INTERNATIONAL STANDARD

**ISO 14990-2**

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

## Part 2: Particular requirements for externally-powered machines

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

*Partie 2: Exigences particulières pour les machines à moteur externe*



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# Foreword

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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 14990-1.



 

# 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 ISO 14990-1:2016, Annex A.

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.

Figure 1 is provided as an aid to the understanding of the interrelationship of the various elements of a machine and its associated equipment. Figure 1 is a block diagram of a typical machine and associated equipment showing the various elements of the electrical equipment addressed in this document.

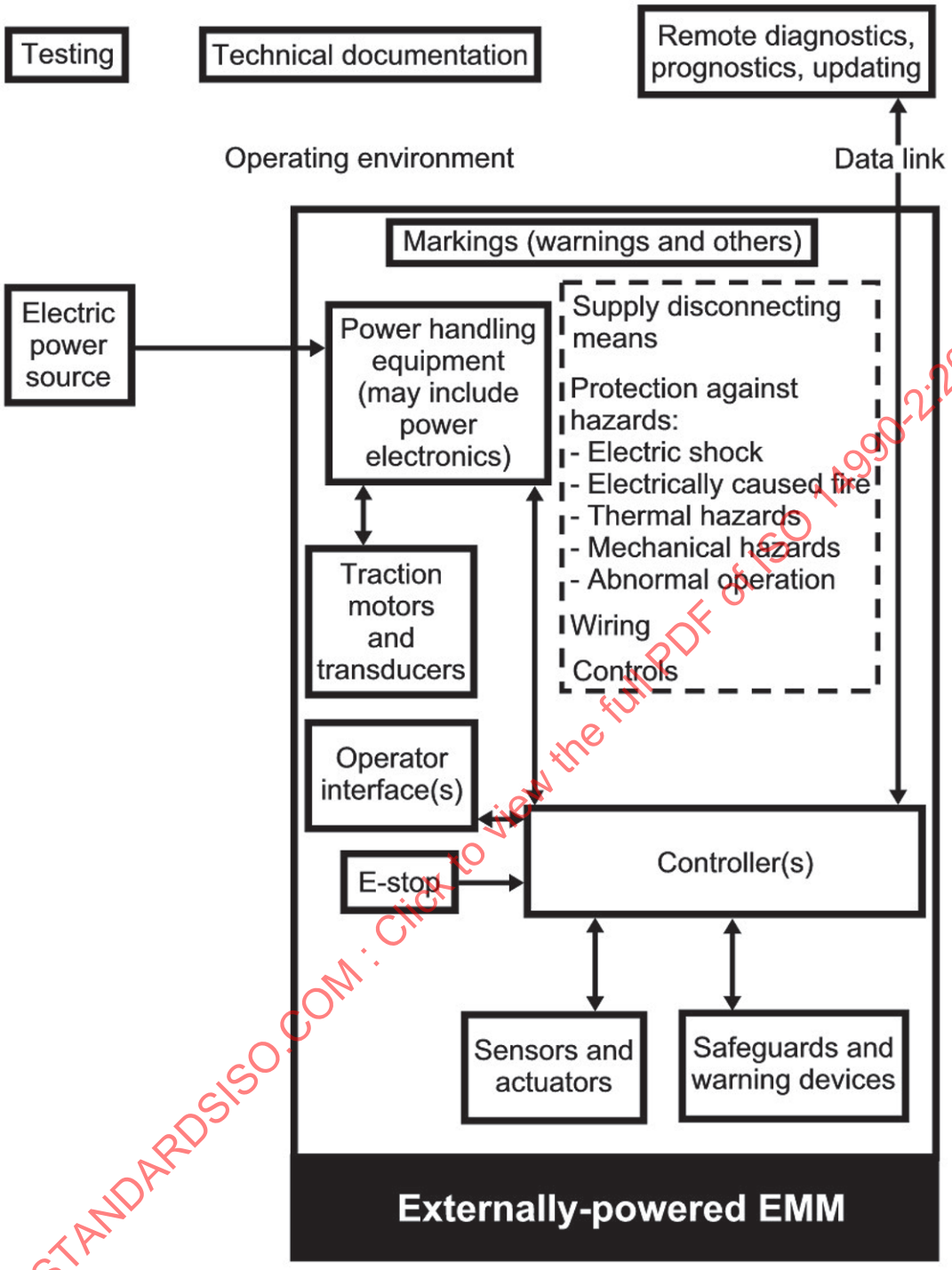




**Figure 1 — Block diagram of a typical machine**

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

## Part 2:
## Particular requirements for externally-powered machines



### 1 Scope

This document specifies the particular safety requirements for the electrical equipment and its components incorporated in externally-powered (mains-connected, including machines powered by external dedicated generators), electrically-driven earth-moving machines (EMMs).

