BS ISO 14990-1:2016

BSI Standards Publication

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

Part 1: General requirements

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National foreword

This British Standard is the UK implementation of ISO 14990-1:2016.

The UK participation in its preparation was entrusted to Technical Committee B/513/1, Earth moving machinery (International).

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

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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

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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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INTERNATIONAL STANDARD ISO 14990-1:2016(E)

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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4.3 Provisions for transportation and storage

The electrical equipment of the EMM shall be designed to withstand, or shall be protected from, the effects of transportation and storage. Provision shall be made to protect against damage from humidity, vibration, and shock, as well as temperatures more severe than those specified in 4.5.1.

4.4 Components and devices

The components of the electrical system shall be

— suitable for their intended use, and

— applied within applicable ratings and in accordance with the supplier's instructions.

NOTE 1 Suitability for intended use includes conformity with relevant International Standards where these exist.

It is recommended that when an IEC component standard does not exist, relevant requirements of suitable International Standards or of other comparable standards be applied (e.g. applicable parts of the IEC 60034 series of motor standards may be applied to switched reluctance motors.).

NOTE 2 ELV components derived from sources of voltages lower than low voltage and without the possibility of "bleed through" are outside the scope of this document.

High-voltage equipment

If factory-built, type-tested HV switchgear is employed it shall comply with applicable standards (e.g. IEC 62271-1, IEC 62271-200, and IEC 62271-201).

4.5 Intended operating environment

4.5.1 General

Electrical equipment shall be suitable for the environment and operating conditions of its intended application. The criteria for environmental and operating conditions given in ISO 15998:2008, 4.6, are recommended. ISO 19014[3)] may be used as an alternative to ISO 15998. An agreement between user and supplier, based upon the enquiry forms provided in ISO 14990-2 and ISO 14990-3, might also be necessary.

NOTE ISO 15998:2008, 4.6, covers the following:

— ambient air temperature range;

— humidity;

— degree of protection (IP Code) (see 4.5.4);

— electromagnetic compatibility (EMC);

— vibration and shock.

An external charging system shall be verified as being compatible with the EMM by the manufacturer, or as specified in ISO 14990-2:2016, 4.2.2.

4.5.2 Exposure

All EMM covered by this document shall be suitable for outdoor use. EMM may also be designed for use indoors. The requirement for suitability for outdoor use includes suitability for outdoor storage during periods of non-use.

3) Under preparation.

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The possibility of harmful internal condensation shall be addressed where necessary by measures such as prevention of condensation or provision for drainage.

4.5.3 Altitude

The electrical equipment of the EMM shall operate properly at altitudes up to 1 000 m above mean sea level. The operator's manual shall instruct the operator as to whether the EMM can be operated at altitudes greater than 1000 m, and if so it shall clearly identify and explain EMM limitations at altitudes greater than 1000 m.

4.5.4 Ingress protection

The electrical equipment of the EMM shall be protected against or be tolerant of the ingress of harmful solids and liquids, including dust, acids, corrosive gases, and salts, that might be present in the operating environment.

For air-cooled resistor grids, a special procedure might be necessary to dry the resistor grid when wet.

4.6 Electrical source

The electrical equipment shall operate correctly with variations of the source

— as specified in ISO 14990-2, for externally-powered machines (e.g. one or more EMMs supplied by one or more dedicated external generator sets),

— as specified in ISO 14990-3, for self-powered machines,

— as otherwise specified by the user.

5 Protection against electric shock hazards

5.1 General

The electrical equipment of the EMM shall provide protection of persons against electric shock. Such protection shall consist of the measures given in 5.2 to 5.11, as appropriate. If an assembly containing live parts is accessible by all persons, the provisions of 5.2 or 5.3, and, if applicable, 5.4, shall be applied.

Exception: If these protective measures are not practicable, other protective measures given in IEC 60364-4-41 or IEC 61140 may be used.

Each circuit or part shall provide protection against indirect contact according to 5.8 or 5.9 or both.

NOTE Classes of equipment and protective provisions are given in IEC 61140.

5.2 Protection by enclosures

Live parts shall be contained within enclosures that comply with the relevant requirements of Clause 4, Clause 12 and Clause 14, and which provide protection against direct contact of at least IP2X or IPXXB.

Exception 1: If the top surfaces of an enclosure are readily accessible, the minimum degree of protection against direct contact provided by those surfaces shall be IP4X or IPXXD.

Exception 2: If an assembly containing live parts is accessible to all persons, the minimum degree of protection against direct contact shall be IP4X or IPXXD.

