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Earth-moving machinery — Electrical safety of machines utilizing electric drives and related components and systems —

Part 1: General requirements

Engins de terrassement — Sécurité électrique des machines utilisant des moteurs électriques et composants et systèmes connexes —

Partie 1: Exigences générales

Reference number
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Contents

Page

Foreword ..... **vii**

Introduction ..... **viii**

1 Scope **1**

2 Normative references **2**

3 Terms, definitions and abbreviated terms **3**
3.1 Electric shock protection-related terms and definitions 3
3.2 Control-related terms and definitions 5
3.3 Electrical infrastructure-related terms and definitions 6
3.4 Risk-related terms and definitions 7
3.5 Miscellaneous terms and definitions 8
3.6 Abbreviated terms 9

4 General requirements **9**
4.1 General 9
4.2 Provisions for handling 9
4.3 Provisions for transportation and storage 10
4.4 Components and devices 10
4.5 Intended operating environment 10
4.5.1 General 10
4.5.2 Exposure 10
4.5.3 Altitude 11
4.5.4 Ingress protection 11
4.6 Electrical source 11

5 Protection against electric shock hazards **11**
5.1 General 11
5.2 Protection by enclosures 11
5.3 Protection by insulation 12
5.4 Protection against residual voltages 13
5.5 Protection by barriers 13
5.6 Protection by inaccessibility 13
5.7 Special considerations for low voltage energy storage devices and related buses 13
5.8 Prevention of touch voltage 14
5.8.1 General 14
5.8.2 Protection by class II construction or equivalent 14
5.8.3 Protection by electrical separation 14
5.9 Protection by automatic disconnection of source 15
5.10 Protection by equipotential bonding 15
5.10.1 General 15
5.10.2 Protective equipotential bonding circuit 16
5.10.3 Functional equipotential bonding 18
5.10.4 Devices for earthing and short-circuiting live parts 19
5.11 Protection by use of PELV 19
5.11.1 General 19
5.11.2 Sources for PELV 19

6 Protection against electrical fire hazards **20**
6.1 General 20
6.2 Fire hazard assessment 20
6.3 Prevention of ignition 20
6.4 Minimizing the spread of fire 20

7 Protection against thermal hazards **20**

8 Protection against mechanical hazards **20**

9 Protection against abnormal operation hazards **20**

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9.1 General ... 20
9.2 Overcurrent protection (OCP) ... 21
9.2.1 General ... 21
9.2.2 Transformers ... 21
9.2.3 Overcurrent protection (OCP) implementation ... 21
9.2.4 Rating and setting of overcurrent protective systems ... 21
9.2.5 Placement of overcurrent protective devices ... 21
9.3 Abnormal temperature protection ... 22
9.4 Earth (or chassis in the case of self-powered machines) fault/residual current protection ... 22
9.5 Protection against overvoltages due to lightning and to switching surges ... 22
9.6 Protection against other abnormal operation hazards ... 22

10 Electric power source ... 22
10.1 Disconnection of source ... 22
10.1.1 General ... 22
10.1.2 Source disconnecting devices ... 23
10.1.3 Equipment disconnecting devices ... 24
10.2 Prevention of unintended start-up ... 24
10.3 External electrical charging ... 24

11 Wiring ... 24
11.1 General ... 24
11.2 Conductors ... 25
11.3 Insulation ... 25
11.4 Conductor and cable ampacity ... 25
11.5 Flexible cables ... 26
11.5.1 General ... 26
11.5.2 Mechanical rating ... 26
11.5.3 Ampacity of cables wound on reels ... 26
11.6 Assemblies having sliding contacts ... 26
11.6.1 Accessibility of live parts ... 26
11.6.2 Protective conductor circuit ... 27
11.6.3 Protective conductor current collectors ... 27
11.6.4 Removable current collectors used for disconnection ... 27
11.6.5 Clearances ... 27
11.6.6 Creepage distances ... 27
11.6.7 Conductor system sectioning ... 28
11.6.8 Construction and installation ... 28
11.7 Connections and routing ... 28
11.7.1 General ... 28
11.7.2 Conductor and cable runs ... 28
11.7.3 Conductors of different circuits ... 29
11.8 Identification of conductors ... 29
11.8.1 General ... 29
11.8.2 Protective conductor identification ... 29
11.8.3 Neutral conductor identification ... 29
11.8.4 Identification by colour ... 30
11.9 Wiring inside enclosures ... 31
11.10 Wiring outside enclosures ... 31
11.10.1 General ... 31
11.10.2 External ducts ... 31
11.10.3 Connection to moving elements of the EMM ... 31
11.10.4 Interconnection of devices on the EMM ... 32
11.10.5 Plug/socket combinations ... 33
11.10.6 Dismantling for shipment ... 34
11.10.7 Spare conductors ... 34
11.11 Ducts and boxes ... 34
11.11.1 General ... 34

