HV equipment is in compliance with the technical documentation;
b) earthing system tests (see 19.2);
c) insulation resistance tests (see 19.3);
d) voltage tests (see 19.4);
e) functional tests (see 19.5);
f) IP tests for HV equipment outside electrical operating areas (see 19.6).

When these tests are performed, it is recommended that they follow the sequence listed.

### 19.2 Earthing system tests

Tests shall be carried out on

a) the machine installation,
b) the connections between the machine installation and the external installation (machine bonding conductors),
c) any earthing system provided as part of the electrical installation of the machine,

to verify that the earthing system satisfies the requirements for protection against indirect contact according to 6.3.

NOTE 1 Guidance on tests and measurements is given in 10.5 of IEC 61936-1:2010 and Clause 8 of EN 50522:2010.

NOTE 2 National deviations due to European regulations for earthing systems are defined in Annex Q of EN 50522:2010.

### 19.3 Insulation resistance tests

The insulation resistance, between the power circuit conductors and the protective bonding circuit, measured at a voltage equal to the rated voltage of the HV equipment or 5 kV, whichever is the lower value, shall be not less than 1 MΩ. The test may be made on individual sections of the complete HV installation.

Exception: For certain parts of HV equipment, incorporating for example busbars, conductor wire or conductor bar systems or slip-ring assemblies, a lower minimum value of insulation resistance is permitted in agreement with the manufacturer.

### 19.4 Voltage tests

Details of the voltage tests shall be agreed between the supplier and user.

Guidance for voltage tests after installation on site is given, for example, in 7.105 of IEC 62271-200:2011.

### 19.5 Functional tests

The functions of electrical equipment shall be tested, particularly those related to safety and safeguarding.

### 19.6 IP tests for HV equipment outside electrical operating areas

IP tests are not necessary for type-tested HV equipment if it is installed according to the manufacturer's instructions and the requirements of IEC 61936-1.

For other electrical equipment, the appropriate tests specified in IEC 60529 shall be carried out.

### 19.7 Retesting

Where a portion of the machine and its associated electrical equipment is changed or modified, that portion shall be re-verified and re-tested, as is appropriate (see 19.1).

# Annex A
(informative)

## Examples of machines covered by IEC 60204-11

The following list shows examples of machines whose HV equipment should conform to this document:

– compressors;
– conveyors;
– cranes;
– extruders;
– hoisting machines;
– internal mixers (rubber and plastics);
– material (e.g. coal) stocking-out and reclaiming machines;
– mills;
– mining and quarrying machines;
– paper and board making machines;
– pumps;
– rolling mills for metals;
– ship loaders;
– tunnelling machines;
– ventilators.

# Annex B
(informative)

## Inquiry form for the HV equipment of machines

It is recommended that the following information be provided by the intended user of the HV equipment. It facilitates an agreement between the user and supplier on basic conditions and additional user requirements to ensure proper design, application and utilisation of the HV equipment of the machine (see 4.1).

NOTE There is a separate inquiry form for the LV equipment of machines in Annex B of IEC 60204-1:2016.

Name of manufacturer/supplier _____

Name of end user _____

Tender/order No. _____ Date _____

Type of machine/serial number _____

1. Are there to be modifications as allowed for within this standard?

   YES_____ NO_____

   NOTE Check network codes for the direct connection of machinery to the distribution network.

***Operating conditions – Special requirements (see 4.4)***

2. Ambient temperature range _____
3. Humidity range _____
4. Altitude _____
5. Environmental (e.g. corrosive atmospheres, particulate matter, EMC) _____

   NOTE Certain environments may be prone to abet microflora or microfauna.

6. Radiation _____
7. Vibration, shock _____
8. Special installation and operation requirements (e.g. flame retardant requirements for cables and conductors)

   _____

***Power supply (supplies) and related conditions (see 4.3)***

9. Anticipated voltage fluctuations (if more than ±10 %)
10. Anticipated frequency fluctuations (if more than in 4.3.2) _____

    Specification of short-term value _____

11. Indicate possible future changes in HV equipment that will require an increase in the electrical HV supply requirements _____

12. Indicate for each source of electrical supply required:

    Nominal voltage (V) _____ AC _____ DC _____

    If AC, number of phases _____ Frequency _____ Hz

    Prospective short-circuit current at the point of supply to the machine _____ kA RMS (see also question 15)

    Fluctuations outside values given in 4.3.2 _____

13. What size and type of cable will be used to connect the supply to the machine?

    – cable cross-sectional area _____
    – conductor material _____
    – cable type _____

    Is monitoring of the protective conductor required? YES _____ NO_____

14. Expected single earth-fault current of the HV supply system

    Value: _____ Duration: _____

    Type of earthing

    – isolated neutral point
    – resonant earthing
    – low impedance neutral earthing
    – resonant earthing and temporary low impedance neutral earthing

    Expected double earth-fault current in systems with isolated neutral point or resonant earthing

    Value: _____ Duration: _____

15. Does the user or the supplier provide the overcurrent and earth fault protection of the supply conductors? (See 7.2)

    _____

    Type and setting of

    – overcurrent protective devices _____
    – earth fault protective devices _____

16. Supply disconnecting and earthing devices

    Type of disconnector to be provided _____

    Are locking facilities to lock in the OFF position required for earthing switches?

    YES _____ NO _____

17. Limit of power up to which three-phase AC motors may be started directly across the incoming supply lines _____ kW

18. Motors

With reference to 7.3 of IEC 60204-1:2016 (overload protection of motors):

– May the number of motor overload detection devices be reduced?

YES _____ NO _____

– Is protection under loss of phase condition required?

YES _____ NO _____

– Is protection under stalled rotor condition required?

YES _____ NO _____

19. Overvoltage protection

Table B.1 indicates applications where the installation of overvoltage protection devices is recommendable to ensure reliable and secure service. Type and ratings of the protection devices shall be individually configured to the installation conditions.

**Table B.1 – Overvoltage protection for HV equipment of machinery**

| Equipment | Recommendation |
|---|---|
| Outdoor installation | Lightning protection (requires customised engineering) |
| Distribution and/or power transformer<br>NOTE For unit transformers see:<br>– motor<br>– generator<br>– converter | No surge protection for normal distribution transformer which is installed in HV cable networks.<br>Surge arresters to be fitted in case of:<br>– connection to overhead line<br>– insulation level is lowest level (“list 1”) to IEC 60071-1<br>– insulation is aged or its level is unknown<br>– switching rate in normal service is high |
| Motor | Surge arresters if starting current < 600 A;<br>additional RC circuits if<br>– insulation is not in line with IEC 60034-15,<br>– insulation is aged or its level is unknown,<br>– intended switching rate is high,<br>– starting is controlled by auto-transformer |
| Generator | Surge arresters if generator short-circuit current is < 600 A;<br>(see table line “Motor” regarding additional RC circuits) |
| Converter transformer | Surge arresters |
| Capacitive circuits<br>(filter circuit, capacitor bank) | If breaker corresponds with class 2 to IEC 62271-100,<br>no surge protection is required. |

***Other considerations***

20. Identification (see 17.1) _____

21. Inscriptions/special markings

    – mark of certification YES _____ NO _____ If YES, which one? _____
    – on HV-equipment? _____ In which language? _____

22. Technical documentation

    On what media? _____ In which language? _____

23. Size, location, and purpose of ducts, open cable trays, or cable supports to be provided by the user (additional sheets to be provided where necessary)

24. If 'two-hand control' is to be provided, state the type: _____

    Where it is type III, state the time limit (0,5 s maximum) within which each pair of pushbuttons is to be operated _____

25. Indicate if special limitations on the size or weight affect the transport of a particular machine or the controlgear assemblies to the installation site:

    – maximum dimensions _____
    – maximum weight _____

26. In the case of machines with frequent repetitive cycles of operation dependent on manual control, how frequently will cycles of operation be repeated?

