PETAL®
utilaj petrolier & metalurgic
www.petal.ro
CERTIFIED ISO 9001 · ISO 14001 OHSAS 18001 UKAS MANAGEMENT SYSTEMS 001

**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

**Aprobat,**
**Reprezentant legal**
**Rățoi Viorel**

**Director proiect,**
**Cucoș Iulian**

| | |
|---|---|
| **Nr. contract de finanțare: 260/ 17.06.2020**<br>**Axa prioritară 1 - Cercetare, dezvoltare tehnologica si inovare (CDI) în sprijinul competitivității economice și dezvoltării afacerilor**<br>**Acțiunea 1.2.1 Stimularea cererii întreprinderilor pentru inovare prin proiecte de CDI derulate de întreprinderi individual sau în parteneriat cu institutele de CD și universități, în scopul inovării de procese și de produse în sectoarele economice care prezintă potențial de creștere** | |
| **Titlul proiectului: Instalație inovatoare pentru cimentare și operațiuni speciale la sondă destinată eficientizării extragerii resurselor energetice convenționale - INOCEM** | **ID: -**<br>**MySMIS: 120032** |

# RAPORT INTERMEDIAR A 2.3.

**Perioada 01 iunie 2023 – 31 august 2023**

**Activitate: A2. Activitatile de Dezvoltare Experimentala**

**Subactivitatea: A2.3. Testarea echipamentului pilot utilizabil comercial in medii reprezentative pentru conditii de functionare reale**

**17 Septembrie 2022 - 16 Decembrie 2023**

**Lider S.C. PETAL S.A. Husi**

**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

**Cuprins** **pag.**

**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

## A. OBIECTIVELE PROIECTULUI

**Obiectivul general** al proiectului constă în realizarea unui produs inovativ complex, destinat exploatării eficiente a resurselor energetice convenționale, având caracteristici funcționale semnificativ îmbunătățite prin schimbări esențiale ale specificațiilor tehnice și ale componentelor și materialelor și printr-un proces inovativ de realizare.

Integrată domeniului de specializare inteligentă *ENERGIE, MEDIU ŞI SCHIMBĂRI CLIMATICE, subdomeniul 3.1. Energie, respectiv 3.1.2. Resurse energetice convenționale, neconvenționale și regenerabile*, instalația destinată operației de cimentare și altor operațiuni speciale la sondele de petrol și gaze naturale, cu performanțe unice pentru producția unui asemenea echipament în România, ce asigură exploatarea superioară a acestor resurse convenționale de energie, cu păstrarea mediului ambient și care va contribui la creșterea calității și la diversificarea ofertei de produse moderne a liderului de proiect pe piața echipamentelor complexe destinate extracției de resurse de petrol și gaze.

**Obiectivele specifice ale proiectului sunt:**

1. Obținerea prin cercetare industrială de metode inovative pentru echipamentul de cimentare și operații speciale la sonde și stabilirea specificațiilor pentru subansambluri și echipamente;

2. Realizarea și testarea subansamblurilor inovative privind acționarea electrică în curent alternativ, antrenarea mecanică și componente de uzură ale pompelor;

3. Realizarea, pe baza documentației tehnice întocmite, a echipamentului pilot utilizabil comercial și testarea în medii reprezentative;

4. Investiții în vederea introducerii în producție a rezultatelor CD, prin achiziții de active corporale și necorporale;

5. Pregătirea fluxului de fabricație și a documentației de punere în fabricație;

6. Crearea a 4 noi locuri de muncă pe durata implementării proiectului, dintre care 2 femei.

**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

## B. OBIECTIVELE SUBACTIVITĂȚII A 2.3

**Subactivitatea A2.3.** ***„Testarea echipamentului pilot utilizabil comercial in medii reprezentative pentru conditii de functionare reale”*** prevăzută a se desfășura între 17 Septembrie 2022 - 16 Decembrie 2023 are ca obiectiv testarea subansamblurilor care au fost realizate anterior in cadrul subactivității A2.2.

Echipamentul pilot este destinat operatiilor de cimentare si altor operatii speciale la sonde. Testarea se va realiza pe platforma special destinata acestui scop la PETAL S.A.. Se are in vedere a fi testata instalatia in conditii reprezentative pentru functionarea reala. In acest scop colectivele de cercetare vor elabora o documentatie de testare care sa cuprinda operatiile necesare de verificare functionala si conditiile operationale in care se vor desfasura acestea.

Testarile vor trebui sa cuprinda, cel putin:

- verificarea presiunii maxime pe care o pot crea pompele cu un lichid de pompare;
- functionarea pentru realizarea unui amestec clasic de cimentare, urmarind realizarea automata a amestecului, parametri instalatiei, posibilele deviatii ale parametrilor de la valori nominale;
- functionarea cu un mestec destinat operatiei de acidificare.

Dupa testare, colectivele de cercetare si implementare vor analiza rezultatele privitoare la performante si modul in care au raspuns inovarile implementate privitor la cresterea a calitatii operatiilor executate de instalatie.

Pe baza proiectelor pentru fiecare componenta si subansamblu se vor realiza practic:

- Testarea solutiilor inovatoare realizate pentru instalatia de cimentare si operatii speciale la sonde se adreseaza tuturor subansamblurilor si componentelor, pe intreg ciclul lor de realizare.
- Inainte de testare, colectivul de cercetare si implementare va stabili manuale de testare pentru fiecare subansamblu, cu fise in care vor fi trecute rezultatele obtinute si persoanele care certifica rezultatele.
- Se va testa fiecare componenta in parte din punct de vedere dimensional imediat dupa producere, pentru a certifica pastrarea conditiilor impuse prin proiectul respectiv. In acest mod, eventualele deficiente de realizare fizica pot fi indreptate fara a periclita termenele de finalizare ale activitatii respective.

**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

- Se vor testa componentele de uzura cu acoperiri speciale in conditii similare cu cele la care vor lucra, in special acidificari si nisip, pentru a observa comportarea acoperirilor la suprafetele de contact cu substantele erozive.
- Se vor testa elementele noi de etansare in cadrul instalatiei de verificare la presiune a componentelor, instalatie din dotarea PETAL S.A.. Astfel, se va aprecia calitatea materialelor si a conceptiei tehnologice de realizare, cu posibilitatea remedierii rapide a eventualelor deficiente.
- Se va testa subsistemul de antrenare mecanica pe bancul de testare existent la PETAL S.A. pentru a observa functionarea lantului cinematic realizat pe baza noilor inovari.
- La sistemul electric de actionare vor fi testate separat, in momentul realizarii componentei respective, atat motorul electric de actionare cat si convertizorul de frecventa.
- Se vor verifica parametri de functionare nominali si acțiunea protectiilor contra regimurilor ce pot conduce la defecte. La finalizarea testarilor componentelor se va testa subansamblul de actionare electrica in ansamblu, determinand caracteristica mecanica si corespondenta cu caracteristica mecanica a pompelor actionate.
- Pentru protectia actionarii electrice exista prin proiect un sistem de protectii (impamantari, scurtcircuite etc.) care vor fi testate.
- Se va urmari testarea comunicatiilor realizate pentru sistemul electric intre componentele acestuia si modul in care ele asigura optimizarea functionarii conform proiectului respectiv.

Colectivul de cercetare pentru implementarea proiectului al liderului S.C. PETAL S.A. Husi participă la această activitate in perioada de raportare 01 iunie 2023 – 31 august 2023 ca etapă premergătoare la realizarea fișelor tehnologice pentru piesele care sunt realizate, va incepe stabilirea manualelor de testare pentru fiecare subansamblu, cu fise in care vor fi trecute rezultatele obtinute si persoanele care certifica rezultatele pentru Pompa triplex, angrenajul mecanism motor, carcasa angrenaj, frema, mecanismul motor și partea hidraulică.

**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

## C. REZUMATUL SUBACTIVITĂȚII A 2.3

### Raportarea 01 iunie 2023 – 31 august 2023

**Subactivitatea A2.3.** ***„Testarea echipamentului pilot utilizabil comercial in medii reprezentative pentru conditii de functionare reale”*** prevăzută a se desfășura între 17 Septembrie 2022 - 16 Decembrie 2023 are ca obiectiv testarea subansamblurilor care au fost realizate anterior in cadrul subactivității A2.2.

Pe baza proiectelor pentru fiecare componenta si subansamblu se vor realiza practic:

- Testarea solutiilor inovatoare realizate pentru instalatia de cimentare si operatii speciale la sonde se adreseaza tuturor subansamblurilor si componentelor, pe intreg ciclul lor de realizare.
- Inainte de testare, colectivul de cercetare si implementare va stabili manuale de testare pentru fiecare subansamblu, cu fise in care vor fi trecute rezultatele obtinute si persoanele care certifica rezultatele.
- Se va testa fiecare componenta in parte din punct de vedere dimensional imediat dupa producere, pentru a certifica pastrarea conditiilor impuse prin proiectul respectiv. In acest mod, eventualele deficiente de realizare fizica pot fi indreptate fara a periclita termenele de finalizare ale activitatii respective.
- Se vor testa componentele de uzura cu acoperiri speciale in conditii similare cu cele la care vor lucra, in special acidificari si nisip, pentru a observa comportarea acoperirilor la suprafetele de contact cu substantele erozive.
- Se vor testa elementele noi de etansare in cadrul instalatiei de verificare la presiune a componentelor, instalatie din dotarea PETAL S.A.. Astfel, se va aprecia calitatea materialelor si a conceptiei tehnologice de realizare, cu posibilitatea remedierii rapide a eventualelor deficiente.
- Se va testa subsistemul de antrenare mecanica pe bancul de testare existent la PETAL S.A. pentru a observa functionarea lantului cinematic realizat pe baza noilor inovari.
- La sistemul electric de actionare vor fi testate separat, in momentul realizarii componentei respective, atat motorul electric de actionare cat si convertizorul de frecventa.