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11.11.2 Rigid metal conduit and fittings 35
11.11.3 Flexible metal conduit and fittings 35
11.11.4 Flexible nonmetallic conduit and fittings 35
11.11.5 Cable trunking systems 35
11.11.6 EMM compartments and cable trunking systems 35
11.11.7 Boxes 35
11.11.8 Motor wiring boxes 35

12 Electric motors and generators 36
12.1 General 36
12.2 Enclosures 36
12.3 Dimensions 36
12.4 Mounting and compartments 36
12.5 Criteria for motor selection or design 36
12.6 Overheating protection 37
12.7 Overspeed protection 37

13 Non-motor loads 37
13.1 Accessories 37
13.2 Local lighting 38
13.2.1 General 38
13.2.2 Source 38
13.2.3 Protection 38
13.2.4 Fittings 38

14 Controls 39
14.1 Control circuits 39
14.1.1 Control circuit voltages 39
14.1.2 Protection 39
14.2 Control functions 39
14.3 Protective interlocks 39
14.3.1 Reclosing or resetting of an interlocking safeguard 39
14.3.2 Operating limits, auxiliary functions, interlocks, and reverse current braking 39
14.4 Control functions in the event of failure 39
14.4.1 General 40
14.4.2 Measures to minimize risk in the event of failure 40
14.4.3 Protection against malfunction due to earth (or chassis in the case of self-powered machines) faults, voltage interruptions and loss of continuity 41
14.5 Operator interface and machine-mounted control devices 42
14.5.1 General 42
14.5.2 Push-buttons 42
14.5.3 Indicator lights and displays 43
14.5.4 Illuminated push-buttons 43
14.5.5 Rotary control devices 43
14.5.6 Start devices 43
14.5.7 Emergency stop devices 43
14.5.8 Emergency switching off devices 43
14.5.9 Enabling control devices 43
14.6 Controlgear: location, mounting, and enclosures 43
14.6.1 General 43
14.6.2 Location and mounting 43
14.6.3 Degrees of protection 44
14.6.4 Enclosures, doors, and openings 45
14.6.5 Access to controlgear 46
14.7 Access to low and high-voltage equipment 46

15 Manuals and technical documentation 46
15.1 General 46
15.2 Information to be provided 46
15.3 Documentation 46

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15.4 Overview diagrams and function diagrams 47
15.5 Circuit diagrams 47
15.6 Operator's manual 47
15.7 Maintenance manual and service literature 47
15.7.1 General 47
15.7.2 Reduction of electrical hazards while servicing 48
15.8 Parts list 48

16 Marking 49
16.1 General 49
16.2 Warning signs 49
16.2.1 Electric shock hazard 49
16.2.2 Hot surfaces hazard 49
16.2.3 Magnetic field hazard 49
16.2.4 Arc flash hazard 49
16.2.5 Residual voltage hazard 50
16.3 Functional identification 50
16.4 Marking of equipment 50
16.4.1 General 50
16.4.2 Indication of hazardous voltages (all machines) 50
16.5 Reference designations 50
16.6 Protective equipotential bonding terminals 50

17 Tests 50
17.1 General 50
17.2 Protective equipotential bonding circuit continuity 51
17.3 Conditions for protection by automatic disconnection of source 51
17.3.1 General 51
17.3.2 Fault loop impedance verification and suitability of the associated overcurrent protective device in TN systems 52
17.4 Insulation resistance tests 52
17.4.1 Low-voltage insulation resistance test 52
17.4.2 High-voltage insulation resistance test 52
17.5 Voltage withstand tests 52
17.6 Protection against residual voltages 53
17.7 Functional tests 53
17.8 Retesting 53
17.9 IP test for high-voltage equipment 53

Annex A (informative) **List of significant hazards 54**

Annex B (normative) **TN systems — Protection against indirect contact 56**

Annex C (informative) **Explanation of emergency operation functions 59**

Annex D (informative) **Comparison of selected requirements of ISO 14990, UN ECE R100 and ISO 6469-3 ..... 60**

Bibliography 65

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html

The committee responsible for this document is ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 3, *Machine characteristics, electrical and electronic systems, operation and maintenance*.