    _____ per hour

    For what length of time is it expected that the machine will be operated at this rate without subsequent pause? _____ min

27. In the case of specially built machines, is a certificate of operating tests with the loaded machine to be supplied? YES_____ NO_____

    In the case of other machines, is a certificate of operating type tests on a loaded prototype machine to be supplied? YES_____ NO_____

28. For cable-less control systems, specify the time delay before automatic machine shutdown is initiated in the absence of a valid signal ____ s

29. Do you need a specific method of conductor identification to be used for the conductors referred to in 14.2?

    YES_____ NO_____ Type _____

30. Type and quantity of accessories for:

    – earthing and short-circuiting (see 16.1) Type _____ No. _____
    – voltage detectors (see 16.2) Type _____ No_____
    – safe working (see 16.3) Type _____ No_____

# Annex C
(informative)

## Relationship between cable rated voltages and highest voltage for HV equipment

The voltage designation of a cable is given in terms of $U_0 / U$ ($U_m$)

where

$U_0$ is the rated power frequency voltage between conductor and earth or metallic screen for which a cable is designed;

$U$ is the rated power frequency voltage between conductors for which the cable is designed (also used as the "nominal system voltage");

$U_m$ is the maximum value of the "highest system voltage" for which the HV equipment may be used (see IEC 60038).

**Table C.1 – Rated voltages of cable and highest voltage for HV equipment**

| Rated voltages of cables and related fittings | | Highest voltage for HV equipment |
|---|---|---|
| $U_0$<br>kV | $U$<br>kV | $U_m$<br>kV |
| 1,8 | 3 | 3,6 |
| 3,6 | 6 | 7,2 |
| 6 | 10 | 12 |
| 8,7 | 15 | 17,5 |
| 12 | 20 | 24 |
| 18 | 30 | 36 |

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SOMMAIRE

AVANT-PROPOS ..... 64
INTRODUCTION ..... 66
1 Domaine d'application ..... 68
2 Références normatives ..... 69
3 Termes et définitions ..... 70
4 Exigences générales ..... 77
4.1 Généralités ..... 77
4.2 Choix des équipements électriques ..... 78
4.3 Alimentation électrique ..... 78
4.3.1 Généralités ..... 78
4.3.2 Caractéristiques de tension ..... 79
4.3.3 Source de puissance embarquée ..... 79
4.4 Environnement physique et conditions de fonctionnement ..... 79
4.4.1 Généralités ..... 79
4.4.2 Compatibilité électromagnétique (CEM) ..... 79
4.5 Transport et stockage ..... 80
4.6 Dispositions pour la manutention ..... 80
4.7 Installation ..... 80
4.7.1 Généralités ..... 80
4.7.2 Assemblage et montage ..... 80
5 Extrémités des conducteurs d'alimentation et appareils de coupure et de sectionnement ..... 80
5.1 Extrémités des conducteurs à haute tension ..... 80
5.2 Borne de terre de l'équipement haute tension ..... 80
5.3 Appareils de sectionnement de l'alimentation pour la mise à la terre ..... 81
5.3.1 Généralités ..... 81
5.3.2 Type ..... 81
5.3.3 Exigences relatives aux sectionneurs ..... 82
5.3.4 Exigences relatives à la mise à la terre et aux courts-circuits ..... 82
5.3.5 Disposition des appareils de sectionnement et de mise à la terre ..... 83
5.4 Appareils de coupure pour éviter un redémarrage intempestif ..... 83
5.5 Appareils de sectionnement et moyens de mise à la terre pour l'équipement HT ..... 84
5.6 Protection contre une manœuvre non autorisée, par inadvertance et/ou par erreur ..... 84
6 Protection contre les chocs électriques ..... 85
6.1 Généralités ..... 85
6.2 Protection contre les contacts directs ..... 85
6.3 Protection contre les contacts indirects ..... 85
6.3.1 Généralités ..... 85
6.3.2 Mesures pour empêcher l'apparition d'une tension de contact dangereuse lors d'un défaut permanent ..... 86
6.3.3 Protection par coupure automatique de l'alimentation lors d'un défaut de durée limitée ..... 86
6.3.4 Protection des machines mobiles ..... 86
7 Protection de l'équipement HT ..... 87

7.1 Généralités ..... 87
7.2 Protection contre les surintensités ..... 87
7.2.1 Généralités ..... 87
7.2.2 Conducteurs d'alimentation ..... 87
7.2.3 Circuits de puissance ..... 88
7.2.4 Transformateurs ..... 88
7.2.5 Appareils de protection contre les surintensités ..... 88
7.2.6 Caractéristiques assignées et réglage des appareils de protection contre les surintensités ..... 88
7.3 Protection des moteurs contre les surchauffes ..... 88
7.4 Protection contre les températures anormales ..... 89
7.5 Protection contre les effets de l'interruption de l'alimentation ou la réduction de la tension et leur rétablissement ultérieur ..... 89
7.6 Protection contre la survitesse des moteurs ..... 89
7.7 Protection contre les défauts à la terre ..... 89
7.8 Protection contre la surtension due à la foudre et les surtensions de manœuvre ..... 89
7.9 Protection contre les phénomènes dangereux dus aux défauts d'arc ..... 90
7.10 Protection contre les surpressions et les fuites ..... 90
7.11 Protection contre l'incendie ..... 90
8 Liaisons équipotentielles ..... 90
8.1 Généralités ..... 90
8.2 Circuit de protection ..... 93
8.2.1 Généralités ..... 93
8.2.2 Conducteurs de protection ..... 93
8.2.3 Continuité du circuit de protection ..... 94
8.2.4 Machines mobiles ..... 94
8.2.5 Points de raccordement du circuit de protection ..... 95
8.2.6 Conducteurs supplémentaires de liaison de protection ..... 95
9 Systèmes, circuits et fonctions de commande ..... 95
10 Interface opérateur et appareils de commande montés sur la machine ..... 96
11 Équipement électronique ..... 96
12 Appareillage de commande: emplacement, montage et enveloppes ..... 96
12.1 Exigences générales ..... 96
12.2 Emplacement et montage ..... 96
12.2.1 Accessibilité et maintenance ..... 96
12.2.2 Séparation physique ..... 97
12.3 Degrés de protection ..... 97
12.4 Enveloppes, portes et ouvertures ..... 97
12.5 Accès aux équipements HT ..... 98
13 Câbles et conducteurs ..... 98
13.1 Exigences générales ..... 98
13.2 Conducteurs ..... 99
13.3 Matériaux d'isolation et de gainage ..... 99
13.4 Courant admissible en fonctionnement normal ..... 100
13.5 Chute de tension dans les câbles et conducteurs ..... 100
13.6 Section minimale ..... 100
13.7 Câbles souples ..... 100
13.7.1 Généralités ..... 100

13.7.2 Dimensionnement mécanique ..... 101
13.7.3 Courant admissible des câbles enroulés sur des tambours ..... 101
13.8 Ensembles de fils conducteurs, barres conductrices et bagues collectrices ..... 101
13.8.1 Protection contre les contacts directs ..... 101
13.8.2 Circuit de protection ..... 102
13.8.3 Collecteurs de courant du conducteur de protection ..... 102
13.8.4 Distances d'isolement dans l'air ..... 102
13.8.5 Lignes de fuite ..... 102
13.8.6 Subdivision du système conducteur ..... 103
13.8.7 Construction et mise en œuvre d'ensembles de fils conducteurs, de barres conductrices et de bagues collectrices ..... 104
14 Pratiques du câblage ..... 104
14.1 Raccordement et cheminement ..... 104
14.1.1 Exigences générales ..... 104
14.1.2 Cheminement des câbles ..... 104
14.2 Identification des conducteurs ..... 105
14.3 Câbles souples ..... 105
14.4 Ensembles fiche-prise ..... 106
14.5 Démontage pour le transport ..... 106
14.6 Chemins de câbles ..... 106
15 Moteurs électriques et équipements associés ..... 107
15.1 Généralités ..... 107
15.2 Boîtiers de connexion de moteur ..... 107
16 Moyens de protection des personnes intervenant sur des installations électriques ..... 107
16.1 Généralités ..... 107
16.2 Équipement pour l'isolement des installations ou des appareils ..... 107
16.3 Appareils pour empêcher le réenclenchement des appareils de sectionnement ..... 107
16.4 Appareils de vérification de l'absence de tension ..... 107
16.5 Appareils de mise à la terre et en court-circuit ..... 107
16.6 Équipements agissant comme barrières de protection contre les parties actives voisines ..... 107
16.7 Stockage de l'équipement de protection individuelle ..... 108
17 Marquages, panneaux d'avertissement et désignations de référence ..... 108
17.1 Généralités ..... 108
17.2 Panneaux d'avertissement ..... 108
18 Documentation technique ..... 109
18.1 Généralités ..... 109
18.2 Instructions d'utilisation ..... 109
18.2.1 Généralités ..... 109
18.2.2 Dispositions pour la manutention ..... 109
18.2.3 Assemblage et montage ..... 109
18.2.4 Connexions ..... 109
18.2.5 Inspection finale de l'installation ..... 109
18.2.6 Panneau d'avertissement ..... 109
19 Essais et vérification ..... 110
19.1 Généralités ..... 110
19.2 Essais de l'installation de mise à la terre ..... 110
19.3 Essais de résistance d'isolement ..... 110