**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

## D. DESCRIEREA ȘTIINȚIFICĂ ȘI TEHNICĂ A ACTIVITĂȚILOR DIN PERIOADA PENTRU CARE SE REALIZEAZĂ PREDAREA

**01 iunie 2023 – 31 august 2023**

### 1. Testare solutie actionare electrica, antrenare mecanica si componente de uzura pompa din cadrul Ansamblului echipament Instalație inovatoare pentru cimentare și operațiuni speciale la sondă care sunt testate conform BS EN 60204-1-2018

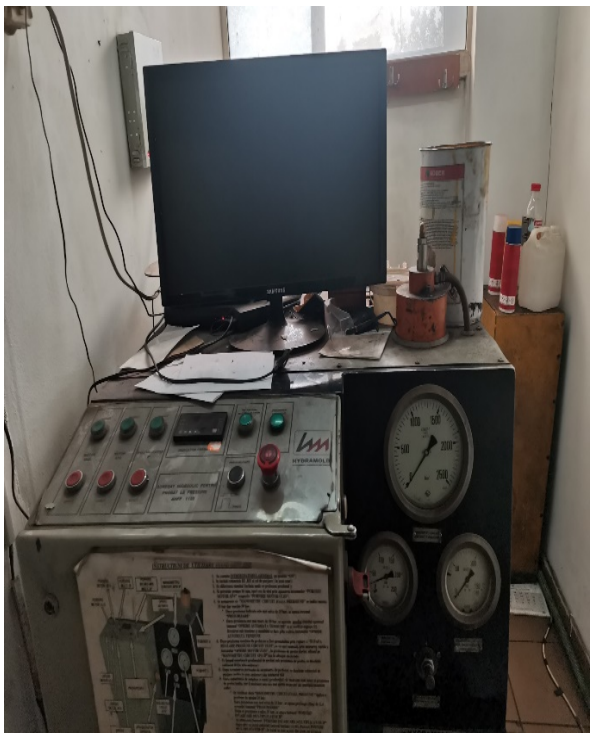
Pe baza proiectelor pentru fiecare componenta si subansamblu se realizează practic:

- Testarea solutiilor inovatoare realizate pentru instalatia de cimentare si operatii speciale la sonde se adreseaza tuturor subansamblurilor si componentelor, pe intreg ciclul lor de realizare.
- Inainte de testare, colectivul de cercetare si implementare va stabili manuale de testare pentru fiecare subansamblu, cu fise in care vor fi trecute rezultatele obtinute si persoanele care certifica rezultatele.
- Se va testa fiecare componenta in parte din punct de vedere dimensional imediat dupa producere, pentru a certifica pastrarea conditiilor impuse prin proiectul respectiv. In acest mod, eventualele deficiente de realizare fizica pot fi indreptate fara a periclita termenele de finalizare ale activitatii respective.
- Se vor testa componentele de uzura cu acoperiri speciale in conditii similare cu cele la care vor lucra, in special acidificari si nisip, pentru a observa comportarea acoperirilor la suprafetele de contact cu substantele erozive.
- Se vor testa elementele noi de etansare in cadrul instalatiei de verificare la presiune a componentelor, instalatie din dotarea PETAL S.A.. Astfel, se va aprecia calitatea materialelor si a conceptiei tehnologice de realizare, cu posibilitatea remedierii rapide a eventualelor deficiente.
- Se va testa subsistemul de antrenare mecanica pe bancul de testare existent la PETAL S.A. pentru a observa functionarea lantului cinematic realizat pe baza noilor inovari.
- La sistemul electric de actionare vor fi testate separat, in momentul realizarii componentei respective, atat motorul electric de actionare cat si convertizorul de frecventa.

**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

Colectivul de cercetare pentru implementarea proiectului al liderului S.C. PETAL S.A. Husi participă la această activitate in perioada de raportare 01 iunie 2023 – 31 august 2023 la realizarea fișelor tehnologice pentru piesele care sunt realizate, a inceput realizarea manualelor de testare pentru fiecare subansamblu, cu fise in care vor fi trecute rezultatele obtinute si persoanele care certifica rezultatele pentru Pompa triplex, angrenajul mecanism motor, carcasa angrenaj, frema, mecanismul motor și partea hidraulică.

Prezentăm in contunuare Standurile pe care se face testarea solutiei de actionare electrica, antrenare mecanica si a componentelor de uzura pompa:



**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei


**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

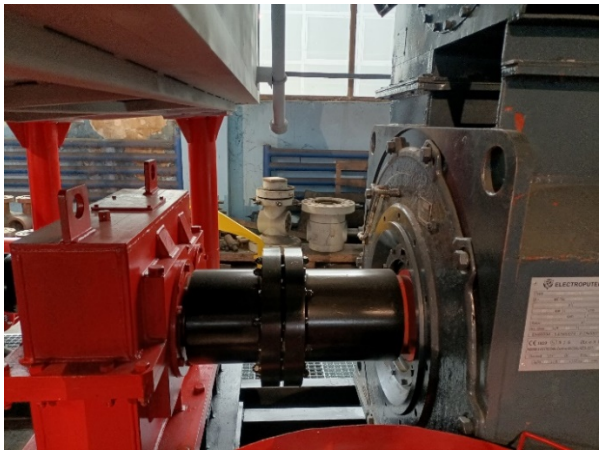
**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

Componentele Ansamblului echipament Instalație inovatoare pentru cimentare și operațiuni speciale la sondă care sunt testate conform BS EN 60204-1-2018**.**

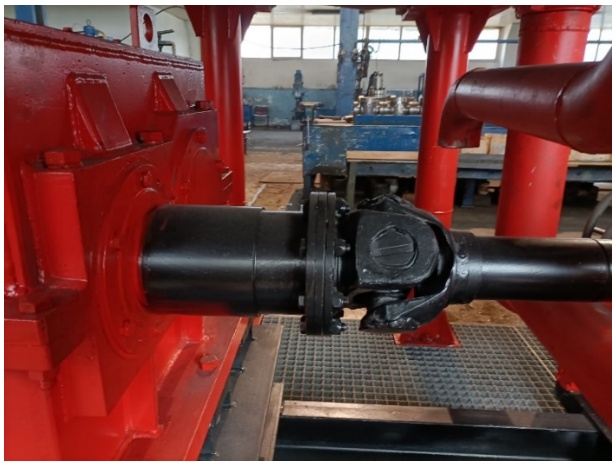
**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei

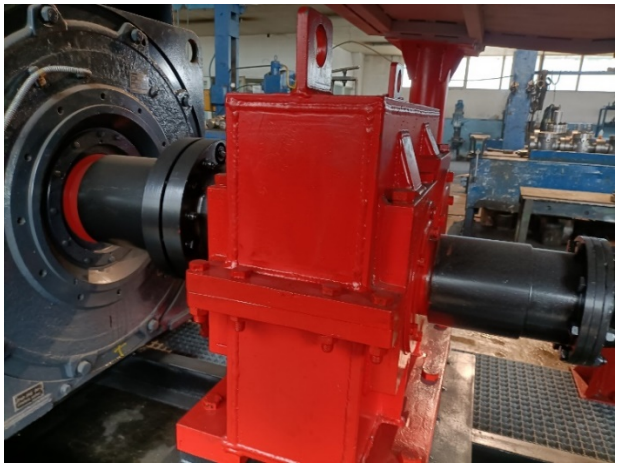
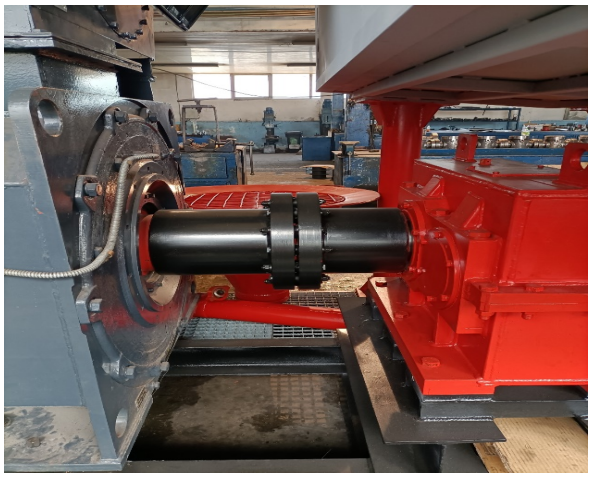





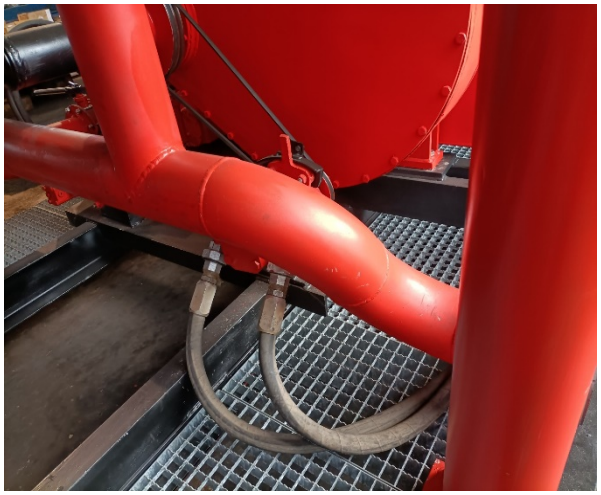
**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei





**Tel:** 0040235/481781
**Fax:** 0040235/481342
**Adresa**: Huși-Vaslui, Str. A. I. Cuza nr.99, 735100 România
**E-mail**: office@petal.ro
ORC: J37/191/2003
CUI: RO841186
**Capital social:** 2.971.825 lei



BS EN 60204-1:2018

BSI Standards Publication

# Safety of machinery - Electrical equipment of machines

Part 1: General requirements

bsi.