This document is intended to be used in conjunction with ISO 14990-2 and ISO 14990-3.

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Introduction

This document is a type-C standard as defined in ISO 12100.

The machinery concerned and the extent to which hazards, hazardous situations, or hazardous events are covered are indicated in Annex A of this document.

When requirements of this type-C standard are different from those stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

Electrification is an enabling technology providing increased flexibility in machine form packaging. Because in the past earth-moving machinery (EMM) electrical systems have predominately been in the 12–24 V DC range, two safety aspects require particular attention:

— significantly higher voltages, such as are utilized in industrial or structural applications and in other transportation sectors;

— greater available electrical energy.

Portions of this document appear to govern electrical design practices (e.g. Clauses 9, 11, 12, and 17). Their requirements are necessary because certain aspects of design cannot be separated from electrical safety.

Some of the content of this document is based on IEC 60204-1 and IEC 60204-11, adapted to the needs of earth-moving machinery. Non-electrical hazards are addressed in the ISO 20474 series.

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Earth-moving machinery — Electrical safety of machines utilizing electric drives and related components and systems —

Part 1: General requirements

1 Scope

This document specifies general safety requirements for the electrical equipment and its components incorporated into earth-moving machines (EMMs) as defined in ISO 6165, and addresses the safety of operators, technicians, service/maintenance personnel and bystanders.

It is applicable to those machines using on-board voltages in the ranges of 50 V–36 kV AC r.m.s. at any frequency and 75 V–36 kV DC — including any repetition rate of pulsating DC — intended for outdoor use. It is applicable to both low and high voltages, except where its applicability to high- or low-voltage equipment only is indicated. Voltages occurring within devices are not considered to be on-board voltages and are thus not within its scope.

NOTE 1 Special considerations typically apply at frequencies greater than 30 kHz. Where reference standards are limited to frequencies below those used on the EMM, it is the responsibility of the user to assess the risks and address them appropriately.

This document covers all significant hazards, hazardous situations, and hazardous events relevant to the voltage range for earth-moving machinery within its scope when the machinery is used as intended or under conditions of misuse reasonably foreseeable by the manufacturer. It specifies appropriate technical measures for eliminating or reducing risks arising from significant hazards, hazardous situations, or hazardous events during commissioning, operation, and maintenance. It is not applicable to machines manufactured before the date of its publication.

It is intended to be used in conjunction with ISO 14990-2 and ISO 14990-3, which give provisions specific to the machine's power source that take precedence over the requirements of this document for the machines covered. For multipurpose machinery, all those parts of ISO 14990 are applicable whose requirements cover the functions and applications of the machine.

Even though this document addresses most hazards associated with the use of low- or high-voltage electrical systems in earth-moving machines, owing to the possible presence of additional electrical hazards, conformance with it cannot be taken as an absolute guarantee of electrical safety. Areas of concern are included in the list of significant hazards found in Annex A.

This document specifies requirements for on-board generators, electrically isolated from other low-voltage systems and provided as power sources for general-purpose socket outlets installed on EMMs, and transformer or inverter power sources for general-purpose socket outlets.

NOTE 2 Local or regional requirements may also apply to general-purpose socket outlet arrangements.

Although nominal 12 V and 24 V (alternator/battery) systems are not addressed, the meeting of some of the requirements, including those of PELV, will ensure that the low-voltage system is sufficiently isolated from 12 V and 24 V systems.

This document does not address risks associated with explosive atmospheres, which are sometimes found in mining and other EMM applications.

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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.