19.4 Essais de tension ..... 110
19.5 Essais fonctionnels ..... 111
19.6 Essais d'IP pour les équipements HT à l'extérieur des zones de service électrique ..... 111
19.7 Contre-essais ..... 111
Annexe A (informative) Exemples de machines couvertes par l'IEC 60204-11 ..... 112
Annexe B (informative) Questionnaire concernant l'équipement HT des machines ..... 113
Annexe C (informative) Relation entre les tensions assignées des câbles et la tension la plus élevée des équipements HT ..... 118
Bibliographie ..... 119

Figure 1 – Schéma fonctionnel d'une machine comportant des équipements HT ..... 67
Figure 2 – Exemple de liaisons équipotentielles pour l'équipement électrique d'une machine ..... 92
Figure 3 – Symbole pour la terre de protection ..... 95
Figure 4 – Panneau d'avertissement «haute tension» ..... 108
Figure 5 – Panneau «DANGER» indiquant la gravité d'un phénomène dangereux ..... 108

Tableau 1 – Températures maximales admissibles des conducteurs dans les conditions normales et de court-circuit ..... 99
Tableau 2 – Facteurs de correction pour des câbles enroulés sur tambours ..... 101
Tableau 3 – Choix du niveau de pollution en fonction du degré de protection et du matériau isolant ..... 103
Tableau 4 – Ligne de fuite minimale des ensembles de lignes conductrices et de bagues collectrices ..... 103
Tableau B.1 – Protection contre la surtension des équipements HT des machines ..... 116
Tableau C.1 – Tensions assignées des câbles et tension la plus élevée pour l'équipement HT ..... 118

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

_____

# SÉCURITÉ DES MACHINES – ÉQUIPEMENT ÉLECTRIQUE DES MACHINES –

## Partie 11: Exigences pour les équipements fonctionnant à des tensions supérieures à 1 000 V en courant alternatif ou 1 500 V en courant continu et ne dépassant pas 36 kV

## AVANT-PROPOS

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La Norme internationale IEC 60204-11 a été établie par le comité d'études 44 de l'IEC: Sécurité des machines – Aspects électrotechniques.

Cette deuxième édition annule et remplace la première édition parue en 2000. Cette édition constitue une révision technique.

Cette édition contient des modifications techniques majeures par rapport à l'édition précédente qui concernent:

– les aspects liés à l'appréciation du risque, tirés de l'ISO 12100;
– les liaisons équipotentielles et la mise à la terre;

– la CEM et la qualité de la puissance;
– les appareillages à haute tension;
– les lignes de fuite pour conducteurs et ensembles de bagues collectrices;
– une liste des machines utilisant des équipements HT dans l'Annexe A.

Cette deuxième édition de l'IEC 60204-11 a été mise à jour et améliorée sur la base de l'expérience acquise avec la première édition et sur la base de l'évolution des équipements haute tension décrits dans les normes applicables.

Concernant les exigences de forme, l'IEC 60204-11 a été alignée sur

– l'IEC 60204-1:2016,
– l'IEC 61936-1:2010 et l'IEC 61936-1:2010/AMD1:2014,
– l'IEC 62271 (toutes les parties).

Cette norme est destinée à être utilisée conjointement avec l'IEC 60204-1.

Le texte de cette Norme internationale est issu des documents suivants:

| FDIS | Rapport de vote |
|---|---|
| 44/819/FDIS | 44/828/RVD |

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60204, publiée sous le titre général *Sécurité des machines – Équipement électrique des machines*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous «http://webstore.iec.ch» dans les données relatives au document recherché. À cette date, le document sera

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# INTRODUCTION

La présente partie de l'IEC 60204 donne les exigences et recommandations relatives à l'équipement électrique haute tension (équipement HT) ainsi qu'à l'équipement électrique basse tension (équipement BT) des machines en vue d'améliorer

– la sécurité des personnes et des biens,

– la cohérence de réponse des commandes,

– la maintenabilité.

La Figure 1 est un schéma fonctionnel d'une machine et de l'équipement associé représentant les différents éléments de l'équipement électrique traité dans le présent document. Les chiffres entre parenthèses (…) se rapportent aux articles et aux paragraphes du présent document. Il est admis que la totalité des éléments pris ensemble, y compris les moyens de protection, les logiciels et la documentation, constitue la machine ou le groupe de machines fonctionnant ensemble avec habituellement au moins un niveau de supervision.

Il convient d'utiliser le présent document conjointement avec l'IEC 60204-1. Les équipements HT peuvent comprendre les parties BT de commande situées dans la même enveloppe générale ou dans des compartiments séparés.