# Annex ZZA
(informative)

## Relationship between this European Standard and the essential requirements of Directive 2006/42/EC [2006 OJ L 157] aimed to be covered

This European Standard has been prepared under a Commission's standardization request M/396 EN to provide one voluntary means of conforming to essential requirements of Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) [2006 OJ L 157].

Once this standard is cited in the Official Journal of the European Union under that Directive, compliance with the normative clauses of this standard given in Table ZZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding requirements of that Directive, and associated EFTA regulations.

**Table ZZA.1 – Correspondence between this European Standard and Annex 1 of Directive 2006/42/EC [2006 OJ L 157]**

| Essential Requirements of Directive 2006/42/EC | Clause(s) / sub-clause(s) of this EN | Remarks / Notes |
|---|---|---|
| 1.2.1 | Clause 4, 5.4, 7.4, 7.5, 7.6, 7.8, 7.10, 8.4, Clause 9, 10.6, 10.9, 11.2.3 | |
| 1.2.2 | 4.4, Clause 10, Clause 11, 16.3 | |
| 1.2.3 | 7.3.1, 7.5, 9.2.3.2, 9.3.1 | |
| 1.2.4.1 | 9.2.2, 9.2.3.3 | |
| 1.2.4.2 | 9.2.2, 9.2.3.3, 9.2.3.6, 9.4 | |
| 1.2.4.3 | 9.2.3.4.2, 10.7 | |
| 1.2.4.4 | 9.2.3.3, 9.2.3.4.2 | |
| 1.2.5 | 9.2.3.5 | |
| 1.2.6 | 5.4, 7.5 | |
| 1.5.1 | All | |
| 1.5.4 | 13.4.5(d), Clause 17 | |
| 1.5.5 | 7.4, 16.2.2 | |
| 1.6.3 | 5.3, 10.8 | |
| 1.6.4 | Clause 11 | |
| 1.7.1. | Clause 16, Clause 17 | |
| 1.7.1.1 | Clause 16, Clause 17 | |
| 1.7.1.2 | 10.1.1, 10.3, 10.4, Clause 16 | |
| 1.7.2 | Clause 16, Clause 17 | |
| 1.7.4.2 (e,g, i,j,m,p,r,s,t) | Clause 17 | |
| 1.7.4.2 u, 1.5.8 | | These essential requirements are specifically excluded as noise has not been considered |

| Essential Requirements of Directive 2006/42/EC | Clause(s) / sub-clause(s) of this EN | Remarks / Notes |
|---|---|---|
| | | during the development of the standard |
| 1.5.10, 1.5.11 | | These essential requirements have been excluded as the electromagnetic compliance information only gives methods that have proved useful and are supplied as guidance. |

**WARNING 1 —** Presumption of conformity stays valid only as long as a reference to this European Standard is maintained in the list published in the Official Journal of the European Union. Users of this standard should consult frequently the latest list published in the Official Journal of the European Union.

**WARNING 2 —** Other Union legislation may be applicable to the product(s) falling within the scope of this standard.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

# SAFETY OF MACHINERY – ELECTRICAL EQUIPMENT OF MACHINES –

## Part 1: General requirements

## FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60204-1 has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects.

This sixth edition cancels and replaces the fifth edition published in 2005. It constitutes a technical revision.

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

a) added requirements to address applications involving power drive systems (PDS);
b) revised electromagnetic compatibility (EMC) requirements;
c) clarified overcurrent protection requirements;
d) requirements for determination of the short circuit current rating of the electrical equipment;

e) revised protective bonding requirements and terminology;

f) reorganization and revision to Clause 9, including requirements pertaining to safe torque off of PDS, emergency stop, and control circuit protection;

g) revised symbols for actuators of control devices;

h) revised technical documentation requirements;

i) general updating to current special national conditions, normative standards, and bibliographical references.

The text of this standard is based on the following documents:

| FDIS | Report on voting |
|---|---|
| 44/765/FDIS | 44/771/RVD |

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60204 series, published under the general title *Safety of machinery – Electrical equipment of machines*, can be found on the IEC website.

The following differing practices of a less permanent nature exist in the countries indicated below.

4.3.1: The voltage characteristics of electricity supplied by public distribution systems in Europe are given in EN 50160:2010.

5.1: Exception is not allowed (USA).

5.1: TN-C systems are not permitted in low-voltage installations in buildings (Norway).

5.2: Terminals for the connection of the protective earthing conductors may be identified by the colour green, the letters “G” or “GR” or “GRD” or “GND”, or the word “ground” or “grounding”, or with the graphical symbol IEC 60417-5019:2006-08 or any combination (USA).

6.3.3 b), 13.4.5 b), 18.2.1: TT power systems are not allowed (USA).

6.3.3, 18.2, Annex A: TN systems are not used. TT systems are the national standard (Japan).

6.3.3 b): The use of residual current protective devices with a rated residual operating current not exceeding 1 A is mandatory in TT systems as a means for fault protection by automatic disconnection of supply (Italy).

7.2.3: Disconnection of the neutral conductor is mandatory in a TN-S system (France and Norway).

7.2.3: Third paragraph: distribution of a neutral conductor with an IT system is not allowed (USA and Norway).

7.10: For evaluation of short circuit ratings the requirements of UL 508A Supplement SB, may be used (USA).

8.2.2: See IEC 60364-5-54:2011, Annex E List of notes concerning certain countries.

9.1.2: Maximum nominal AC control circuit voltage is 120 V (USA).

12.2: Only stranded conductors are allowed on machines, except for 0,2 $mm^2$ solid conductors within enclosures (USA).

12.2: The smallest power circuit conductor allowed on machines is 0,82 $mm^2$ (AWG 18) in multiconductor cables or in enclosures (USA).

Table 5: Cross-sectional area is specified in NFPA 79 using American Wire Gauge (AWG) (USA). See Annex G.

13.2.2: For the protective conductor, the colour identification GREEN (with or without YELLOW stripes) is used as equivalent to the bicolour combination GREEN-AND-YELLOW (USA and Canada).

13.2.3: The colour identification WHITE or GREY is used for earthed neutral conductors instead of the colour identification BLUE (USA and Canada).

15.2.2: First paragraph: Maximum value between conductors 150 V (USA).

15.2.2: Second paragraph, 5th bullet: The full load current rating of lighting circuits does not exceed 15 A (USA).

16.4: Nameplate marking requirements (USA).

A.2.2.2: The permissible maximum value of $R_A$ is regulated (e.g. when $U_o \geq 300$V, $R_A$ shall be less than 10 Ω, when $U_o < 300$ V, $R_A$ shall be less than 100 Ω, $U_o$ is the nominal AC line to earth voltage in volts (V) (Japan).

A.2.2.2: The maximum permissible value of $R_A$ is 83 Ω (Netherlands).

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

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

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

# INTRODUCTION

This part of IEC 60204 provides requirements and recommendations relating to the electrical equipment of machines so as to promote:

– safety of persons and property;

– consistency of control response;

– ease of operation and maintenance.

More guidance on the use of this part of IEC 60204 is given in Annex F.

Figure 1 has been provided as an aid to the understanding of the inter-relationship of the various elements of a machine and its associated equipment. Figure 1 is a block diagram of a typical machine and associated equipment showing the various elements of the electrical equipment addressed in this part of IEC 60204. Numbers in parentheses ( ) refer to Clauses and Subclauses in this part of IEC 60204. It is understood in Figure 1 that all of the elements taken together including the safeguards, tooling/fixturing, software, and the documentation, constitute the machine, and that one or more machines working together with usually at least one level of supervisory control constitute a manufacturing cell or system.

# SAFETY OF MACHINERY – ELECTRICAL EQUIPMENT OF MACHINES –

## Part 1: General requirements

## 1 Scope

This part of IEC 60204 applies to electrical, electronic and programmable electronic equipment and systems to machines not portable by hand while working, including a group of machines working together in a co-ordinated manner.

NOTE 1 This part of IEC 60204 is an application standard and is not intended to limit or inhibit technological advancement.

NOTE 2 In this part of IEC 60204, the term “electrical” includes electrical, electronic and programmable electronic matters (i.e. “electrical equipment” means electrical, electronic and programmable electronic equipment).

NOTE 3 In the context of this part of IEC 60204, the term “person” refers to any individual and includes those persons who are assigned and instructed by the user or his agent(s) in the use and care of the machine in question.

The equipment covered by this part of IEC 60204 commences at the point of connection of the supply to the electrical equipment of the machine (see 5.1).

NOTE 4 The requirements for the electrical supply installation are given in the IEC 60364 series.

This part of IEC 60204 is applicable to the electrical equipment or parts of the electrical equipment that operate with nominal supply voltages not exceeding 1 000 V for alternating current (AC) and not exceeding 1 500 V for direct current (DC), and with nominal supply frequencies not exceeding 200 Hz.

NOTE 5 Information on electrical equipment or parts of the electrical equipment that operate with higher nominal supply voltages can be found in IEC 60204-11.

This part of IEC 60204 does not cover all the requirements (for example guarding, interlocking, or control) that are needed or required by other standards or regulations in order to protect persons from hazards other than electrical hazards. Each type of machine has unique requirements to be accommodated to provide adequate safety.

This part of IEC 60204 specifically includes, but is not limited to, the electrical equipment of machines as defined in 3.1.40.

NOTE 6 Annex C lists examples of machines whose electrical equipment can be covered by this part of IEC 60204.

This part of IEC 60204 does not specify additional and special requirements that can apply to the electrical equipment of machines that, for example:

– are intended for use in open air (i.e. outside buildings or other protective structures);
– use, process, or produce potentially explosive material (for example paint or sawdust);
– are intended for use in potentially explosive and/or flammable atmospheres;
– have special risks when producing or using certain materials;
– are intended for use in mines;
– are sewing machines, units, and systems (which are covered by IEC 60204-31);
– are hoisting machines (which are covered by IEC 60204-32);
– are semiconductor fabrication equipment (which are covered by IEC 60204-33).