It is applicable to those machines using on-board voltages in the range 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. Voltages occurring within devices are not considered to be on-board voltages and are thus not within its scope.

It is intended to be used in conjunction with ISO 14990-1, which gives general requirements for EMMs regardless of how they are powered. Requirements specific to self-powered machines are given in ISO 14990-3. However, it is possible for an EMM to be both self-powered *and* externally-powered (e.g. a battery-powered machine having a built-in charger with power supply function), in which case ISO 14990-3 is also applicable.

### 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 14990-1:2016, *Earth-moving machinery — Electrical safety of machines utilizing electric drives or related components and systems — Part 1: General requirements*

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

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

IEC 60364-5-52, *Low-voltage electrical installations — Part 5-52: Selection and erection of electrical equipment — Wiring systems*

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

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

### 3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms, definitions and abbreviated terms given in ISO 14990-1 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

# 4 General requirements

## 4.1 General

The requirements of ISO 14990-1:2016, Clause 4, shall apply except as modified by this clause.

## 4.2 Special conditions

The enquiry form given in Annex A can be used as the basis for an agreement between user and supplier to address special conditions, or where certain provisions of this document might not be applicable. The waiver of any requirement shall be limited to situations not covered by this document.

## 4.3 Supplies

### 4.3.1 AC supplies

**Voltage:** Steady-state voltage: 0,9 to 1,1 of nominal voltage.

**Frequency:** 0,99 to 1,01 of nominal frequency continuously; 0,98 to 1,02 short time.

**Harmonics:** Harmonic distortion not exceeding 10 % of the total r.m.s. voltage between live conductors for the sum of the 2nd to the 5th harmonic. An additional 2 % of the total r.m.s. voltage between live conductors for the sum of the 6th to the 30th harmonic is permissible.

**Voltage unbalance:** Neither the voltage of the negative sequence component nor the voltage of the zero sequence component in three-phase supplies exceeding 2 % of the positive sequence component.

**Voltage interruption:** Supply interrupted or at zero voltage for not more than 3 ms at any random time in the supply cycle with more than 1 s between successive interruptions.

**Voltage dips:** Voltage dips not exceeding 20 % of the peak voltage of the supply for more than one cycle with more than 1 s between successive dips.

### 4.3.2 DC supplies

#### 4.3.2.1 From batteries

**Voltage:** 0,85 to 1,15 of nominal voltage; 0,7 to 1,2 of nominal voltage in the case of battery-operated vehicles.

**Voltage interruption:** Not exceeding 5 ms.

#### 4.3.2.2 From converting equipment

**Voltage:** 0,9 to 1,1 of nominal voltage.

**Voltage interruption:** Not exceeding 20 ms with more than 1 s between successive interruptions.

NOTE This is a variation on IEC Guide 106 for ensuring the proper operation of electronic equipment.

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



 

# 5 Protection against electric shock hazards

## 5.1 General

The requirements of ISO 14990-1:2016, Clause 5 shall apply except as modified by this clause.

**5.1.1** See Figure 2 for an example of equipotential bonding for electrical equipment of an externally-powered EMM.

**5.1.2** For EMM 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. 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. The supply to the electrical equipment of the machine or to the relevant part of the machine shall be switched off whenever

— loss of continuity of the protective bonding circuit is detected, or

— failure of the monitoring means occurs.

**Exception:** Maintenance operations involving devices such as battery chargers, block heaters and similar devices, and GFCI/RCD protected circuits.

**5.1.3** Each protective conductor connecting point on a machine shall be marked or labelled as such using the symbol IEC 60417-5019[1)] or with the letters "PE", or by use of the bicolour combination GREEN-AND-YELLOW, or by any combination of these. The graphical symbol is preferred.