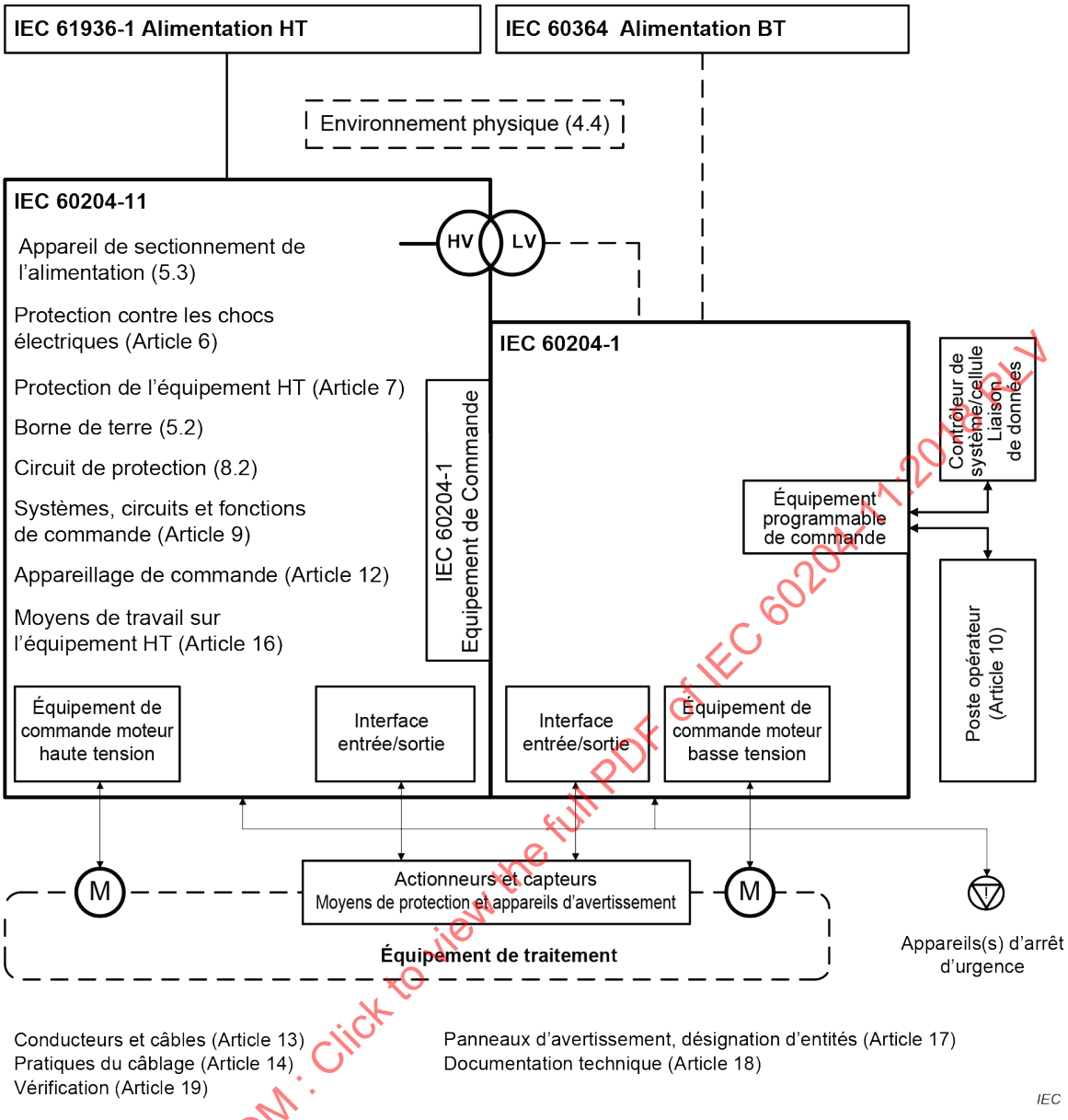


**Figure 1 – Schéma fonctionnel d'une machine comportant des équipements HT**

# SÉCURITÉ DES MACHINES – ÉQUIPEMENT ÉLECTRIQUE DES MACHINES –

## Partie 11: Exigences pour les équipements fonctionnant à des tensions supérieures à 1 000 V en courant alternatif ou 1 500 V en courant continu et ne dépassant pas 36 kV

## 1 Domaine d'application

La présente partie de l'IEC 60204 est applicable aux équipements et systèmes électriques et électroniques des machines, y compris à un groupe de machines fonctionnant de manière coordonnée, qui fonctionnent à une tension nominale supérieure à 1 000 V en courant alternatif ou 1 500 V en courant continu et non supérieure à 36 kV en courant alternatif ou continu et pour des fréquences nominales n'excédant pas 60 Hz.

Dans le présent document, le terme «équipement HT» couvre aussi l'équipement BT faisant partie intégrante de l'équipement fonctionnant en haute tension. Les exigences du présent document couvrent essentiellement les parties fonctionnant en haute tension, sauf spécification explicite contraire.

NOTE 1 Les équipements BT qui ne font pas partie de l'équipement HT sont couverts par l'IEC 60204-1:2016.

NOTE 2 Dans le présent document, le terme «électrique» est utilisé dans le sens général d'électrique et d'électronique (c'est-à-dire que le terme «équipement électrique» désigne à la fois l'équipement électrique et l'équipement électronique).

NOTE 3 Le présent document ne s'applique pas aux installations électriques haute tension indépendantes pour lesquelles des normes IEC spécifiques existent.

L'équipement électrique défini dans le présent document commence au point de raccordement de l'alimentation à l'équipement électrique de la machine (voir 5.1).

NOTE 4 Pour les exigences d'installations électriques haute tension, voir l'IEC 61936-1.

Le présent document est une norme générique de sécurité. Elle ne couvre pas toutes les exigences (par exemple, protection, verrouillage ou commande) qui sont nécessaires ou exigées par d'autres normes ou réglementations destinées à protéger les personnes contre des phénomènes dangereux autres que les phénomènes dangereux électriques. Chaque type de machine est couvert par des exigences qui lui sont propres et qui sont à prendre en compte pour obtenir une sécurité adéquate.

NOTE 5 Dans certaines machines, l'alimentation à haute tension peut être produite par un transformateur élévateur (autotransformateur) alimenté par un système basse tension (par exemple, par un générateur basse tension).

NOTE 6 Dans le cadre du présent document, le terme «personne» s'applique à n'importe quel individu et le terme «personnel» fait référence aux personnes désignées et formées par l'utilisateur ou par son ou ses agent(s) à l'utilisation ou l'entretien de la machine concernée.

Le présent document inclut, entre autres, les machines, comme défini en 3.29 (l'Annexe A énumère des exemples de machines dont l'équipement électrique peut être couvert par le présent document).

Concernant la protection contre les chocs électriques provenant d'équipements haute tension, le présent document fait référence à l'IEC 61936-1. Lorsqu'il s'agit d'équipements basse tension, le présent document fait référence à l'IEC 60204-1:2016.

NOTE 7 Les normes relatives aux hautes et basses tensions utilisent différents termes concernant la protection contre les chocs électriques. Tandis que les normes relatives à la haute tension utilisent les termes «contact direct» et «contact indirect», les normes relatives à la basse tension utilisent respectivement «protection principale» et «protection en cas de défaut».

Des exigences complémentaires et spécifiques peuvent s'appliquer à l'équipement électrique des machines qui

– sont utilisées à l'air libre (c'est-à-dire à l'extérieur de bâtiments ou d'autres structures de protection);
– utilisent, transforment ou produisent des matériaux potentiellement explosifs (par exemple de la peinture ou de la sciure);
– sont utilisées dans des atmosphères potentiellement explosives et/ou inflammables;
– présentent des risques particuliers lors de la fabrication ou de l'utilisation de certains matériaux;
– sont utilisées dans les mines.

Les phénomènes dangereux résultant de bruits et de vibrations sont exclus du domaine d'application du présent document.

## 2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60071-2:1996, *Coordination de l'isolement – Partie 2: Guide d'application*

IEC 60076-5, *Transformateurs de puissance – Partie 5: Tenue au court-circuit*

IEC 60204-1:2016, *Sécurité des machines – Équipement électrique des machines – Partie 1: Exigences générales*

IEC 60364-5-54:2011, *Installations électriques basse-tension – Partie 5-54: Choix et mise en œuvre des matériels électriques – Installations de mise à la terre et conducteurs de protection*

IEC 60417, *Symboles graphiques utilisables sur le matériel* (disponible à l'adresse http://www.graphical-symbols.info/equipment)

IEC 60445, *Principes fondamentaux et de sécurité pour les interfaces hommes-machines, le marquage et l'identification – Identification des bornes de matériels, des extrémités de conducteurs et des conducteurs*

IEC 60529, *Degrés de protection procurés par les enveloppes (Code IP)*

IEC 60865-1, *Courants de court-circuit – Calcul des effets – Partie 1: Définitions et méthodes de calcul*

IEC 61800 (toutes les parties), *Entraînements électriques de puissance à vitesse variable*

IEC 61936-1:2010, *Installations électriques en courant alternatif de puissance supérieure à 1 kV – Partie 1: Règles communes*
IEC 61936-1:2010/AMD1:2014

IEC 62061, *Sécurité des machines – Sécurité fonctionnelle des systèmes de commande électriques, électroniques et électroniques programmables relatifs à la sécurité*

IEC 62271-102, *Appareillage à haute tension – Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif*

IEC 62271-103, *Appareillage à haute tension – Partie 103: Interrupteurs pour tensions assignées supérieures à 1 kV et inférieures ou égales à 52 kV*

IEC 62271-105, *Appareillage à haute tension – Partie 105: Combinés interrupteurs-fusibles pour courant alternatif de tensions assignées supérieures à 1 kV et jusqu'à 52 kV inclus*

IEC 62271-107, *Appareillage à haute tension – Partie 107: Circuits-switchers fusiblés pour courant alternatif de tension assignée supérieure à 1 kV et jusqu'à 52 kV inclus*

IEC 62271-200:2011, *Appareillage à haute tension – Partie 200: Appareillage sous enveloppe métallique pour courant alternatif de tensions assignées supérieures à 1 kV et inférieures ou égales à 52 kV*

IEC 62271-201, *Appareillage à haute tension – Partie 201: Appareillage sous enveloppe isolante solide pour courant alternatif de tensions assignées supérieures à 1 kV et inférieures ou égales à 52 kV*

IEC 62745, *Sécurité des machines – Exigences pour les systèmes de commande sans fil des machines*

ISO 13849-1, *Sécurité des machines – Parties des systèmes de commande relatives à la sécurité – Partie 1: Principes généraux de conception*

ISO 3864-1:2011, *Symboles graphiques – Couleurs de sécurité et signaux de sécurité – Partie 1: Principes de conception pour les signaux de sécurité et les marquages de sécurité*

ISO 3864-2:2016, *Symboles graphiques – Couleurs de sécurité et signaux de sécurité – Partie 2: Principes de conception pour l'étiquetage de sécurité des produits*

ISO 7010:2011, *Symboles graphiques – Couleurs de sécurité et signaux de sécurité – Signaux de sécurité enregistrés*

ISO 12100, *Sécurité des machines – Principes généraux de conception – Appréciation du risque et réduction du risque*

EN 50178, *Electronic equipment for use in power installations* (disponible en anglais seulement)



## 3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

**3.1**
**température ambiante**
température de l'air ou du milieu dans lequel l'équipement doit être utilisé

**3.2**
**barrière**
élément assurant la protection contre les contacts avec les parties actives dans toute direction habituelle d'accès

**3.3**
**protection principale**
protection contre les chocs électriques en l'absence de défaut

Note 1 à l'article: Précédemment appelée «protection contre les contacts directs».