ISO 2860, *Earth-moving machinery — Minimum access dimensions*

ISO 2867:2011, *Earth-moving machinery — Access systems*

ISO 3457:2003, *Earth-moving machinery — Guards — Definitions and requirements*

ISO 9244:2008, *Earth-moving machinery — Machine safety labels — General principles*. Amended by ISO ISO 9244:2008/Amd. 1:2016

ISO 14990-2:2016, *Earth-moving machinery — Electrical safety of machines utilising electric drives and related components and systems — Part 2: Particular requirements for externally-powered machines*

ISO 14990-3, *Earth-moving machinery — Electrical safety of machines utilising electric drives and related components and systems — Part 3: Particular requirements for self-powered machines*

ISO 15817, *Earth-moving machinery — Safety requirements for remote operator control systems*

IEC 60071-1:2006, *Insulation Coordination — Part 1: Definitions, principles and rules.* Amended by IEC 60071-1:2006/Amd. 1:2010

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

IEC 60204-1:2005, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*. Amended by IEC 60204-1:2005/Amd. 1:2008

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

IEC 60364-4-41:2005, *Electrical installations of buildings Part 4-41: Protection for safety Protection against electric shock*

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

IEC 60417-DB, *Graphical symbols for use on equipment*[1)]

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

IEC 60617-DB, *Graphical symbols for diagrams*[2)]

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

IEC 60871-1: 2014, *Shunt capacitors for AC power systems having a rated voltage above 1 000 V — Part 1: General*

IEC 60947-1, *Low-voltage switchgear and controlgear — Part 1: General rules*

IEC 61230, *Live working — Portable equipment for earthing or earthing and short-circuiting*

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

IEC 61557 (all parts), *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. — Equipment for testing, measuring or monitoring of protective measures*

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1) Online database: available at http://www.graphical-symbols.info/

2) Online database: available at http://std.iec.ch/iec60617

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IEC 61558-1, *Safety of power transformers, power supply units and similar — Part 1: General requirements and tests*

IEC 61558-2-6, *Safety of power transformers, power supply units and similar — Part 2-6: Particular requirements for safety isolating transformers for general use*

IEC 61984, *Connectors — Safety requirements and tests*

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

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms, definitions and abbreviated terms given in ISO 12100 and the following 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 Electric shock protection-related terms and definitions

3.1.1
electrically protective barrier
barrier
part providing protection against direct contact from any usual direction of access

[SOURCE: IEV 826-12-23]

3.1.2
direct contact
electric contact of persons with live parts

[SOURCE: IEV 826-12-03, modified]

3.1.3
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* (3.1.1) without the use of a key or tool, and which is clearly marked by appropriate warning signs

[SOURCE: IEC 60204-1: 2005, 3.15]

3.1.4
electrically protective enclosure
protective enclosure
enclosure
electrical enclosure (3.1.5) surrounding internal parts of equipment to prevent access to hazardous-live-parts from any direction

[SOURCE: IEV 826-12-22]

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3.1.5
electrical enclosure
enclosure (3.1.4) providing protection against the foreseen dangers created by electricity

[SOURCE: IEV 826-12-21, modified]

Note 1 to entry: Some electrical enclosures also provide protection for equipment. It can be either of discrete construction or an enclosed space within the *machine* (3.5.2).

3.1.6
equipotential bonding
provision of electric connections between conductive parts, intended to achieve equipotentiality

[SOURCE: IEV 195-1-10]

3.1.7
protective equipotential bonding
equipotential bonding (3.1.6) for the purposes of safety

[SOURCE: IEV 195-01-15]

3.1.8
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: IEV 826-12-10]

3.1.9
extra-low voltage
ELV
voltage supplied from a source within the device that does not exceed 50 V between conductors and between conductors and earth (or chassis in the case of self-powered machines) when the device is supplied at rated voltage

[SOURCE: IEC 60335-1, 3.4.1, modified]

3.1.10
extraneous conductive part
conductive part not forming part of the electrical equipment and liable to introduce a potential, generally the ground (or chassis in the case of self-powered machines) potential

[SOURCE: IEV 826-12-11, modified]

3.1.11
indirect contact
contact of persons with *exposed conductive parts* (3.1.8) which have become live due to fault conditions

[SOURCE: IEV 826-12-04, modified]

3.1.12
live part
conductor or conductive part intended to be energized in normal use, including a neutral conductor, but, by convention, not a PEN conductor

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

[SOURCE: IEC 60204-1: 2005, 3.33]

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3.1.13
obstacle
part preventing unintentional direct contact, but not preventing direct contact by deliberate action

[SOURCE: IEC 60204-1: 2005, 3.38]

3.1.14
protective conductor
conductor provided for purposes of safety, e.g. protection against electric shock

[SOURCE: IEV 826-13-22, modified]

Note 1 to entry: A protective conductor is typically used to connect any of the following:

— exposed conductive parts;

— extraneous conductive parts;

— PE (or chassis ground in the case of self-powered machines) terminal.