**3.1.2**
**ambient temperature**
temperature of the air or other medium where the equipment is to be used

**3.1.3**
**barrier**
part providing protection against contact with live parts from any usual direction of access

**3.1.4**
**basic protection**
protection against electric shock under fault-free conditions

Note 1 to entry: Previously referred to as “protection against direct contact”

[SOURCE: IEC 60050-195:1998, 195-06-01, modified – The note has been added.]

**3.1.5**
**cable tray**
cable support consisting of a continuous base and raised edges and no covering

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

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

**3.1.6**
**cable trunking system**
system of closed enclosures comprising a base with a removable cover intended for the complete surrounding of insulated conductors or cables

**3.1.7**
**concurrent**
occurring or operating at the same time (but not necessarily synchronously)

**3.1.8**
**conductor wire**
conductor bar
conductive wire or bar of a feeder system with a sliding current collector

**3.1.9**
**conduit**
part of a closed wiring system of circular or non-circular cross-section for insulated conductors and/or cables in electrical installations

Note 1 to entry: Conduits should be sufficiently close-jointed so that the insulated conductors and/or cables can only be drawn in and not inserted laterally.

[SOURCE: IEC 60050-442:1998, 442-02-03, modified – The definition has been amended and the note has been added.]

**3.1.10**
**control circuit**, <of a machine>
circuit used for the control, including monitoring, of a machine and the electrical equipment

**3.1.11**
**control device**
device connected into the control circuit and used for controlling the operation of the machine

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

**3.1.12**
**control station**
**operator control station**
assembly of one or more control actuators (see 3.1.1) fixed on the same panel or located in the same enclosure

Note 1 to entry: A control station may also contain related equipment, for example, potentiometers, signal lamps, instruments, display devices, etc.

[SOURCE: IEC 60050-441:1984, 441-12-08, modified – The second preferred term has been added, the word "switches" has been replaced by "actuators" in the definition and the note has been added.]

**3.1.13**
**controlgear**
switching devices and their combination with associated control, measuring, protective, and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures, and supporting structures, intended in principle for the control of electrical energy consuming equipment

[SOURCE: IEC 60050-441:1984, 441-11-03]

**3.1.14**
**controlled stop**
stopping of machine motion with power to the machine actuators maintained during the stopping process

**3.1.15**
**direct contact**
contact of persons or livestock with live parts

Note 1 to entry: See 3.1.4.

[SOURCE: IEC 60050-826:2004, 826-12-03, modified – The note has been added.]

**3.1.16**
**direct opening action**, <of a contact element>
achievement of contact separation as the direct result of a specified movement of the switch actuator through non-resilient members (for example not dependent upon springs)

[SOURCE: IEC 60947-5-1:2003, K.2.2]

**3.1.17**
**duct**
enclosed channel designed expressly for holding and protecting electrical conductors, cables, and busbars

Note 1 to entry: Conduits (see 3.1.9), cable trunking systems (see 3.1.6) and underfloor channels are types of duct.

**3.1.18**
**earth**
**local earth**
**ground** (US)
**local ground** (US)
part of the Earth which is in electric contact with an earth electrode and the electrical potential of which is not necessarily equal to zero

[SOURCE: IEC 60050-195:1998,195-01-03]

**3.1.19**
**electrical operating area**
room or location for electrical equipment to which access is intended to be restricted to skilled or instructed persons, by the opening of a door or the removal of a barrier without the use of a key or tool, and which is clearly marked by appropriate warning signs

**3.1.20**
**electronic equipment**
part of the electrical equipment containing circuitry dependent for its operation on electronic devices and components

**3.1.21**
**emergency stop device**
manually actuated control device used to initiate an emergency stop function

Note 1 to entry: See 9.2.3.4.2.

[SOURCE: ISO 13850:2006, 3.2, modified – The note has been added.]

**3.1.22**
**emergency switching off device**
manually actuated control device used to switch off or to initiate the switching off of the supply of electrical energy to all or a part of an installation where a risk of electric shock or another risk of electrical origin is involved

Note 1 to entry: See 9.2.3.4.3.

**3.1.23**
**enclosed electrical operating area**
room or location for electrical equipment to which access is intended to be restricted to skilled or instructed persons by the use of a key or tool to open a door, or remove a barrier, and which is clearly marked by appropriate warning signs

**3.1.24**
**enclosure**
part providing protection of equipment against certain external influences and, in any direction, basic protection as protection against direct contact

Note 1 to entry: The existing definition taken from the IEV needs the following explanations within the scope of this part of IEC 60204:

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

b) Barriers, shaped openings, or any other means suitable to prevent or limit the penetration of the specified test probes, whether attached to the enclosure or formed by the enclosed equipment, are considered as part of the enclosure, except where they can be removed without the use of a key or tool.

c) An enclosure may be:

   – a cabinet or box, either mounted on the machine or separate from the machine;

   – a compartment consisting of an enclosed space within the machine structure.

[SOURCE: IEC 60050-195:1998, 195-02-35, modified – The definition has been amended.]

**3.1.25**
**electrical equipment**
items used in connection with the utilisation of electricity by machines or parts of machines, for example material, fittings, devices, components, appliances, fixtures, apparatus, and similar

**3.1.39**
**machine actuator**
power mechanism of the machine used to effect motion (for example, motor, solenoid, pneumatic or hydraulic cylinder)

**3.1.40**
**machinery**
**machine**
assembly of linked parts or components, at least one of which moves, with the appropriate machine actuators, control and power circuits, joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material

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

Note 2 to entry: The term "component" is used here in a general sense and it does not refer only to electrical components.

[SOURCE: ISO 12100:2010, 3.1, modified – The definition has been amended and Note 2 referring to an Annex has been removed and replaced by the present Note 2 to entry.]

**3.1.41**
**marking**
signs or inscriptions primarily for the purpose of identifying equipment, components and/or devices

**3.1.42**
**neutral conductor**
**N**
conductor electrically connected to the neutral point and capable of contributing to the distribution of electrical energy

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

**3.1.43**
**obstacle**
part preventing unintentional direct contact with live parts, but not preventing direct contact by deliberate action

[SOURCE: IEC 60050-195:1998, 195-06-16, modified – The words “(electrically) protective” have been removed from the term.]

**3.1.44**
**overcurrent**
current exceeding the rated value

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

[SOURCE: IEC 60050-826:2004, 826-11-14, modified – The definition has been amended.]

**3.1.45**
**overload of a circuit**
time/current relationship in a circuit which is in excess of the rated full load of the circuit when the circuit is not under a fault condition

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

**3.1.46**
**plug/socket combination**
component and a suitable mating component, appropriate to terminate conductors, intended for connection or disconnection of two or more conductors

Note 1 to entry: Examples of plug/socket combination include:

– connectors which fulfil the requirements of IEC 61984;

– a plug and socket-outlet, a cable coupler, or an appliance coupler in accordance with IEC 60309-1;

– a plug and socket-outlet in accordance with IEC 60884-1 or an appliance coupler in accordance with IEC 60320-1.

**3.1.47**
**power circuit**
circuit that supplies power to units of equipment used for productive operation and to transformers supplying control circuits

**3.1.48**
**prospective short-circuit current**
***I*cp**
r.m.s. value of the current which would flow when the supply conductors to the electrical equipment are short-circuited by a conductor of negligible impedance located as near as practicable to the supply terminals of the electrical equipment

[SOURCE: IEC 61439-1: 2011, 3.8.7, modified – “assembly” has been replaced by “electrical equipment”]

**3.1.49**
**protective bonding**
equipotential bonding for protection against electric shock

Note 1 to entry: Measures for protection against electric shock can also reduce the risk of burns or fire.

Note 2 to entry: Protective bonding can be achieved with protective conductors and protective bonding conductors and by conductive joining of conductive parts of the machine and its electrical equipment.

**3.1.50**
**protective bonding circuit**
protective conductors and conductive parts connected together to provide protection against electric shock in the event of an insulation failure

**3.1.51**
**protective conductor**
conductor providing a primary fault current path from the exposed conductive parts of the electrical equipment to a protective earthing (PE) terminal

**3.1.52**
**redundancy**
application of more than one device or system, or part of a device or system, with the objective of ensuring that in the event of one failing to perform its function, another is available to perform that function

**3.1.53**
**reference designation**
distinctive code which serves to identify an object in the documentation and on the equipment

**3.1.54**
**risk**
combination of the probability of occurrence of harm (i.e. physical injury or damage to health) and the severity of that harm

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

**3.1.63**
**switching device**
device designed to make and/or break the current in one or more electric circuits

Note 1 to entry: A switching device may perform one or both of these actions.

[SOURCE: IEC 60050-441:1984, 441-14-01]

**3.1.64**
**uncontrolled stop**
stopping of machine motion by removing electrical power to the machine actuators

Note 1 to entry: This definition does not imply any particular state of other stopping devices, for example mechanical or hydraulic brakes.

**3.1.65**
**user**
entity who utilizes the machine and its associated electrical equipment

### 3.2 Abbreviated terms

AWG American Wire Gauge
AC Alternating Current
BDM Basic Drive Module
CCS Cableless Control System
DC Direct Current
EMC Electro-Magnetic Compatibility
EMI Electro-Magnetic Interference
IFLS Insulation Fault Location System
MMI Man-Machine interface
PDS Power Drive System
PELV Protective Extra-Low Voltage
RCD Residual Current protective Device
SPD Surge Protective Devices
SCPD Short-Circuit Protective Device
SELV Safe Extra-Low Voltage
SLP Safely-Limited Position
STO Safe Torque Off

## 4 General requirements

### 4.1 General

This standard specifies requirements for the electrical equipment of machines.