[SOURCE: IEC 60050-195:1998, 195-06-01, modifiée – La note à l'article a été ajoutée.]

**3.4**
**chemin de câbles**
**tablette**
support de câbles constitué d'une base continue avec des rebords, mais ne comportant pas de couvercle

Note 1 à l'article: Un chemin de câbles peut être perforé ou en treillis.

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

**3.5**
**fil conducteur**
**barre conductrice**
**rail de contact**
fil, barre ou rail conducteur d'un système d'alimentation avec collecteur de courant coulissant

**3.6**
**circuit de commande**
<d'une machine> circuit utilisé pour la commande, y compris la surveillance, d'une machine et de l'équipement électrique

**3.7**
**appareil de commande**
appareil raccordé au circuit de commande et servant à commander le fonctionnement de la machine

EXEMPLE Un capteur de position, un auxiliaire manuel de commande, un relais, un électrodistributeur.

**3.8**
**appareillage de commande**
terme général applicable aux appareils de connexion et à leur combinaison avec des appareils de commande, de mesure, de protection et de réglage qui leur sont associés, ainsi qu'aux ensembles de tels appareils avec les connexions, les accessoires, les enveloppes et les supports correspondants, destinés en principe à la commande des appareils utilisateurs d'énergie électrique

[SOURCE: IEC 60050-441:2000, 441-11-03]

**3.9**
**canalisation**
canal fermé destiné expressément au support et à la protection de conducteurs, de câbles et de barres omnibus

Note 1 à l'article: Les conduits, les systèmes de goulottes et les canaux enterrés sont des types de canalisations.

**3.10**
**installation de mise à la terre**
ensemble des liaisons électriques et dispositifs mis en œuvre dans la mise à la terre d'un réseau, d'une installation ou d'un matériel

[SOURCE: IEC 60050-826:2004, 826-13-04]

**3.11**
**zone de service électrique**
local ou emplacement pour équipements électriques dont l'accès est destiné à être restreint aux personnes qualifiées ou averties, par ouverture d'une porte ou retrait d'une barrière, sans l'aide d'une clé ou d'un outil et qui est clairement marqué à l'aide de panneaux d'avertissement appropriés

Note 1 à l'article: Une personne avertie (en électricité) est une personne suffisamment informée ou surveillée par une personne qualifiée en électricité pour lui permettre de percevoir les risques et d'éviter les phénomènes dangereux que peut présenter l'électricité (voir l'IEC 60050-826:2004, 826-18-02).

Note 2 à l'article: Une personne qualifiée (en électricité) est une personne ayant la formation, les connaissances techniques et l'expérience appropriées pour lui permettre de percevoir les risques et d'éviter les phénomènes dangereux associés à l'électricité (voir l'IEC 60050-826:2004, 826-18-01).

**3.12**
**équipement électronique**
partie d'un équipement électrique comprenant des circuits basés principalement sur des appareils et composants électroniques

**3.13**
**zone fermée de service électrique**
local ou emplacement destiné à l'exploitation des installations et des équipements électriques dont l'accès est destiné à être restreint aux personnes qualifiées ou averties ou au personnel sous la surveillance de personnes qualifiées ou averties, par exemple par ouverture d'une porte ou retrait d'une barrière de protection seulement à l'aide d'une clé ou d'un outil et qui est clairement identifié par des panneaux d'avertissement appropriés

Note 1 à l'article: Voir aussi les Notes à l'article 1 et 2 de la définition 3.11.

**3.14**
**enveloppe**
partie procurant un degré de protection spécifié de l'équipement contre les influences externes et, dans toutes les directions, un degré de protection spécifié contre l'approche des parties actives ou le contact avec elles ou contre le contact avec des pièces en mouvement

Note 1 à l'article: Cette définition nécessite les explications suivantes dans le cadre du domaine d'application du présent document:

Les enveloppes assurent la protection de personnes ou d'animaux domestiques ou d'élevage contre l'accès aux parties dangereuses.

Les barrières, formes des ouvertures, ou tout autre moyen approprié pour prévenir ou limiter la pénétration des calibres d'essai spécifiés, soit fixés sur l'enveloppe, soit formés par l'appareillage sous enveloppe, sont considérés comme faisant partie de l'enveloppe, sauf s'ils peuvent être démontés sans l'aide d'une clé ou d'un outil.

Une enveloppe peut être

– une armoire ou un coffret, monté sur la machine, ou séparé de la machine;
– un compartiment, constitué par un espace fermé dans la structure de la machine.

[SOURCE: IEC 50050-441:2000, 441-13-01, modifiée – "à un ensemble" a été supprimé, "dans toutes les directions" et la note ont été ajoutés.]

**3.15**
**équipement**
éléments utilisés dans le cadre d'une installation électrique par les machines ou des parties de machines, par exemple, matériel, accessoires, dispositifs, composants, appareils, fixations, instruments et analogues

**3.15.1**
**équipement électrique haute tension**
éléments définis dans l'IEC 60204-11:2018, 3.15 conçus pour fonctionner à des tensions supérieures à 1 000 V en courant alternatif ou 1 500 V en courant continu

Note 1 à l'article: Pour faciliter la lecture du présent document, «équipement HT» est utilisé lorsque le contexte est évident.

**3.16**
**liaison équipotentielle**
mise en œuvre de liaisons électriques entre parties conductrices destinée à réduire les différences de potentiel et réaliser l'équipotentialité entre ces parties

[SOURCE: IEC 60050-195:1998, 195-01-10, modifiée – les mots «destinée à réduire les différences de potentiel» et «entre ces parties» ont été ajoutés.]

**3.17**
**conducteur de liaison de protection**
**conducteur d'équipotentialité**
conducteur de protection prévu pour réaliser une liaison équipotentielle de protection

[SOURCE: IEC 60050-195:1998, 195-02-10]

**3.18**
**masse**
**partie conductrice accessible**
partie conductrice d'un matériel, susceptible d'être touchée, et qui n'est pas normalement sous tension, mais peut le devenir lorsque l'isolation principale est défaillante

[SOURCE: IEC 60050-195:1998, 195-06-10]

**3.19**
**élément conducteur étranger**
partie conductrice ne faisant pas partie de l'installation électrique et susceptible d'introduire un potentiel électrique, généralement celui d'une terre locale

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

**3.20**
**défaillance**
cessation de l'aptitude d'un dispositif à accomplir une fonction requise

Note 1 à l'article: Après défaillance d'une entité, cette entité présente un défaut.

Note 2 à l'article: Une «défaillance» est un passage d'un état à un autre, par opposition à un «défaut», qui est un état.

Note 3 à l'article: La notion de défaillance, telle qu'elle est définie, ne s'applique pas à une entité constituée seulement de logiciel.

Note 4 à l'article: En pratique, les termes «défaut» et «défaillance» sont souvent utilisés comme synonymes.

[SOURCE: IEC 60050-603:1986, 603-05-06, modifiée – Les notes ont été ajoutées.]