3.1.15
protective extra-low voltage
PELV
earthed (or chassis-bonded in the case of self-powered machines) circuit operating at safety extra-low voltage which is separated from other circuits by basic insulation and protective screening, double insulation or reinforced insulation

[SOURCE: IEC 60335-1, 3.4.4, modified]

Note 1 to entry: Protective screening is the separation of circuits from live parts by means of an earthed (or chassis-bonded in the case of self-powered machines) screen.

3.1.16
safety extra-low voltage
SELV
voltage not exceeding 42 V between conductors and between conductors and earth (or chassis in the case of self-powered machines), the no-load voltage not exceeding 50 V

[SOURCE: IEC 60335-1, 3.4.2, modified]

Note 1 to entry: When safety extra-low voltage is obtained from the source mains, it is through a safety isolating transformer or a convertor with separate windings, the insulation of which complies with double insulation or reinforced insulation requirements.

3.1.17
touch voltage
voltage between conductive parts when touched simultaneously by a person or animal

[SOURCE: IEV 195-05-11]

Note 1 to entry: The value of the effective touch voltage may be appreciably influenced by the impedance of the person or the animal in electric contact with these conductive parts.

3.2 Control-related terms and definitions

3.2.1
actuator
part of the actuating system to which an external actuating force is applied

Note 1 to entry: An actuator typically takes the form of a handle, knob, push-button, roller, plunger, etc.

Note 2 to entry: Cf. 3.2.5.

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[SOURCE: IEC 60204-1: 2005, 3.1, modified]

3.2.2
controlgear
switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, *enclosures* (3.1.4) and supporting structures, intended in principle for the control of electric energy consuming equipment

[SOURCE: IEV 441-11-03]

3.2.3
emergency switching-off device
manually actuated control device used to switch off the source of electrical energy to all or a part of the electrical equipment of a *machine* (3.5.2) where a risk of electric shock or another risk of electrical origin is involved

[SOURCE: IEC 60204-1: 2005, 3.18, modified]

3.2.4
emergency stop device
manually actuated control device used to initiate an emergency stop function

[SOURCE: ISO 13850, 3.2]

3.2.5
machine actuator
electromechanical or electronic power mechanism used to effect a function of the *machine* (3.5.2)

[SOURCE: IEC 60204-1: 2005, 3.34, modified]

3.3 Electrical infrastructure-related terms and definitions

3.3.1
ampacity
maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating

3.3.2
cable trunking system
system of enclosures, each consisting of a base with a removable cover, intended to completely enclose insulated conductors, cables, cords and for the accommodation of other electrical devices

[SOURCE: IEV 442-02-34, modified]

3.3.3
direct opening action
<of a contact element> achievement of contact separation as the direct result of a specified movement of the switch *actuator* (3.2.1) through non-resilient members (e.g. not dependent upon springs)

[SOURCE: IEC 60947-5-1: 2009, K.2.2]

3.3.4
duct
enclosed channel designed specifically to hold and protect electrical conductors, cables, and busbars

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

[SOURCE: IEC 60204-1: 2005, 3.14, modified]

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3.3.5
functional equipotential bonding
equipotential bonding for operational reasons other than safety

[SOURCE: IEV 195-01-16]

3.3.6
high voltage
HV
voltage greater than 1 000 V AC and not exceeding 36 kV AC r.m.s or greater than 1500 V DC and not exceeding 36 kV DC

3.3.7
low voltage
voltage greater than 50 V AC and not greater than 1000 V AC r.m.s or greater than 75 V DC and not greater than 1500 V DC

3.4 Risk-related terms and definitions

3.4.1
failure
termination of the ability of a device to perform a required function

Note 1 to entry: After failure, the item has a *fault* (3.4.2).