The risks associated with the hazards relevant to the electrical equipment shall be assessed as part of the overall requirements for risk assessment of the machine. This will:

– identify the need for risk reduction; and
– determine adequate risk reductions; and
– determine the necessary protective measures

for persons who can be exposed to those hazards, while still maintaining an appropriate performance of the machine and its equipment.

Hazardous situations can result from, but are not limited to, the following causes:

– failures or faults in the electrical equipment resulting in the possibility of electric shock, arc, or fire;
– failures or faults in control circuits (or components and devices associated with those circuits) resulting in the malfunctioning of the machine;
– disturbances or disruptions in power sources as well as failures or faults in the power circuits resulting in the malfunctioning of the machine;
– loss of continuity of circuits that can result in a failure of a safety function, for example those that depend on sliding or rolling contacts;
– electrical disturbances for example, electromagnetic, electrostatic either from outside the electrical equipment or internally generated, resulting in the malfunctioning of the machine;
– release of stored energy (either electrical or mechanical) resulting in, for example, electric shock, unexpected movement that can cause injury;
– acoustic noise and mechanical vibration at levels that cause health problems to persons;
– surface temperatures that can cause injury.

Safety measures are a combination of the measures incorporated at the design stage and those measures required to be implemented by the user.

The design and development process shall identify hazards and the risks arising from them. Where the hazards cannot be removed and/or the risks cannot be sufficiently reduced by inherently safe design measures, protective measures (for example safeguarding) shall be provided to reduce the risk. Additional means (for example, awareness means) shall be provided where further risk reduction is necessary. In addition, working procedures that reduce risk can be necessary.

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

NOTE Those additional specifications can:

– provide additional features that are dependent on the type of machine (or group of machines) and the application;
– facilitate maintenance and repair; and
– improve the reliability and ease of operation.

## 4.2 Selection of equipment

### 4.2.1 General

Electrical components and devices shall:

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

### 4.2.2 Switchgear

In addition to the requirements of IEC 60204-1, depending upon the machine, its intended use and its electrical equipment, the designer may select parts of the electrical equipment of the machine that are in compliance with relevant parts of the IEC 61439 series (see also Annex F).

### 4.3 Electrical supply

#### 4.3.1 General

The electrical equipment shall be designed to operate correctly with the conditions of the supply:

– as specified in 4.3.2 or 4.3.3, or

– as otherwise specified by the user, or

– as specified by the supplier of a special source of supply (see 4.3.4)

#### 4.3.2 AC supplies

| | |
|---|---|
| Voltage | Steady state voltage: 0,9 to 1,1 of nominal voltage. |
| Frequency | 0,99 to 1,01 of nominal frequency continuously;<br>0,98 to 1,02 short time. |
| Harmonics | Harmonic distortion not exceeding 12 % of the total r.m.s. voltage between live conductors for the sum of the 2nd through to the 30th harmonic. |
| 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 rms voltage of the supply for more than one cycle with more than 1 s between successive dips. |

#### 4.3.3 DC supplies

From batteries:

| | |
|---|---|
| Voltage | 0,85 to 1,15 of nominal voltage;<br>0,7 to 1,2 of nominal voltage in the case of battery-operated vehicles. |
| Voltage interruption | Not exceeding 5 ms. |

From converting equipment:

| | |
|---|---|
| Voltage | 0,9 to 1,1 of nominal voltage. |
| Voltage interruption | Not exceeding 20 ms with more than 1 s between successive interruptions. |

NOTE This is a variation to IEC Guide 106 to ensure proper operation of electronic equipment.

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

#### 4.3.4 Special supply systems

For special supply systems (e.g. on-board generators, DC bus, etc.) the limits given in 4.3.2 and 4.3.3 may be exceeded provided that the equipment is designed to operate correctly with those conditions.

### 4.4 Physical environment and operating conditions

#### 4.4.1 General

The electrical equipment shall be suitable for the physical environment and operating conditions of its intended use. The requirements of 4.4.2 to 4.4.8 cover the physical environment and operating conditions of the majority of machines covered by this part of

For machines supplied from parallel sources, the requirements of IEC 60364-1 for multiple source systems apply.

Terminals for the incoming supply connection shall be clearly identified in accordance with IEC 60445. The terminal for the external protective conductor shall be identified in accordance with 5.2.

### 5.2 Terminal for connection of the external protective conductor

For each incoming supply, a terminal shall be provided in the same compartment as the associated line conductor terminals for connection of the machine to the external protective conductor.

The terminal shall be of such a size as to enable the connection of an external protective copper conductor with a cross-sectional area determined in relation to the size of the associated line conductors in accordance with Table 1.

**Table 1 – Minimum cross-sectional area of copper protective conductors**

| Cross-sectional area of line conductors $S$ mm$^2$ | Minimum cross-sectional area of the corresponding protective conductor (PE) $S_P$ mm$^2$ |
|---|---|
| $S \leq 16$ | S |
| $16 < S \leq 35$ | 16 |
| $S > 35$ | $S/2$ |

Where an external protective conductor of a material other than copper is used, the terminal size and type shall be selected accordingly.

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

### 5.3 Supply disconnecting (isolating) device

#### 5.3.1 General

A supply disconnecting device shall be provided:

– for each incoming supply to (a) machine(s);

NOTE The incoming supply can be connected directly to the supply disconnecting device of the machine or to the supply disconnecting device of a feeder system of the machine. Feeder systems of machines can include conductor wires, conductor bars, slip-ring assemblies, flexible cable systems (reeled, festooned) or inductive power supply systems.

– for each on-board power supply.

The supply disconnecting device shall disconnect (isolate) the electrical equipment of the machine from the supply when required (for example for work on the machine, including the electrical equipment).

Where two or more supply disconnecting devices are provided, protective interlocks for their correct operation shall also be provided in order to prevent a hazardous situation, including damage to the machine or to the work in progress.

#### 5.3.2 Type

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

a) switch-disconnector, with or without fuses, in accordance with IEC 60947-3, utilization category AC-23B or DC-23B;

b) control and protective switching device suitable for isolation, in accordance with IEC 60947-6-2;

c) a circuit-breaker suitable for isolation in accordance with IEC 60947-2;

d) any other switching device in accordance with an IEC product standard for that device and which meets the isolation requirements and the appropriate utilization category and/or specified endurance requirements defined in the product standard;

e) a plug/socket combination for a flexible cable supply.

### 5.3.3 Requirements

Where the supply disconnecting device is one of the types specified in 5.3.2 a) to d) it shall fulfil all of the following requirements:

– isolate the electrical equipment from the supply and have one OFF (isolated) and one ON position marked with "O" and "I" (symbols IEC 60417-5008 (2002-10) and IEC 60417-5007 (2002-10), see 10.2.2);

– have a visible contact gap or a position indicator which cannot indicate OFF (isolated) until all contacts are actually open and the requirements for the isolating function have been satisfied;

– have an operating means (see 5.3.4);

– be provided with a means permitting it to be locked in the OFF (isolated) position (for example by padlocks). When so locked, remote as well as local closing shall be prevented;

– disconnect all live conductors of its power supply circuit. However, for TN supply systems, the neutral conductor may or may not be disconnected except in countries where disconnection of the neutral conductor (when used) is compulsory;

– have a breaking capacity sufficient to interrupt the current of the largest motor when stalled together with the sum of the normal running currents of all other motors and other loads. The calculated breaking capacity may be reduced by the use of a proven diversity factor. Where motor(s) are supplied by converter(s) or similar devices, the calculation should take into account the possible effect on the required breaking capacity.

Where the supply disconnecting device is a plug/socket combination, it shall comply with the requirements of 13.4.5 and shall have the breaking capacity, or be interlocked with a switching device that has a breaking capacity, sufficient to interrupt the current of the largest motor when stalled together with the sum of the normal running currents of all other motors and other loads. The calculated breaking capacity may be reduced by the use of a proven diversity factor. Where the interlocked switching device is electrically operated (for example a contactor) it shall have an appropriate utilisation category. Where motor(s) are supplied by converter(s) or similar devices, the calculation should take into account the possible effect on the required breaking capacity.

NOTE A suitably rated plug and socket-outlet, cable coupler, or appliance coupler, in accordance with IEC 60309-1 can fulfil these requirements.

Where the supply disconnecting device is a plug/socket combination, a switching device with an appropriate utilisation category shall be provided for switching the machine on and off. This can be achieved by the use of the interlocked switching device described above.

### 5.3.4 Operating means of the supply disconnecting device

The operating means (for example, a handle) of the supply disconnecting device shall be external to the enclosure of the electrical equipment.

Where excepted circuits are not disconnected by the supply disconnecting device:

– permanent warning label(s) shall be appropriately placed in proximity to the operating means of the supply disconnecting device to draw attention to the hazard;
– a corresponding statement shall be included in the maintenance manual, and one or more of the following shall apply:
  - the conductors are identified by colour taking into account the recommendation of 13.2.4;
  - excepted circuits are separated from other circuits;
  - excepted circuits are identified by permanent warning label(s).

### 5.4 Devices for removal of power for prevention of unexpected start-up

Devices for removal of power for the prevention of unexpected start-up shall be provided where a start-up of the machine or part of the machine can create a hazard (for example during maintenance). Such devices shall be appropriate and convenient for the intended use, be suitably placed, and readily identifiable as to their function and purpose. Where their function and purpose is not otherwise obvious (e.g. by their location) these devices shall be marked to indicate the extent of removal of power.

NOTE 1 This part of IEC 60204 does not address all provisions for prevention of unexpected start up. Further information is provided in ISO 14118.

NOTE 2 Removal of power means removal of the connection to the source of electrical energy but does not imply isolation.