**3.21**
**panne**
état d'une entité inapte à accomplir une fonction exigée, à l'exclusion de son inaptitude due à la maintenance préventive ou à d'autres actions programmées, ou due à un manque de moyens extérieurs

Note 1 à l'article: Une panne est souvent la conséquence d'une défaillance de l'entité elle-même, mais elle peut exister sans défaillance préalable.

Note 2 à l'article: En anglais, le terme «fault» et sa définition sont identiques à ceux donnés dans l'IEC 60050-192:2015, 192-04-01. Dans le domaine des machines, le terme français «défaut» et le terme allemand «Fehler» sont utilisés en lieu et place des termes «Panne» et «Fehlzustand» qui accompagnent cette définition.

**3.22**
**protection en cas de défaut**
protection contre les chocs électriques dans des conditions de premier défaut

Note 1 à l'article: Appelée précédemment «protection contre les contacts indirects».

[SOURCE: IEC 60050-195:1998, 195-06-02]

**3.23**
**phénomène dangereux**
source potentielle de blessure physique ou d'atteinte à la santé

Note 1 à l'article: L'expression «phénomène dangereux» peut être qualifiée de manière à faire apparaître l'origine (par exemple phénomène dangereux mécanique, phénomène dangereux électrique) ou la nature du dommage potentiel (par exemple phénomène dangereux de choc électrique, phénomène dangereux de coupure, phénomène dangereux d'intoxication, phénomène dangereux d'incendie).

Note 2 à l'article: Le phénomène dangereux envisagé dans cette définition est:

– soit présent en permanence pendant l'utilisation normale de la machine (par exemple déplacement d'éléments mobiles dangereux, arc électrique pendant une phase de soudage, mauvaise posture, émission de bruit, température élevée);
– soit il peut apparaître de manière inattendue (par exemple explosion, écrasement résultant d'une mise en fonctionnement intempestive ou inattendue, projection résultant d'une rupture, chute résultant d'une accélération ou d'une décélération).

[SOURCE: ISO 12100:2010, 3.6, modifiée – "dommage" a été remplacé par "blessure physique ou d'atteinte à la santé" et la Note 3 a été supprimée.]

**3.24**
**verrouillage**
**verrouillage pour la protection**
disposition d'appareils fonctionnant ensemble pour:

– éviter les situations dangereuses, ou
– éviter les dommages à l'équipement ou au matériel, ou
– éviter les opérations spécifiées, ou
– garantir des opérations correctes

**3.25**
**partie active**
conducteur ou partie conductrice destiné à être sous tension en service normal, y compris le conducteur de neutre, mais par convention, excepté le conducteur PEN, le conducteur PEM ou le conducteur PEL

Note 1 à l'article: La notion n'implique pas nécessairement un risque de choc électrique.

[SOURCE: IEC 60050-195:1998, 195-02-19]

**3.26**
**conducteur d'équipotentialité de la machine**
conducteur reliant la liaison équipotentielle de la machine à l'installation de mise à la terre

Note 1 à l'article: Il s'agit d'un conducteur de terre tel que défini dans l'IEC 60050-826:2004, 826-13-12 et utilisé dans l'IEC 61936-1.

Note 2 à l'article: Cette définition correspond au terme «conducteur de terre» défini dans l'IEC 61936-1.

**3.27**
**actionneur**
mécanisme de puissance utilisé pour animer une machine

EXEMPLE Moteur, solénoïde, vérin pneumatique ou hydraulique.

**3.28**
**conducteur (de) neutre**
conducteur relié électriquement au point neutre et pouvant contribuer à la distribution de l'énergie électrique

[SOURCE: IEC 60050-195:1998, 195-02-06]

**3.29**
**machine**
ensemble de pièces ou d'organes liés entre eux, dont au moins un est mobile, auxquels sont associés, selon les besoins, des actionneurs, des circuits de commande et de puissance, etc., réunis de façon solidaire en vue d'une application définie, notamment pour la transformation, le traitement, le déplacement et le conditionnement d'un matériau

Note 1 à l'article: Le terme "machine" désigne également:

– un ensemble de machines qui, afin de concourir à un seul et même résultat, sont disposées et commandées de manière à être solidaires dans leur fonctionnement;
– des équipements interchangeables modifiant la fonction d'une machine du marché dans le but d'être assemblés avec une machine ou un ensemble de différentes machines ou un tracteur par l'opérateur lui-même, ces équipements n'étant ni des pièces de rechange ni des outils.

**3.30**
**obstacle**
élément empêchant un contact direct fortuit mais ne s'opposant pas à un contact direct par une action délibérée

[SOURCE: IEC 60050-826:2004, 826-12-24, modifiée – Dans le terme, "de protection électrique" a été supprimé.]

**3.31**
**surintensité**
courant électrique supérieur au courant électrique assigné

Note 1 à l'article: Pour des conducteurs, on considère que le courant assigné est égal au courant admissible.

[SOURCE: IEC 60050-826:2004, 826-11-14]

**3.32**
**surcharge**
<d'un circuit> relation temps/courant dans un circuit supérieure à la pleine charge assignée du circuit lorsque ce dernier n'est pas en défaut

Note 1 à l'article: Il convient de ne pas utiliser le terme «surcharge» comme un synonyme de «surintensité».

**3.33**
**ensemble fiche-prise**
composant et composant adapté d'accouplement, appropriés pour terminer les conducteurs, destinés à la connexion et à la déconnexion de deux ou plusieurs conducteurs

**3.34**
**circuit de puissance**
circuit utilisé pour transmettre l'énergie du réseau aux éléments d'équipement électrique utilisés directement pour le travail effectué par la machine et aux transformateurs alimentant les circuits de commande

**3.35**
**circuit de protection**
ensemble des conducteurs de protection et des parties conductrices utilisé afin d'assurer la protection contre les chocs électriques en cas de défaut d'isolement

**3.36**
**conducteur de protection**
conducteur fournissant un chemin de courant de défaut primaire depuis les masses de l'équipement électrique jusqu'à une borne de terre (PE – *protective earthing*) de protection

Note 1 à l'article: Le terme équivalent utilisé dans l'IEC 61936-1 est «conducteur d'équipotentialité de protection».

**3.37**
**désignation de référence**
code distinct servant à identifier un élément sur un schéma, une liste ou un diagramme et sur l'équipement

**3.38**
**risque**
combinaison de la probabilité d'un dommage (c'est-à-dire blessure physique ou atteinte à la santé) et de la gravité de ce dommage

[SOURCE: ISO 12100:2010, 3.12, modifiée – Le texte entre parenthèses a été ajouté.]

**3.39**
**mode opératoire sûr**
méthode de travail qui réduit le risque

**3.40**
**moyen de protection**
protecteur ou appareil de protection utilisé comme mesure de sécurité pour protéger les personnes contre un phénomène dangereux présent ou imminent

**3.41**
**protection**
mesures de sécurité faisant appel à des moyens spécifiques appelés «moyens de protection» pour protéger les personnes des phénomènes dangereux qui ne peuvent raisonnablement être éliminés ou suffisamment réduits à la conception

**3.42**
**plancher de service**
niveau sur lequel se trouvent généralement les personnes intervenant pour le fonctionnement ou la maintenance de l'équipement électrique

**3.43**
**courant de court-circuit**
surintensité résultant d'un court-circuit dû à un défaut ou à un branchement incorrect dans un circuit électrique

[SOURCE: IEC 60050-441:2000, 441-11-07]

**3.44**
**fournisseur**
entité qui fournit l'équipement ou les services associés à la machine

EXEMPLE Un fabricant, un maître d'œuvre, un installateur, un intégrateur.

Note 1 à l'article: L'utilisateur peut aussi agir en tant que son propre fournisseur.

**3.45**
**appareil de connexion**
appareil destiné à établir ou à interrompre le courant dans un ou plusieurs circuits électriques

Note 1 à l'article: Un appareil de connexion peut réaliser une ou plusieurs de ces actions.

[SOURCE: IEC 60050-441:2000, 441-14-01, modifiée – La note a été ajoutée.]