Exception 3: Air-cooled resistor grids shall only be required to meet a minimum of IP2X or IPXXB, provided they do not create hazardous conditions in the installed position when exposed to rain or dust. If IP2X or IPXXB is not practical, it is also acceptable to use the crushing requirement dimensions

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specified in ISO 3457:2003, 10.7. Normal maintenance procedures shall be specified in the operator's manual, if necessary, to prevent debris build-up.

It shall not be possible to open an enclosure (e.g. via a door, lid, or cover) unless one of the following conditions, a) to c), is satisfied.

a) **Access requires the use of a key or tool**

Live parts likely to be touched when performing adjustments while the equipment is connected shall be protected against direct contact to at least IP2X or IPXXB.

Door-mounted live parts within the enclosure shall be protected against direct contact to at least IP1X or IPXXA.

b) **Live parts inside the enclosure are automatically disconnected if the enclosure is opened**

An example of this measure is an interlock which operates a disconnecting device, arranged such that if the door is open, the disconnecting device is open and cannot be closed if the door is open.

Accessibility of live parts behind doors and not directly interlocked with the disconnecting device shall be limited to skilled persons.

Parts that remain live after switching off the disconnecting device(s) shall be protected against direct contact to at least IP2X or IPXXB. Such parts shall be marked with a warning in accordance with 16.2.1 (see 11.8 for identification of conductors by colour).

Exception 1: this marking requirement does not apply to

— parts that might be live only because they are part of an interlock circuit and that are colour-identified in accordance with 11.8 as potentially live,

— the source terminals of a source disconnecting device if it is mounted alone in an enclosure.

Exception 2: a special device or tool furnished or specified by the supplier may be used to bypass the interlock if the following conditions are met:

— the disconnecting device can be opened and locked in the OFF (open) position, or unauthorized closure of the disconnect is prevented if the interlock is bypassed;

— the interlock function is automatically returned to service upon closing the door;

— live parts likely to be touched when performing adjustments while the equipment is connected shall be protected against direct contact to at least IP2X or IPXXB, and door-mounted live parts within the enclosure shall be protected against direct contact to at least IP1X or IPXXA.

Appropriate information is provided with the electrical equipment in accordance with Clause 15.

c) **All live parts are protected against direct contact to at least IP2X or IPXXB if the enclosure can be opened without the use of a key or a tool or without automatic disconnection of live parts**

If protection is provided by a barrier, a tool shall be required for removal of the barrier or else all live parts protected by it shall be automatically disconnected when it is removed.

If a hazard can be caused by manual actuation of devices such as contactors or relays, manual actuation should be prevented by barriers or obstacles that require a tool for removal.

5.3 Protection by insulation

Live parts protected by insulation shall be completely enclosed by insulation which can be removed only by destruction.

NOTE Paints, varnishes, lacquers, and similar products alone are not generally considered adequate for protection against electric shock.

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5.4 Protection against residual voltages

When a source voltage of electrical equipment is removed (e.g. by disconnection or by stopping a generator), residual voltages within the equipment shall conform to the values in Table 1. If the rate of discharge required to comply with the time limit specified would prevent the equipment from functioning as intended, a warning marking shall be placed at a prominent location on or adjacent to the capacitance enclosure. The warning marking shall state a minimum time interval required before the capacitor enclosure may be opened. This requirement does not apply to components containing stored charge of 60 µC or less. For high-voltage equipment, IEC 60871-1:2014, Clause 21 shall apply.

Table 1 — Residual voltage discharge requirements

Equipment type	Maximum discharge time	Maximum voltage at time limit
Low voltage	10 s	60 V
High voltage	10 min	75 V

In any case, in order to ensure discharge before opening the enclosure, it is recommended that a prominent marking in accordance with 16.2.1 be provided, warning the service person to wait a specified amount of time. The amount of time specified should be greater than that required for discharge to either a voltage ≤60 V, or a stored charge ≤60 µC. The recommended maximum time is 5 min.

Service literature shall provide a method for verification of discharge of residual voltages prior to servicing, and shall stress the necessity of doing so. Service literature shall instruct the service person as to wearing of proper personal protective equipment (PPE) and verification that the residual voltage measuring device is functioning correctly.

Service literature shall provide a procedure for manual discharge of residual voltages in the event of failure of the automatic discharge means. If a device is required for manual discharge of residual voltages, the device shall be provided or specified by the EMM manufacturer.

For low voltage systems, If disconnection by means of a plug or connector results in accessible live parts, voltages of the accessible live parts greater than 60 V shall decrease to 60 V or less within 1 s after disconnection. Alternatively, protection against direct contact to a level of at least IP2X or IPXXB shall be provided. Energy storage devices (e.g. batteries or double-layer energy storage capacitors) are excluded if a warning marking is provided.

5.5 Protection by barriers

Requirements for protection by barriers are given by IEC 60364-4-41:2005, A.2.