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.

[SOURCE: IEV 191-04-01, modified]

3.4.2
fault
state of a device characterized by its inability to perform a required function

Note 1 to entry: A fault is often the result of a *failure* (3.4.1) of the item itself, but in some instances exists without prior failure.

[SOURCE: IEC 60204-1: 2005, 3.26, modified]

3.4.3
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 (e.g. mechanical hazard, electrical hazard) or the nature of the potential harm (e.g. electric shock hazard, cutting hazard, toxic hazard, and fire hazard).

Note 2 to entry: The hazard envisaged in this definition is either

— permanently present during the intended use of the *machine* (3.5.2) (e.g. motion of hazardous moving elements, electric arc during a welding phase, unhealthy posture, noise emission, high temperature), or

— can appear unexpectedly (e.g.: 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]

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3.4.4
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]

3.4.5
safeguard
guard or protective device or protective function provided as a means to protect persons from a *hazard* (3.4.3)

[SOURCE: IEC 60204-1:2005, 3.49, modified]

3.4.6
safeguarding
protective measure using safeguards to protect persons from the *hazards* (3.4.3) which cannot reasonably be eliminated or from the *risks* (3.4.4) which cannot be sufficiently reduced by inherently safe design measures

[SOURCE: ISO 12100:2010, 3.21]

3.5 Miscellaneous terms and definitions

3.5.1
electrically instructed person
instructed person
person adequately advised or supervised by an electrically skilled person to enable him or her to perceive *risks* (3.4.4) and to avoid *hazards* (3.4.3) which electricity can create

[SOURCE: IEV 826-18-02, modified]

3.5.2
machinery
machine
assembly of linked parts or components, at least one of which moves, with the appropriate *machine actuators* (3.2.5), control and power circuits, joined together for a specific application

Note 1 to entry: The term machinery also covers an assembly of machines which, in order to achieve the same end, are arranged and controlled so that they function as an integral whole.

[SOURCE: ISO 12100:2010, 3.1, modified]

3.5.3
overload
<of a circuit> non-fault time-current event in a circuit, in which the electrical ratings of the circuit are exceeded

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

[SOURCE: IEC 60204-1: 2005, 3.40, modified]

3.5.4
electrically skilled person
skilled person
person with relevant training, education, and experience to enable him or her to perceive risks and to avoid hazards associated with electricity

[SOURCE: IEV 826-18-01, modified]

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3.6 Abbreviated terms

EMM earth-moving machinery

ELV extra-low voltage

PE protective earthing (or protective equipotential bonding to chassis in the case of self-powered machines)

PELV protective extra-low voltage

SELV safety extra-low voltage

PPE personal protective equipment

TN *terra* neutral (IEC 60364-1-defined earthing system)

TT *terra terra* (IEC 60364-1-defined earthing system)

IT isolation *terra* (IEC 60364-1-defined earthing system)

OCP overcurrent protection (e.g. a fuse, a circuit breaker, or a solid-state device including its control system)

AC alternating current

DC direct current

4 General requirements

4.1 General

The overall risk assessment for the machine shall include risks associated with electrical hazards. Appropriate risk assessment methods are given in ISO 12100. Annex A provides a list of significant hazards and hazardous situations associated with the use (or misuse), maintenance, and servicing of electrical equipment of earth-moving machines.

Hazards and the risks arising from them shall be identified during the design and development process.

Hazards and risks shall be addressed in the following order of priority or hierarchy:

a) design measures shall provide inherent safety to eliminate hazards or sufficiently reduce risks; if such measures are not practicable;

b) protective measures such as safeguarding shall provide further reduction of risk; if such measures are not practicable, or if still further risk reduction is necessary;

c) additional measures, such as awareness means, shall be employed;

d) working procedures that reduce risk during EMM operation and maintenance shall be implemented in the operator's and service manuals.

Safety measures may be incorporated at the design stage (preferred), or the user may be instructed to implement some measures.

4.2 Provisions for handling

If the user or service personnel are instructed to, or are likely to need, to remove heavy or bulky electrical equipment from the EMM for transport or service, provisions shall be made for handling, such as lifting eyes, fork pockets or the like.

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