The supply disconnecting device or other devices in accordance with 5.3.2 may be used for prevention of unexpected start-up.

Disconnectors, withdrawable fuse links and withdrawable links may be used for protection of unexpected start-up only if they are located in an enclosed electrical operating area (see 3.1.23).

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

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

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

### 5.5 Devices for isolating electrical equipment

Devices shall be provided for isolating (disconnecting) the electrical equipment or part(s) of the electrical equipment to enable work to be carried out when it is de-energised and isolated. Such devices shall be:

– appropriate and convenient for the intended use;
– suitably placed;

– readily identifiable as to which part(s) or circuit(s) of the equipment is served. Where their function and purpose is not otherwise obvious (e.g. by their location) these devices shall be marked to indicate the extent of the equipment that they isolate.

The supply disconnecting device (see 5.3) may, in some cases, fulfil that function. However, where it is necessary to work on individual parts of the electrical equipment of a machine, or on one of the machines fed by a common conductor bar, conductor wire or inductive power supply system, a disconnecting device shall be provided for each part, or for each machine, requiring separate isolation.

In addition to the supply disconnecting device, the following devices that fulfil the isolation function may be provided for this purpose:

– devices described in 5.3.2;
– disconnectors, withdrawable fuse links and withdrawable links only if located in an enclosed electrical operating area (see 3.1.23) and relevant information is provided with the electrical equipment (see Clause 17).

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

Where the devices described in 5.4 and 5.5 are located outside an enclosed electrical operating area they shall be equipped with means to secure them in the OFF position (disconnected state), (for example by provisions for padlocking, trapped key interlocking). When so secured, remote as well as local reconnection shall be prevented.

Where the devices described in 5.4 and 5.5 are located inside an enclosed electrical operating area other means of protection against reconnection (for example warning labels) can be sufficient.

However, when a plug/socket combination according to 5.3.2 e) is so positioned that it can be kept under the immediate supervision of the person carrying out the work, means for securing in the disconnected state need not be provided.

## 6 Protection against electric shock

### 6.1 General

The electrical equipment shall provide protection of persons against electric shock by:

– basic protection (see 6.2 and 6.4), and;
– fault protection (see 6.3 and 6.4).

The measures for protection given in 6.2, 6.3, and, for PELV, in 6.4, are a selection from IEC 60364-4-41. Where those measures are not practicable, for example due to the physical or operational conditions, other measures from IEC 60364-4-41 may be used (e.g. SELV).

### 6.2 Basic protection

#### 6.2.1 General

For each circuit or part of the electrical equipment, the measures of either 6.2.2 or 6.2.3 and, where applicable, 6.2.4 shall be applied.

Exception: where those measures are not appropriate, other measures for basic protection (for example by using barriers, by placing out of reach, using obstacles, using construction or installation techniques that prevent access) as defined in IEC 60364-4-41 may be applied (see also 6.2.5 and 6.2.6).

– protective bonding of exposed conductive parts (see 8.2.3),

– and one of the following:

a) In TN systems, the following protective devices may be used:

- overcurrent protective devices;
- residual current protective devices (RCDs) and associated overcurrent protective device(s).

NOTE 2 The preventive maintenance can be enhanced by use of a residual current monitoring device, RCM, complying with IEC 62020.

b) in TT systems, either:

- RCDs and associated overcurrent protective device(s) to initiate the automatic disconnection of the supply on detection of an insulation fault from a live part to exposed conductive parts or to earth, or
- overcurrent protective devices may be used for fault protection provided a suitably low value of the fault loop impedance $Z_s$ (see A.2.2.3) is permanently and reliably assured;

NOTE 3 The preventive maintenance can be enhanced by use of a residual current monitoring device, RCM, complying with IEC 62020.

c) In IT systems the relevant requirements of IEC 60364-4-41 shall be fulfilled. During an insulation fault, an acoustic and optical signal shall be sustained. After annunciation, the acoustic signal may then be manually muted. This can require an agreement between the supplier and user regarding the provision of insulation monitoring devices and/or insulation fault location system(s).

NOTE 4 In large machines, the provision of an insulation fault location system (IFLS) in accordance with IEC 61557-9 can facilitate maintenance.

Where automatic disconnection is provided in accordance with a), and disconnection within the time specified in A.1.1 cannot be assured, supplementary protective bonding shall be provided as necessary to meet the requirements of A.1.3.

Where a power drive system (PDS) is provided, fault protection shall be provided for those circuits of the power drive system that are supplied by the converter. Where this protection is not provided within the converter, the necessary protection measures shall be in accordance with the converter manufacturer’s instructions.

## 6.4 Protection by the use of PELV

### 6.4.1 General requirements

The use of PELV (Protective Extra-Low Voltage) is to protect persons against electric shock from indirect contact and limited area direct contact (see 8.2.1).

PELV circuits shall satisfy all of the following conditions:

a) the nominal voltage shall not exceed:

- 25 V AC r.m.s. or 60 V ripple-free DC when the equipment is normally used in dry locations and when large area contact of live parts with the human body is not expected; or
- 6 V AC r.m.s. or 15 V ripple-free DC in all other cases;

NOTE "Ripple-free" is conventionally defined for a sinusoidal ripple voltage as a ripple content of not more than 10 % r.m.s.

b) one side of the circuit or one point of the source of the supply of that circuit shall be connected to the protective bonding circuit;

c) live parts of PELV circuits shall be electrically separated from other live circuits. Electrical separation shall be not less than that required between the primary and secondary circuits of a safety isolating transformer (see IEC 61558-1 and IEC 61558-2-6 );

d) conductors of each PELV circuit shall be physically separated from those of any other circuit. When this requirement is impracticable, the insulation provisions of 13.1.3 shall apply;

e) plugs and socket-outlets for a PELV circuit shall conform to the following:

- plugs shall not be able to enter socket-outlets of other voltage systems;
- socket-outlets shall not admit plugs of other voltage systems.

#### 6.4.2 Sources for PELV

The source for PELV shall be one of the following:

– a safety isolating transformer in accordance with IEC 61558-1 and IEC 61558-2-6;

– a source of current providing a degree of safety equivalent to that of the safety isolating transformer (for example a motor generator with winding providing equivalent isolation);

– an electrochemical source (for example a battery) or another source independent of a higher voltage circuit (for example a diesel-driven generator);

– an electronic power supply conforming to appropriate standards specifying measures to be taken to ensure that, even in the case of an internal fault, the voltage at the outgoing terminals cannot exceed the values specified in 6.4.1.

## 7 Protection of equipment

### 7.1 General

This Clause 7 details the measures to be taken to protect equipment against the effects of:

– overcurrent arising from a short-circuit;

– overload and/or loss of cooling of motors;

– abnormal temperature;

– loss of or reduction in the supply voltage;

– overspeed of machines/machine elements;

– earth fault/residual current;

– incorrect phase sequence;

– overvoltage due to lightning and switching surges.

### 7.2 Overcurrent protection

#### 7.2.1 General

Overcurrent protection shall be provided where the current in any circuit can exceed either the rating of any component or the current carrying capacity of the conductors, whichever is the lesser value. The ratings or settings to be selected are detailed in 7.2.10.

#### 7.2.2 Supply conductors

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

The supplier of the electrical equipment shall state in the installation documents the data necessary for conductor dimensioning (including the maximum cross-sectional area of the supply conductor that can be connected to the terminals of the electrical equipment) and for selecting the overcurrent protective device (see 7.2.10 and 17).

### 7.2.3 Power circuits

Devices for detection and interruption of overcurrent, selected in accordance with 7.2.10, shall be applied to each live conductor including circuits supplying control circuit transformers.

The following conductors, as applicable, shall not be disconnected without disconnecting all associated live conductors:

– the neutral conductor of AC power circuits;

– the earthed conductor of DC power circuits;

– DC power conductors bonded to exposed conductive parts of mobile machines.

Where the cross-sectional area of the neutral conductor is at least equal to or equivalent to that of the line conductors, it is not necessary to provide overcurrent detection for the neutral conductor nor a disconnecting device for that conductor. For a neutral conductor with a cross-sectional area smaller than that of the associated line conductors, the measures detailed in 524 of IEC 60364-5-52:2009 shall apply.

In IT systems, it is recommended that the neutral conductor is not used. However, where a neutral conductor is used, the measures detailed in 431.2.2 of IEC 60364-4-43:2008 shall apply.

### 7.2.4 Control circuits

Conductors of control circuits directly connected to the supply voltage shall be protected against overcurrent in accordance with 7.2.3.

Conductors of control circuits supplied by a transformer or DC supply shall be protected against overcurrent (see also 9.4.3.1.1):

– in control circuits connected to the protective bonding circuit, by inserting an overcurrent protective device into the switched conductor;

– in control circuits not connected to the protective bonding circuit;

  - where all control circuits of the equipment have the same current carrying capacity, by inserting an overcurrent protective device into the switched conductor, or;
  - where different control circuits of the equipment have different current carrying capacity, by inserting an overcurrent protective device into both switched and common conductors of each control circuit.

Exception: Where the supply unit provides current limiting below the current carrying capacity of the conductors in a circuit and below the current rating of connected components, no separate overcurrent protective device is required.

### 7.2.5 Socket outlets and their associated conductors

Overcurrent protection shall be provided for the circuits feeding the general purpose socket outlets intended primarily for supplying power to maintenance equipment. Overcurrent protective devices shall be provided in the unearthed live conductors of each circuit feeding such socket outlets. See also 15.1.

### 7.2.6 Lighting circuits

All unearthed conductors of circuits supplying lighting shall be protected against the effects of short-circuits by the provision of overcurrent devices separate from those protecting other circuits.

– SPDs for the suppression of overvoltages due to lightning shall be connected to the incoming terminals of the supply disconnecting device.
– SPDs for the suppression of overvoltages due to switching surges shall be connected as necessary for equipment requiring such protection.