## 5.2 Guidance for type of neutral earthing system

For high-voltage equipment, the following general limitations for different voltage ranges and lengths of supply cable apply.

a) **Direct earthing of the neutral**

Only appropriate for system voltages less than 2 kV, (automatic disconnection of supply is always required).

b) **Low impedance earthing of the neutral**

May be appropriate for system voltages up to 36 kV and cable length up to 4 km (automatic disconnection of supply is normally necessary).

c) **Isolated or high impedance earthing of the neutral**

Appropriate for system voltages up to 36 kV and cable length up to 8 km, with the permissible cable length depending upon the capacitive reactance of all cables connected to the supply (automatic disconnection of supply is not normally necessary).



1) ISO Online browsing platform: available at http://www.iso.org/obp. Search using 5019.

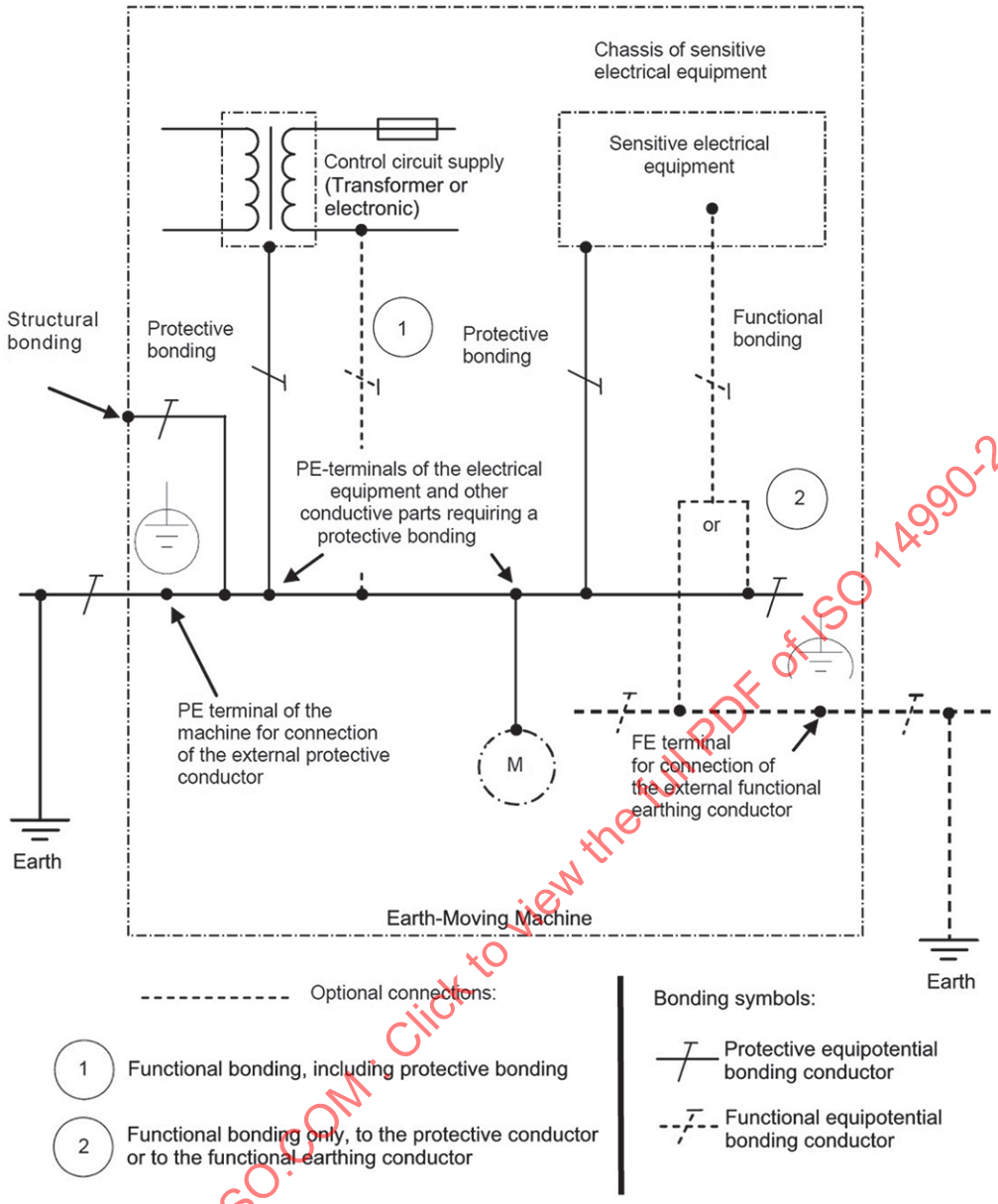


**Figure 2 — Example of equipotential bonding for externally-powered EMM**
(based on IEC 60204–1: 2009, Figure 2)



## 6 Protection against electrical fire hazards

The requirements of ISO 14990-1:2016, Clause 6 shall apply.