NOTE Unless they can be removed without the use of a key or tool, barriers 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 to be part of the enclosure.

5.6 Protection by inaccessibility

Requirements for protection by placing out of reach or by obstacles are given by IEC 60364-4-41:2005, B.3 and B.2, respectively.

5.7 Special considerations for low voltage energy storage devices and related buses

Low-voltage energy storage devices and bus systems that remain energized during servicing shall provide protection from inadvertent contact. Energy storage devices shall be contained in electrical enclosures meeting all the other requirements of Clause 6, except that it shall be allowed to service these devices with low voltage and hazardous amperages exposed. The means of protection shall be

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one or more of methods given in a) to d), below, in addition to e), or methods that offer equivalent levels of hazard reduction:

a) bus systems connecting multiple energy devices: coated or covered by insulating materials in all locations, except in the areas where the electrical connections are made;

b) recessed, separated, or recessed and separated connections to reduce inadvertent contact between exposed live components of differing voltages;

c) bus systems mounted in ways that deflect dropped tools away from making direct contact, such as vertically mounted busbars;

d) bus systems that are interconnected by contact relays, knife switches, or similar devices that allow the energy storage device to be broken in to smaller, less hazardous storage sub-units;

e) warning labels, servicing instructions, or both indicating

— the hazards of electrical shorting,

— methods to be used to prevent shorting, such as using insulated tools and insulated gloves,

— appropriate personal protection equipment.

Energy storage device terminals shall

— be fully shrouded, or

— have insulating barriers installed between them,

or both.

5.8 Prevention of touch voltage

5.8.1 General

Measures to prevent the occurrence of a touch voltage include use of class II or equivalent insulation, and electrical separation.

5.8.2 Protection by class II construction or equivalent

This measure is intended to prevent the occurrence of touch voltages on accessible parts due to a fault in basic insulation.

Protection is accomplished by one or more of the following:

— class II electrical devices or apparatus (double insulation, reinforced insulation or equivalent insulation according to IEC 61140);

— switchgear and controlgear assemblies having total insulation according to IEC 61439-1;

— supplementary or reinforced insulation according to IEC 60364-4-41.

5.8.3 Protection by electrical separation

This measure is intended to prevent a touch voltage on exposed conductive parts that become energized due to a fault in basic insulation of live parts of that circuit. The requirements of IEC 60364-4-41:2005, C.3, apply.

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5.9 Protection by automatic disconnection of source

This measure is intended to interrupt one or more of the line conductors by the automatic operation of a protective device in the event of a fault. Interruption shall occur within a time sufficiently short enough to limit the duration of a touch voltage to a time within which the touch voltage is not hazardous. Interruption times are given in Annex B.

Coordination is required between the following:

— the type of source and earthing (or chassis equipotential bonding in the case of self-powered machines) system;

— the impedances of the relevant parts of the protective equipotential bonding system;

— the characteristics of the protective devices.

This measure includes both protective equipotential bonding of exposed conductive parts and one of the following:

a) in TN systems, OCP for automatic disconnection of the source on detection of an insulation fault, or

b) in TT systems, residual current protective devices to initiate automatic disconnection of the source upon detection of an insulation fault from a live part to exposed conductive parts or to earth (or chassis in the case of self-powered machines), or

c) in IT systems, either

   1) insulation monitoring for the first fault from a live part to exposed conductive parts or to earth (or chassis in the case of self-powered machines), or

2) residual current protective devices that initiate automatic disconnection.

   In respect of 1), above, the insulation monitoring device shall initiate an audible signal, a visual signal, or both, and this signal shall continue as long as the fault persists. Machine operators and service personnel shall be warned about a “first fault” according to 15.7.2.

   NOTE The provision of an earth (or chassis in the case of self-powered machines) fault location system facilitates troubleshooting.

TN, TT, and IT systems are defined by IEC 60364-1, which covers voltages up to 1 000 V AC and 1 500V DC.

This document extends the range of application for TN, TT, and IT systems to 36 kV AC or DC.

Foreseeable misuse, e.g. disabling of the audible or visual signal while continuing operating the machine, shall be also considered.

If automatic disconnection is provided in accordance with a), above, and disconnection time is greater than specified in B.1, supplementary equipotential bonding shall be provided as necessary to comply with B.3 (see Annex B).

5.10 Protection by equipotential bonding

5.10.1 General

Protective equipotential bonding (see 5.10.2) protects persons against electric shock from indirect contact in the event of a fault.

Functional equipotential bonding (see 5.10.3) serves a different purpose, which is to minimize the consequences of insulation failures or electrical disturbances which could affect the operation of the EMM. Functional equipotential bonding is usually achieved by connection to the protective equipotential bonding circuit, but if the level of electrical disturbances on the protective equipotential bonding circuit

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