NOTE 1 Information about the correct selection and installation of SPDs is given for example in IEC 60364-4-44, IEC 60364-5-53, IEC 61643-12, IEC 62305-1 and IEC 62305-4.

NOTE 2 Equipotential bonding of the machine, its electrical equipment and extraneous-conductive-parts to a common bonding network of the building/site can help mitigate electromagnetic interference, including the effects of lightning, on the equipment.

### 7.10 Short-circuit current rating

The short-circuit current rating of the electrical equipment shall be determined. This can be done by the application of design rules or by calculation or by test.

NOTE The short-circuit current rating may be determined, for example, in accordance with IEC 61439-1, IEC 60909-0, IEC/TR 60909-1, or IEC/TR 61912-1.

## 8 Equipotential bonding

### 8.1 General

This Clause 8 provides requirements for protective bonding and functional bonding. Figure 4 illustrates those concepts.

Protective bonding is a basic provision for fault protection to enable protection of persons against electric shock (see 6.3.3 and 8.2).

The objective of functional bonding (see 8.4) is to reduce:

– the consequence of an insulation failure which could affect the operation of the machine;
– electrical disturbances to sensitive electrical equipment which could affect the operation of the machine;
– induced currents from lightning which could damage the electric equipment.

Functional bonding is achieved by connection to the protective bonding circuit, but where the level of electrical disturbances on the protective bonding circuit is not sufficiently low for proper functioning of electrical equipment, it can be necessary to use separate conductors for protective and functional bonding.

## 8.2 Protective bonding circuit

### 8.2.1 General

The protective bonding circuit consists of the interconnection of:

- PE terminal(s) (see 5.2);
- the protective conductors (see 3.1.51) in the equipment of the machine including sliding contacts where they are part of the circuit;
- the conductive structural parts and exposed conductive parts of the electrical equipment;

Exception: see 8.2.5.

- conductive structural parts of the machine.

All parts of the protective bonding circuit shall be so designed that they are capable of withstanding the highest thermal and mechanical stresses that can be caused by earth-fault currents that could flow in that part of the protective bonding circuit.

The cross-sectional area of every protective conductor which does not form part of a cable or which is not in a common enclosure with the line conductor shall be not less than

– 2,5 $mm^2$ Cu or 16 $mm^2$ Al if protection against mechanical damage is provided,
– 4 $mm^2$ Cu or 16 $mm^2$ Al if protection against mechanical damage is not provided.

NOTE The use of steel for a protective conductor is not excluded.

A protective conductor not forming part of a cable is considered to be mechanically protected if it is installed in a conduit, trunking or protected in a similar way. Conductive structural parts of equipment in accordance with 6.3.2.2 need not be connected to the protective bonding circuit. Conductive structural parts of the machine need not be connected to the protective bonding circuit where all the equipment provided is in accordance with 6.3.2.2.

Exposed conductive parts of equipment in accordance with 6.3.2.3 shall not be connected to the protective bonding circuit.

It is not necessary to connect exposed conductive parts to the protective bonding circuit where those parts are mounted so that they do not constitute a hazard because:

– they cannot be touched on large surfaces or grasped with the hand and they are small in size (less than approximately 50 mm × 50 mm); or
– they are located so that either contact with live parts, or an insulation failure, is unlikely.

This applies to small parts such as screws, rivets, and nameplates and to parts inside an enclosure, irrespective of their size (for example electromagnets of contactors or relays and mechanical parts of devices).

### 8.2.2 Protective conductors

Protective conductors shall be identified in accordance with 13.2.2.

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

Metal enclosures or frames or mounting plates of electrical equipment, connected to the protective bonding circuit, may be used as protective conductors if they satisfy the following three requirements:

- their electrical continuity shall be assured by construction or by suitable connection so as to ensure protection against mechanical, chemical or electrochemical deterioration;
- they comply with the requirements of 543.1 of IEC 60364-5-54:2011;
- they shall permit the connection of other protective conductors at every predetermined tap-off point.

The cross-sectional area of protective conductors shall either be calculated in accordance with 543.1.2 of IEC 60364-5-54:2011, or selected in accordance with Table 1 (see 5.2). See also 8.2.6. and 17.2 (d) of this document.

Each protective conductor shall:

- be part of a multicore cable, or;
- be in a common enclosure with the line conductor, or;
- have a cross-sectional area of at least;
- 2,5 $mm^2$ Cu or 16 $mm^2$ Al if protection against mechanical damage is provided;
- 4 $mm^2$ Cu or 16 $mm^2$ Al if protection against mechanical damage is not provided.

NOTE 1 The use of steel for a protective conductor is not excluded.

A protective conductor not forming part of a cable is considered to be mechanically protected if it is installed in a conduit, trunking or protected in a similar way.

The following parts of the machine and its electrical equipment shall be connected to the protective bonding circuit but shall not be used as protective conductors:

- conductive structural parts of the machine;
- metal ducts of flexible or rigid construction;
- metallic cable sheaths or armouring;
- metallic pipes containing flammable materials such as gases, liquids, powder.
- flexible or pliable metal conduits;
- constructional parts subject to mechanical stress in normal service;
- flexible metal parts; support wires; cable trays and cable ladders.

NOTE 2 Information on cathodic protection is provided in 542.2.5 and 542.2.6 of IEC 60364-5-54:2011.

### 8.2.3 Continuity of the protective bonding circuit

Where a part is removed for any reason (for example routine maintenance), the protective bonding circuit for the remaining parts shall not be interrupted.

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

Where the electrical equipment is mounted on lids, doors, or cover plates, continuity of the protective bonding circuit shall be ensured and a protective conductor (see 8.2.2) is recommended. Where a protective conductor is not provided, fastenings, hinges or sliding contacts designed to have a low resistance shall be used (see 18.2.2, Test 1).

The continuity of conductors in cables that are exposed to damage (for example flexible trailing cables) shall be ensured by appropriate measures (for example monitoring).

Mode selection by itself shall not initiate machine operation. A separate actuation of the start control shall be required.

For each specific operating mode, the relevant safety functions and/or protective measures shall be implemented.

Indication of the selected operating mode shall be provided (for example the position of a mode selector, the provision of an indicating light, a visual display indication).

#### 9.2.3.6 Monitoring of command actions

Movement or action of a machine or part of a machine that can result in a hazardous situation shall be monitored by providing, for example, overtravel limiters, motor overspeed detection, mechanical overload detection or anti-collision devices.

NOTE On some manually controlled machines (for example, manual drilling machine), operators provide monitoring.

#### 9.2.3.7 Hold-to-run controls

Hold-to-run controls shall require continuous actuation of the control device(s) to achieve operation.

#### 9.2.3.8 Two-hand control

Three types of two-hand control are defined in ISO 13851, the selection of which is determined by the risk assessment. These shall have the following features:

Type I: this type requires:

- the provision of two control devices and their concurrent actuation by both hands;
- continuous concurrent actuation during the hazardous situation;
- machine operation shall cease upon the release of either one or both of the control devices when hazardous situations are still present.

A Type I two-hand control device is not considered to be suitable for the initiation of hazardous operation.

Type II: a Type I control requiring the release of both control devices before machine operation can be reinitiated.

Type III: a Type II control requiring concurrent actuation of the control devices as follows:

- it shall be necessary to actuate the control devices within a certain time limit of each other, not exceeding 0,5 s;
- where this time limit is exceeded, both control devices shall be released before machine operation can be initiated.

#### 9.2.3.9 Enabling control

Enabling control (see also 10.9) is a manually activated control function interlock that:

a) when activated allows a machine operation to be initiated by a separate start control, and
b) when de-activated
    - initiates a stop function, and
    - prevents initiation of machine operation.

Enabling control shall be so arranged as to minimize the possibility of defeating, for example by requiring the de-activation of the enabling control device before machine operation may be reinitiated.

#### 9.2.3.10 Combined start and stop controls

Push-buttons and similar control devices that, when operated, alternately initiate and stop motion shall only be provided for functions which cannot result in a hazardous situation.

### 9.2.4 Cableless control system (CCS)

#### 9.2.4.1 General requirements

Subclause 9.2.4 deals with the functional requirements of control systems employing cableless (for example radio, infra-red) techniques for transmitting control signals and data between operator control station(s) and other parts of the control system(s).

NOTE 1 Reference to a machine in 9.2.4 is intended to be read as “machine or part(s) of a machine”.

〈C〉 Where a safety function of a CCS relies on data transmission the transmission reliability shall be considered. 〈C〉

The CCS shall have functionality and a response time suitable for the application based on the risk assessment.

NOTE 2 IEC 61784-3 describes communication failures of communication networks and requirements for safety-related data transmission.

NOTE 3 Further requirements for cableless control systems are under development by IEC TC 44 in draft IEC 62745[1].

#### 9.2.4.2 Monitoring the ability of a cableless control system to control a machine

The ability of a cableless control system (CCS) to control a machine shall be automatically monitored, either continuously or at suitable intervals. The status of this ability shall be clearly indicated (for example, by an indicating light, a visual display indication, etc.)

If the communication signal is degraded in a manner that might lead to the loss of the ability of a CCS to control a machine (e.g., reduced signal level, low battery power) a warning to the operator shall be provided before the ability of the CCS to control a machine is lost.

When the ability of a CCS to control a machine has been lost for a time that is determined from a risk assessment of the application, an automatic stop of the machine shall be initiated.

NOTE In some cases, for example, in order to avoid this automatic stop generating an unexpected hazardous condition, it can be necessary for the machine to go to a predetermined state before stopping.

Restoration of the ability of a CCS to control a machine shall not restart the machine. Restart shall require a deliberate action, for example manual actuation of a start button.

#### 9.2.4.3 Control limitation

Measures shall be taken (e.g. coded transmission) to prevent the machine from responding to signals other than those from the intended cableless operator control station(s).