## 7 Protection against thermal hazards

The requirements of ISO 14990-1:2016, Clause 7 shall apply.

## 8 Protection against mechanical hazards

The requirements of ISO 14990-1:2016, Clause 8 shall apply.

# 9 Protection against abnormal operation hazards

## 9.1 General

The requirements of ISO 14990-1:2016, Clause 9 shall apply except as modified by this clause.

## 9.2 Supply conductors

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

The supplier of the electrical equipment shall state on the installation diagram the data necessary for selecting the overcurrent protective device.

## 9.3 Socket outlets

Overcurrent protection shall be provided in the unearthed live conductors of each circuit feeding general-purpose socket outlets intended primarily for supplying power to maintenance equipment.

## 9.4 Protection against 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, shutting down 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 responses to ensure coordination.

## 9.5 Phase sequence protection

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

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

— a machine transferred from one supply to another,

— a mobile machine with a facility for connection to an external power supply,

— supply cable repairs.

## 9.6 Protection against overvoltages 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. If provided,

— devices for the suppression of overvoltages due to lightning shall be connected to the incoming terminals of the supply disconnecting device;

— devices for the suppression of overvoltages due to switching surges shall be connected across the terminals of all equipment requiring such protection.

## 10 Electric power source

The requirements of ISO 14990-1:2016, Clause 10 shall apply except as modified by this clause.

NOTE Externally-powered (mains-connected) EMMs include machines powered by external dedicated generators, which in turn include any off-board electric power generation equipment intended to provide power to the machine.

### 10.1 Incoming supply conductor terminations

Where a neutral conductor is used it shall be clearly indicated in the technical documentation of the machine, such as in the installation diagram and in the circuit diagram, and a separate insulated terminal, labelled "N" in accordance with 16.1, shall be provided for the neutral conductor.

There shall be no connection between the neutral conductor and the protective bonding circuit inside the electrical equipment nor shall a combined PEN terminal be provided.

**Exception:** a connection may be made between the neutral terminal and the PE terminal at the point of the connection of the power supply to the machine for TN-C systems.

TN, TT, and IT systems are defined by IEC 60364-1, which covers voltages up to 1 000 V AC and 1 500 V DC This document extends the range of application for TN, TT, and IT systems to 36 kV AC or DC.

All terminals for the incoming supply connection shall be clearly identified in accordance with IEC 60445 and 16.1. For the identification of the external protective conductor terminal, see 10.3.

The following practices are recommended:

— the electrical equipment of EMM should, if practicable, be connected to a single incoming supply;

— if one or more additional supplies are necessary for certain parts of the equipment (e.g. equipment that operates at a different voltage), those supplies should be derived, as far as is practicable, from devices such as transformers or converters forming part of the electrical equipment of the machine;

— unless a plug is provided with the machine for the connection to the supply, the supply conductors should be terminated at the supply disconnecting device (for some systems, such as cable drum, this is not practical, but there should be a disconnecting device at the closest practical point to the power source).

### 10.2 Terminal for connection to the external protective earthing system

A terminal shall be provided near the phase conductor terminals for each incoming supply. Depending upon the supply distribution system, this terminal shall be for connection of the EMM to the external protective earthing system or to the external protective conductor.

The terminal shall be sized to accommodate an external protective copper conductor with a cross-sectional area given by Table 1. If an external protective conductor of a material other than copper is used, the terminal size shall be selected accordingly (see also ISO 14990-1:2016, 5.10.2.2).



 

**Table 1 — Minimum cross-sectional area of the external protective copper conductor**

| Cross-sectional area of copper phase conductors supplying the equipment<br>$S$<br>mm$^2$ | Minimum cross-sectional area of the external protective copper conductor[a]<br>$S_p$<br>mm$^2$ |
|---|---|
| $S \leq 16$ | $S$ |
| $16 < S \leq 35$ | 16[b] |
| $S > 35$ | $S/2$[b] |

[a] Based on IEC 60364-5-54:2011 Table 54.2.

[b] PEN conductors shall be in accordance with IEC 60364–5-52.

At each incoming supply point, the terminal for connection of the external protective earthing system or the external protective conductor shall be marked or labelled with the letters PE (see IEC 60445).