**3.46**
**borne**
partie conductrice d'un appareil comportant une connexion électrique aux circuits externes

**3.47**
**utilisateur**
entité qui utilise la machine et son équipement électrique associé

## 4 Exigences générales

### 4.1 Généralités

Le présent document traite des équipements électriques haute tension des machines.

Les risques associés aux phénomènes dangereux relatifs à l'équipement HT doivent être appréciés dans le cadre de l'appréciation du risque, par exemple conformément à l'ISO 12100. Ceci:

– identifie la nécessité d'une réduction du risque;
– détermine les réductions de risque adéquates, et
– détermine les mesures de protection nécessaires pour les personnes pouvant être exposées à ces phénomènes dangereux, tout en continuant à maintenir un fonctionnement approprié de la machine et de ses équipements.

Les situations dangereuses peuvent être dues, entre autres, à:

– des défaillances ou des défauts de l'équipement électrique conduisant à la possibilité de choc ou d'arc électrique ou d'incendie;
– des défaillances ou des défauts dans les circuits de commande (ou dans les composants ou appareils associés à ces circuits) conduisant à un dysfonctionnement de la machine;
– des perturbations ou des interruptions dans les sources d'alimentation ainsi que des défaillances ou des défauts dans les circuits de puissance conduisant à un dysfonctionnement de la machine;

– une perte de continuité dans les circuits, par exemple les circuits qui dépendent de contacts glissants ou roulants, qui peut conduire à une défaillance d'une fonction de sécurité;

– des perturbations électriques, par exemple des perturbations électromagnétiques ou électrostatiques, en provenance de l'extérieur de l'équipement électrique ou générées de façon interne, et conduisant à un dysfonctionnement de la machine;

– un relâchement d'énergie accumulée (électrique ou mécanique) conduisant, par exemple, à un choc électrique ou à un mouvement inattendu pouvant provoquer une blessure;

– un bruit acoustique et une vibration mécanique d'un niveau tel qu'ils provoquent des problèmes de santé aux personnes;

– des températures de surface pouvant provoquer des blessures.

Les mesures de sécurité combinent les mesures prises au niveau de la conception et celles dont la mise en œuvre par l'utilisateur est exigée.

Le processus de conception et de développement doit identifier les phénomènes dangereux et les risques qui en résultent. Lorsque les phénomènes dangereux ne peuvent être éliminés et/ou que les risques ne peuvent être suffisamment réduits par l'application de mesures de prévention intrinsèque, des mesures de protection (par exemple, la protection) doivent être fournies afin de réduire le risque. Des dispositions complémentaires (par exemple, des moyens de sensibilisation) doivent être fournies si une réduction du risque plus importante est nécessaire. De plus, des procédures de travail réduisant le risque peuvent être nécessaires.

Lorsque l'utilisateur est connu, il est recommandé d'utiliser l'Annexe B afin de faciliter l'échange d'informations entre l'utilisateur et le ou les fournisseurs concernant les conditions de base et sur les spécifications de l'utilisateur complémentaires relatives à l'équipement électrique.

NOTE Ces spécifications complémentaires peuvent

– fournir les caractéristiques supplémentaires qui dépendent du type de machine (ou groupe de machines) et de l'application;

– faciliter la maintenance et la réparation, et

– améliorer la fiabilité et la facilité d'emploi.

### 4.2 Choix des équipements électriques

Les composants et appareils électriques doivent

– convenir à l'usage auquel ils sont destinés;

– être conformes aux normes IEC pertinentes; et

– s'appliquer conformément aux instructions du fournisseur.

Il convient de choisir les appareillages HT soumis à un essai de type parmi ceux fabriqués et soumis à l'essai conformément à l'IEC 62271 (toutes les parties).

Il convient de choisir les entraînements électriques de puissance HT à vitesse variable et leurs éléments parmi ceux fabriqués et soumis à l'essai conformément à l'IEC 61800 (toutes les parties).

### 4.3 Alimentation électrique

#### 4.3.1 Généralités

L'équipement électrique doit être prévu pour fonctionner convenablement dans les conditions d'alimentation

– comme spécifié en 4.3.2, ou

– comme spécifié par l'utilisateur (voir l'Annexe B), ou

– comme spécifié par le fournisseur dans le cas de source particulière d'alimentation (voir 4.3.3).

### 4.3.2 Caractéristiques de tension

Il convient que les équipements haute tension des machines soient en mesure de fonctionner dans les conditions d'alimentation décrites par les exigences de l'IEC TS 62749.

| | |
|---|---|
| Tension | Tension permanente comprise entre 0,9 et 1,1 de la valeur nominale.<br><br>NOTE 1 En cas de réduction de la tension sous la valeur nominale, les performances des actionneurs peuvent être affectées. |
| Fréquence | ±1 % de la valeur nominale de façon continue;<br>±2 % sur une courte période. |
| Harmoniques | Il convient que la distorsion harmonique totale (THD – *total harmonic distortion*) de la tension soit inférieure ou égale à 8 % de la tension efficace totale entre conducteurs actifs (somme des harmoniques de rang 2 à 50). |
| Déséquilibre de tension | Ni la tension de la composante inverse, ni la tension de la composante homopolaire dans une alimentation triphasée ne doivent être supérieures à 2 % de la tension de la composante directe. |

NOTE 2 Les caractéristiques de tension continue de l'alimentation électrique sont à l'étude.

### 4.3.3 Source de puissance embarquée

Pour des alimentations spécifiques telles que les générateurs embarqués, les limites données en 4.3.2 peuvent être dépassées si l'équipement électrique est conçu pour fonctionner correctement dans ces conditions.

## 4.4 Environnement physique et conditions de fonctionnement

### 4.4.1 Généralités

L'équipement HT doit convenir à l'utilisation dans l'environnement physique et dans les conditions de fonctionnement spécifiés de 4.4.2 à 4.4.8 de l'IEC 60204-1:2016. Des influences et conditions environnementales supplémentaires peuvent se présenter, auquel cas elles doivent être prises en considération. Lorsque l'environnement physique ou les conditions de fonctionnement diffèrent de ceux spécifiés, un accord peut être nécessaire entre le fournisseur et l'utilisateur (voir l'Annexe B pour la spécification des exigences minimales).

### 4.4.2 Compatibilité électromagnétique (CEM)

Les équipements haute tension des machines ne doivent pas engendrer de perturbations électromagnétiques supérieures aux niveaux adaptés à leur environnement de fonctionnement prévu. De plus, les équipements HT doivent présenter un niveau d'immunité adapté aux perturbations électromagnétiques de manière à pouvoir fonctionner dans leur environnement prévu.

Des essais d'immunité et/ou d'émission sont exigés pour l'équipement électrique à moins que les conditions suivantes ne soient remplies:

– les appareils et les composants intégrés satisfont aux exigences CEM concernant l'environnement CEM prévu, spécifiées dans la norme de produit applicable (ou dans une norme générique en l'absence de norme de produit); et

– l'installation et le câblage électriques sont conformes aux instructions fournies par le fournisseur des appareils et des composants eu égard aux influences réciproques

(câblage, blindage, mise à la terre, etc.), ou à l'Annexe H informative de l'IEC 60204-1:2016 si lesdites instructions ne sont pas disponibles.

Concernant les systèmes de commande d'équipements HT, les règles de base applicables à la CEM décrites en 9.6 de l'IEC 61936-1:2010 et de l'IEC 61936-1:2010/AMD1:2014 s'appliquent. Concernant les équipements HT électroniques (par exemple, convertisseurs de puissance, entraînements électriques de puissance), les dispositions de CEM de la norme de produit correspondante s'appliquent.

### 4.5 Transport et stockage

Le 4.5 de l'IEC 60204-1:2016 s'applique.

### 4.6 Dispositions pour la manutention

Les équipements électriques lourds et massifs qui doivent être désolidarisés de la machine pour le transport, ou qui sont indépendants de celle-ci, doivent être équipés de moyens adaptés à la manutention par grue ou équipement similaire (voir aussi 14.5). Le cas échéant, l'équipement doit être étiqueté afin de présenter la méthode correcte de levage. Le poids maximal de l'équipement lorsque celui-ci est entièrement équipé doit également être indiqué.