### 10.3 Protection against unauthorized, inadvertent and/or mistaken connection

Devices which are described in ISO 14990-1:2016, 10.2 and 10.3, and which are located outside an enclosed electrical operating area shall be equipped with means to secure them in the OFF (disconnected) position (e.g. by provisions for padlocking or trapped key interlocking). Such a lock-off arrangement shall prevent remote as well as local reconnection.

If a non-lockable disconnecting device (e.g. withdrawable fuse-links or withdrawable links) is provided, other means of protection against reconnection (e.g. warning labels in accordance with 16.1) may be provided.

However, when a plug/socket combination according to ISO 14990-1:2016, 11.10.5 e) is so positioned that it can be kept under the immediate supervision of the person carrying out the work, means for securing in the disconnected state need not be provided.

## 11 Wiring

The requirements of ISO 14990-1:2016, Clause 11 shall apply except as modified by this clause.

### 11.1 Flexible cables

For high-voltage equipment, each flexible cable (e.g. trailing cable) for the high voltage power supply to the electrical equipment of EMM shall contain a protective conductor (see ISO 14990-1:2016, 5.10.2.3). The cross-sectional area of the protective conductor shall comply with Table 1. A protective conductor of cross-sectional area least 25 mm$^2$ may be divided into several conductors of equal cross-sectional areas within the flexible cable.

### 11.2 Conductor wires, conductor bars, and slip-ring assemblies — Clearances

Clearances between conductors and between adjacent systems of conductor wires, conductor bars, slip-ring assemblies, and current collectors shall be as follows for a rated impulse voltage of at least overvoltage category III:

— **for low-voltage equipment**, as specified by IEC 60664-1;

— **for high-voltage equipment**: suitable for the rated short-duration power frequency withstand voltage and the lower level of the rated lightning impulse withstand voltage shown in IEC 60071-1:2011, Table 2.

## 11.3 Connections and routing — Conductor and cable runs

**Exception** to ISO 14990-1:2016, 11.7**:** Where it is impracticable to provide terminals in a junction box (e.g. on mobile machines having long flexible cables or cable runs exceeding a length that can be supplied by the cable manufacturer on one cable drum), splices or joints may be used.

## 11.4 Connection to moving elements of the EMM

Connections to frequently moving parts shall be made using conductors complying with ISO 14990-1:2016, 11.2 and cables complying with ISO 14990-1:2016, 11.5. Flexible cable and flexible conduit shall be installed so as to avoid excessive flexing and straining, particularly at fittings.

Support shall be provided for cables subject to movement so that there is neither mechanical strain on the connection points nor sharp flexing. If a cable loop is employed, it shall permit a cable bending radius not less than 10 times the cable diameter.

Flexible cables shall be installed or protected so as to minimize the likelihood of damage due to situations such as the following:

— contact with the EMM structure during movements;

— feeding in and out of cable baskets or reels;

— acceleration forces and wind forces on festooned or suspended cables;

— excessive rubbing by cable collector;

— exposure to excessive heat;

— being run over by the machine itself;

— being run over by vehicles or other machines.

Particular attention shall be given to voltage drop across the supply conductors.

The cable sheath shall be resistant to normal wear and environmental contaminants such as oil, water, coolants, and abrasive dust.

A space of at least 25 mm shall be maintained between cables subject to movement and other moving parts. If that distance is not practicable, fixed barriers between the cables and the moving parts shall be provided.

Flexible conduit located adjacent to moving parts shall not be damaged under all conditions of operation. Flexible conduit shall not be used where rapid or frequent movements occur unless specifically intended for that purpose.

The cable handling system shall not induce lateral cable angles exceeding five degrees. Torsion in the cable when being wound on and off cable reels and approaching and leaving cable guidance devices shall be minimized.

At least two turns of a flexible cable shall always remain on a reel.

Flexible cable handling devices shall not cause excessive cable bending. The inner bending radius at all points shall not be less than the following:

— 6 times a cable diameter (or thickness) up to 20 mm;

— 8 times a cable diameter (or thickness) greater than 20 mm.

**Exception 1:** cables of diameter or thickness greater than 8 mm and up to 20 mm being fed through guide rollers shall be subject to a bending radius not less than 8 times the cable diameter or thickness.



 

**Exception 2:** the cable manufacturer shall rate the cable to the application taking into account relevant factors, such as the number times/hour the cable is flexed.

The length of a straight section between two bends shall be at least 20 times the cable diameter or thickness.

## 12 Electric motors

The requirements of ISO 14990-1:2016, Clause 12 shall apply except as modified by this clause.

### 12.1 Criteria for motor selection or design

Motors and associated equipment shall be selected or designed taking into account the anticipated service and environmental conditions. Aspects that shall be considered include the following:

— type of motor;

— duty cycle;

— fixed speed or variable speed operation, (and for air-cooled motors the consequent variable ventilation);

— mechanical vibration;

— type of motor control;

— influence of the waveshapeform of the voltage and/or current feeding the motor on the temperature rise, particularly when it is supplied from an electronic adjustable speed drive;

— variation of counter-torque load with time and speed, including overhauling loads;

— effects of loads with large inertia;

— effects of constant torque or constant power operation;

— possible need of inductive reactors between a motor and an electronic adjustable speed drive;

— method of starting and the possible influence of the inrush current on the operation of other users of the same power supply, taking also into account possible special considerations stipulated by the supply authority.

## 13 Non-motor loads

The requirements of ISO 14990-1:2016, Clause 13 shall apply.

## 14 Controls

The requirements of ISO 14990-1:2016, Clause 14 shall apply except as modified by this clause.

### 14.1 Control circuit supply

Control circuits supplied by an AC source shall be supplied by control transformers. Such transformers shall have separate windings. If several transformers are used, it is recommended that the windings of those transformers be connected such that the secondary voltages are in phase.

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

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

## 15 Manuals and documentation

The requirements of ISO 14990-1:2016, Clause 15 shall apply except as modified by this clause.

### 15.1 Information to be provided

The information provided with the electrical equipment shall include the following:

a) a description (including interconnection diagrams) of the safeguards, interlocking functions and interlocking of guards against hazards;

b) a description of the safeguarding, and of the means provided and procedures needed for disabling the safeguarding (e.g. for adjustments or maintenance);

c) information on residual risks associated with the protection measures, an indication of whether any particular training is required, and specification of any necessary personal protective equipment;

d) electrical supply requirements;

e) information regarding load currents, peak starting currents and permitted voltage drops, as applicable, with particular attention given to voltage drop across the supply conductors.

### 15.2 Installation documents

General documentation provisions should be according to ISO 20474-1 unless specifically noted below.

The recommended position, type, and cross-sectional areas of the supply cables to be installed on site shall be clearly indicated.

The data necessary for choosing the type, characteristics, rated currents, and setting of the overcurrent protective device for the supply conductors to the electrical equipment of the machine shall be stated (see 9.2).

Where necessary, the size, purpose, and location of any ducts in the foundation that are to be provided by the user shall be detailed (see Annex A).

The size, type, and purpose of ducts, cable trays, or cable supports between the machine and the associated equipment that are to be provided by the user shall be detailed.

Where necessary, the diagram shall indicate where space is required for the removal or servicing of the electrical equipment.

NOTE 1 Examples of installation diagrams can be found in IEC 61082–1.

In addition, where appropriate, an interconnection diagram or table shall be provided. That diagram or table shall give full information about all external connections. Where the electrical equipment is intended to be operated from more than one source of electrical supply, the interconnection diagram or table shall indicate the modifications or interconnections required for the use of each supply.

NOTE 2 Examples of interconnection diagrams/tables can be found in IEC 61082–1.



 

# 16 Marking

The requirements of ISO 14990-1:2016, Clause 16 shall apply except as modified by this clause.

## 16.1 Marking of equipment

Equipment (for example controlgear assemblies) shall be legibly and durably marked in a way that is plainly visible after the equipment is installed. A nameplate giving the following information shall be attached to the enclosure adjacent to each incoming supply:

— name or trade mark of supplier;

— certification mark, when required;

— serial number, where applicable;

— rated voltage, number of phases and frequency (if AC), and full-load current for each supply;

— short-circuit rating of the equipment;

— main document number should be in accordance with IEC 62023.

The full-load current shown on the nameplate shall be not less than the running currents for all motors and other equipment that can be in operation at the same time under normal conditions.

For equipment having earth leakage currents greater than 10 mA AC or DC, a warning marking shall be provided adjacent to the PE terminal, and where necessary on the nameplate of the electrical equipment. The warning shall include information about the leakage current and the minimum cross-sectional area of the external protective conductor.

Where only a single motor controller is used, that information may instead be provided on the machine nameplate where it is plainly visible.

# 17 Tests

The requirements of ISO 14990-1:2016, Clause 17 shall apply.