### 4.7 Installation

#### 4.7.1 Généralités

L'équipement électrique haute tension doit être installé conformément aux exigences de l'Article 8 de l'IEC 61936-1:2010 et de l'IEC 61936-1:2010/AMD1:2014 et aux instructions du fournisseur afin de:

– permettre l'accès en toute sécurité du personnel à des fins de manœuvre et de maintenance;

– faciliter l'élimination des défauts dans des conditions sûres de fonctionnement.

Lorsque l'éclairage est installé pour l'équipement HT, les dispositions correspondantes de 7.2.6 et de 15.2 de l'IEC 60204-1:2016 s'appliquent. Voir 18.2.

#### 4.7.2 Assemblage et montage

Lorsque l'équipement n'est pas complètement assemblé pour le transport, il convient de marquer de manière claire toutes les unités de transport. Il convient de fournir avec l'équipement des schémas détaillés représentant l'assemblage de ces parties séparées, y compris le câblage lié et les dispositions visant à maintenir l'intégrité de l'équipement en matière de sécurité.

## 5 Extrémités des conducteurs d'alimentation et appareils de coupure et de sectionnement

### 5.1 Extrémités des conducteurs à haute tension

Toutes les extrémités pour le raccordement de l'alimentation doivent être clairement identifiées en accord avec l'IEC 60445.

### 5.2 Borne de terre de l'équipement haute tension

L'équipement haute tension doit être équipé d'une borne de terre pour le raccordement d'un conducteur de terre adapté aux conditions de défaut spécifiées.

Le point de raccordement doit être marqué avec le symbole «terre de protection» IEC 60417-5019:2006-08.

## 5.3 Appareils de sectionnement de l'alimentation pour la mise à la terre

### 5.3.1 Généralités

Un appareil de sectionnement de l'alimentation doit être fourni pour

– chaque source d'alimentation d'une machine;

  Exception: Dans le cas d'une production embarquée (par exemple, générateur diesel) comme unique source d'alimentation, le sectionneur n'est pas nécessaire si la tension peut être réduite jusqu'à un niveau nul et maintenue à ce niveau par d'autres moyens;

– les systèmes d'alimentation utilisant des ensembles de fils conducteurs, de barres conductrices, de bagues collectrices, des systèmes de câbles souples (sur tourets, en guirlandes), d'une ou de plusieurs machines;

– chaque alimentation embarquée en présence de plusieurs générateurs pour une même alimentation (par exemple, barre omnibus commune).

Cet appareil de sectionnement doit séparer l'équipement haute tension de la machine du réseau d'alimentation lorsque cela est exigé (par exemple, pour une intervention sur la machine ou sur son équipement électrique).

NOTE 1 Les sectionneurs sont en mesure d'ouvrir et de fermer un circuit uniquement à un courant négligeable (un courant ne dépassant pas 0,5 A) ou si aucune variation significative de la tension ne se produit aux bornes. Par conséquent, les appareils de sectionnement exigent toujours des interrupteurs ou disjoncteurs associés pour la commutation du fonctionnement normal et des courants de défaut; voir l'Article 7.

NOTE 2 Le sectionnement HT implique la séparation (isolation) physique.

S'il y a deux sectionneurs ou plus, des verrouillages de protection pour leur fonctionnement correct doivent être utilisés de sorte qu'aucune situation dangereuse ne puisse survenir ou qu'aucun dommage ne puisse nuire au personnel ou à la machine.

Pour chaque alimentation HT, des dispositions doivent être prévues pour la mise à la terre et en court-circuit de toutes les parties actives en les connectant à l'installation de mise à la terre (par exemple, pour une intervention sur l'équipement HT).

### 5.3.2 Type

L'appareil de sectionnement de l'alimentation doit être l'un des suivants:

a) un interrupteur-sectionneur;

  NOTE 1 Un interrupteur-sectionneur est souvent combiné à des fusibles HPC.

b) un sectionneur équipé d'un dispositif de verrouillage pour garantir qu'il ne peut fonctionner que si un interrupteur ou un disjoncteur associé a coupé le circuit de charge;

c) un ensemble fiche-prise (voir 3.33) pour un câble souple (par exemple, sur tourets, en guirlandes) alimentant une machine mobile dans les conditions suivantes:

  – Il ne doit pas être possible de raccorder ou de déconnecter un ensemble fiche-prise pendant des conditions de charge ou en présence de tension. Les effets des courants de charge doivent être pris en compte.

  – L'ensemble fiche-prise doit être raccordé de sorte que le côté raccordé à la source présente un degré de protection au moins égal à IP 2XH ou IP XXBH s'il est utilisé dans une zone fermée de service électrique, ou à IP 4XH ou IP XXDH s'il est utilisé à l'extérieur de la zone fermée de service électrique.

  NOTE 2 Les ensembles fiche-prise haute tension sont conçus conformément à l'EN 50181.

Lorsqu'ils sont utilisés, les sectionneurs doivent être conçus et choisis conformément à l'IEC 62271-102.

### 5.3.3 Exigences relatives aux sectionneurs

Lorsque le sectionneur est de l'un des types définis en 5.3.2 a) ou en 5.3.2 b), il doit être conforme à l'IEC 62271-102.

Par exemple, le sectionneur doit

– avoir une poignée extérieure pour assurer la fonction de sectionnement (il peut s'agir de la poignée utilisée pour commander l'appareil de mise à la terre);
– avoir un indicateur de position fiable;
– déconnecter tous les conducteurs actifs du circuit d'alimentation.

La MISE HORS TENSION (sectionné) et une position MISE SOUS TENSION doivent être clairement marquées par «O» et «I» (symboles IEC 60417-5008:2002-10 et IEC 60417-5007:2002-10).

Si un interrupteur-sectionneur (spécifié en 5.3.2. a)) est utilisé, il doit se conformer à l'IEC 62271-102 et l'IEC 62271-103 et son pouvoir de coupure doit être suffisant pour interrompre le courant du moteur le plus puissant lorsque le rotor est bloqué avec la somme des courants de fonctionnement normal de tous les autres moteurs et/ou charges. Le pouvoir de coupure calculé peut être réduit en utilisant un facteur de diversité (simultanéité) reconnu.

NOTE Concernant les moteurs alimentés par des convertisseurs ou des appareils similaires, le courant maximal de fonctionnement du convertisseur s'applique.

L'ouverture intempestive des sectionneurs doit être empêchée. Selon l'appréciation du risque, les systèmes de verrouillage commandés à distance doivent avoir un niveau d'intégrité de sécurité (SIL – *safety integrity level*) ou un niveau de performance (PL – *performance level*) approprié conformément à l'IEC 62061 ou à l'ISO 13849-1.

Lorsqu'un interrupteur-sectionneur est associé à des fusibles HT, l'ensemble doit être conforme à l'IEC 62271-105.

Lorsque des circuits-switchers fusiblés sont utilisés, l'ensemble doit être conforme à l'IEC 62271-107.

Si un moyen de manœuvre externe (par exemple, une poignée) est prévu, il convient qu'il soit de couleur noire ou grise. Exception: Si un interrupteur-sectionneur peut être manœuvré localement pour assurer la fonction d'arrêt d'urgence, son actionneur doit satisfaire aux exigences de couleurs de 10.2.1 de l'IEC 60204-1:2016.

### 5.3.4 Exigences relatives à la mise à la terre et aux courts-circuits

Les moyens de mise à la terre doivent pouvoir supporter le courant présumé de court-circuit de l'alimentation.

Lorsqu'il est utilisé, le sectionneur de terre doit être conforme à l'IEC 62271-102.

Par exemple, le sectionneur de terre doit

– avoir un indicateur de position fiable;
– avoir une poignée extérieure pour assurer la fonction de mise à la terre (il peut s'agir de la poignée utilisée aussi pour commander l'appareil de sectionnement);
– mettre à la terre et en court-circuit tous les conducteurs actifs à l'installation de mise à la terre.

Il convient que le verrouillage mécanique en position MISE SOUS TENSION et en position MISE HORS TENSION soit possible, de préférence par des cadenas.