Cableless operator control station(s) shall only control the intended machine(s) and shall affect only the intended machine functions.

---

1 Under consideration.

# 10 Operator interface and machine-mounted control devices

## 10.1 General

### 10.1.1 General requirements

Control devices for operator interface shall, as far as is practicable, be selected, mounted, and identified or coded in accordance with IEC 61310 series.

The possibility of inadvertent operation shall be minimized by, for example, positioning of devices, suitable design, provision of additional protective measures. Particular consideration shall be given to the selection, arrangement, programming and use of operator input devices such as touchscreens, keypads and keyboards for the control of hazardous machine operations, and of sensors (for example position sensors) that can initiate machine operation. Further information can be found in IEC 60447.

Ergonomic principles shall be taken into account in the location of operator interface devices.

### 10.1.2 Location and mounting

As far as is practicable, machine-mounted control devices shall be:

- readily accessible for service and maintenance;
- mounted in such a manner as to minimize the possibility of damage from activities such as material handling.

The actuators of hand-operated control devices shall be selected and installed so that:

- they are not less than 0,6 m above the servicing level and are within easy reach of the normal working position of the operator;
- the operator is not placed in a hazardous situation when operating them.

The actuators of foot-operated control devices shall be selected and installed so that:

- they are within easy reach of the normal working position of the operator;
- the operator is not placed in a hazardous situation when operating them.

### 10.1.3 Protection

The degree of protection (IP rating in accordance with IEC 60529) together with other appropriate measures shall provide protection against:

- the effects of liquids, vapours, or gases found in the physical environment or used on the machine;
- the ingress of contaminants (for example swarf, dust, particulate matter).

In addition, the operator interface control devices shall have a minimum degree of protection against contact with live parts of IPXXD in accordance with IEC 60529.

### 10.1.4 Position sensors

Position sensors (for example position switches, proximity switches) shall be so arranged that they will not be damaged in the event of overtravel.

Position sensors in circuits with safety-related control functions (for example, to maintain the safe condition of the machine or prevent hazardous situations arising at the machine) shall have direct opening action (see IEC 60947-5-1) or shall provide similar reliability (see 9.4.2).

### 10.1.5 Portable and pendant control stations

Portable and pendant operator control stations and their control devices shall be so selected and arranged as to minimize the possibility of machine operations caused by inadvertent actuation, shocks and vibrations (for example if the operator control station is dropped or strikes an obstruction) (see also 4.4.8).

## 10.2 Actuators

### 10.2.1 Colours

Actuators (see 3.1.1) shall be colour-coded as follows.

The colours for START/ON actuators should be WHITE, GREY, BLACK or GREEN with a preference for WHITE. RED shall not be used.

The colour RED shall be used for emergency stop and emergency switching off actuators (including supply disconnecting devices where it is foreseen that they are for use in an emergency). If a background exists immediately around the actuator, then this background shall be coloured YELLOW. The combination of a RED actuator with a YELLOW background shall only be used for emergency operation devices.

The colours for STOP/OFF actuators should be BLACK, GREY, or WHITE with a preference for BLACK. GREEN shall not be used. RED is permitted, but it is recommended that RED is not used near an emergency operation device.

WHITE, GREY, or BLACK are the preferred colours for actuators that alternately act as START/ON and STOP/OFF actuators. The colours RED, YELLOW, or GREEN shall not be used.

WHITE, GREY, or BLACK are the preferred colours for actuators that cause operation while they are actuated and cease the operation when they are released (for example hold-to-run). The colours RED, YELLOW, or GREEN shall not be used.

Reset actuators shall be BLUE, WHITE, GREY, or BLACK. Where they also act as a STOP/OFF actuator, the colours WHITE, GREY, or BLACK are preferred with the main preference being for BLACK. GREEN shall not be used.

The colour YELLOW is reserved for use in abnormal conditions, for example, in the event of an abnormal condition of the process, or to interrupt an automatic cycle.

Where the same colour WHITE, GREY, or BLACK is used for various functions (for example WHITE for START/ON and for STOP/OFF actuators) a supplementary means of coding (for example shape, position, symbol) shall be used for the identification of actuators.

### 10.2.2 Markings

In addition to the functional identification as described in 16.3, recommended symbols to be placed near to or preferably directly on certain actuators are given in Table 2 or 3.

**Table 4 – Colours for indicator lights and their meanings with respect to the condition of the machine**

| Colour | Meaning | Explanation | Action by operator |
|---|---|---|---|
| RED | Emergency | Hazardous condition | Immediate action to deal with hazardous condition (for example switching off the machine supply, being alert to the hazardous condition and staying clear of the machine) |
| YELLOW | Abnormal | Abnormal condition<br>Impending critical condition | Monitoring and/or intervention (for example by re-establishing the intended function) |
| BLUE | Mandatory | Indication of a condition that requires action by the operator | Mandatory action |
| GREEN | Normal | Normal condition | Optional |
| WHITE | Neutral | Other conditions; may be used whenever doubt exists about the application of RED, YELLOW, GREEN, BLUE | Monitoring |

Indicating towers on machines should have the applicable colours in the following order from the top down; RED, YELLOW, BLUE, GREEN and WHITE.

### 10.3.3 Flashing lights and displays

For further distinction or information and especially to give additional emphasis, flashing lights and displays can be provided for the following purposes:

– to attract attention;
– to request immediate action;
– to indicate a discrepancy between the command and actual state;
– to indicate a change in process (flashing during transition).

It is recommended that higher flashing frequencies are used for higher priority information (see IEC 60073 for recommended flashing rates and pulse/pause ratios).

Where flashing lights or displays are used to provide higher priority information, additional acoustic warnings should be considered.

## 10.4 Illuminated push-buttons

Illuminated push-button actuators shall be colour-coded in accordance with 10.2.1. Where there is difficulty in assigning an appropriate colour, WHITE shall be used.

The colour of active emergency stop actuators shall remain RED regardless of the state of the illumination.

## 10.5 Rotary control devices

Devices having a rotational member, such as potentiometers and selector switches, shall have means of prevention of rotation of the stationary member. Friction alone shall not be considered sufficient.

## 10.6 Start devices

Actuators used to initiate a start function or the movement of machine elements (for example slides, spindles, carriers) shall be constructed and mounted so as to minimize inadvertent operation.

### 10.7 Emergency stop devices

#### 10.7.1 Location of emergency stop devices

Devices for emergency stop shall be readily accessible.

Emergency stop devices shall be provided at each location where the initiation of an emergency stop can be required.

There can be circumstances where confusion can occur between active and inactive emergency stop devices caused by, for example, unplugging or otherwise disabling an operator control station. In such cases, means (for example, design and information for use) shall be provided to minimise confusion.

#### 10.7.2 Types of emergency stop device

The types of device for emergency stop include, but are not limited to:

- a push-button device for actuation by the palm or the fist (e.g. mushroom head type);
- a pull-cord operated switch;
- a pedal-operated switch without a mechanical guard.

The devices shall be in accordance with IEC 60947-5-5.

#### 10.7.3 Operation of the supply disconnecting device to effect emergency stop

Where a stop category 0 is suitable, the supply disconnecting device may serve the function of emergency stop where:

- it is readily accessible to the operator; and
- it is of the type described in 5.3.2 a), b), c), or d).

Where intended for emergency use, the supply disconnecting device shall meet the colour requirements of 10.2.1.

### 10.8 Emergency switching off devices

#### 10.8.1 Location of emergency switching off devices

Emergency switching off devices shall be located as necessary for the given application. Normally, those devices will be located separate from operator control stations. Where confusion can occur between emergency stop and emergency switching off devices, means shall be provided to minimise confusion.

NOTE This can be achieved by, for example, the provision of a break-glass enclosure for the emergency switching off device.

#### 10.8.2 Types of emergency switching off device

The types of device for initiation of emergency switching off include:

- a push-button operated switch with a palm or mushroom head type of actuator;
- a pull-cord operated switch.

The devices shall have direct opening action (see Annex K of IEC 60947-5-1:2003 and IEC 60947-5-1:2003/AMD1:2009).

#### 10.8.3 Local operation of the supply disconnecting device to effect emergency switching off

Where the supply disconnecting device is to be locally operated for emergency switching off, it shall be readily accessible and shall meet the colour requirements of 10.2.1.

### 10.9 Enabling control device

The enabling control function is described in 9.2.3.9.

Enabling control devices shall be selected and arranged so as to minimize the possibility of defeating.

Enabling control devices shall be selected that have the following features:

– designed in accordance with ergonomic principles;
– for a two-position type:
  - position 1: off-function of the switch (actuator is not operated);
  - position 2: enabling function (actuator is operated).
– for a three-position type:
  - position 1: off-function of the switch (actuator is not operated);
  - position 2: enabling function (actuator is operated in its mid position);
  - position 3: off-function (actuator is operated past its mid position);
  - when returning from position 3 to position 2, the enabling function is not activated.

NOTE IEC 60947-5-8 specifies requirements for three-position enabling switches.

## 11 Controlgear: location, mounting, and enclosures

### 11.1 General requirements

All controlgear shall be located and mounted so as to facilitate:

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

### 11.2 Location and mounting

#### 11.2.1 Accessibility and maintenance

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

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

No devices except devices for operating, indicating, measuring, and cooling shall be mounted on doors or on access covers of enclosures that are expected to be removed.

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

Plug-in devices that are handled during normal operation shall be provided with non-interchangeable features where the lack of such a facility can result in malfunctioning.

Plug/socket combinations that are handled during normal operation shall be located and mounted so as to provide unobstructed access.

Test points for connection of test equipment, where provided, shall be:

– mounted so as to provide unobstructed access;
– clearly identified to correspond with the documentation;
– adequately insulated;
– sufficiently spaced.

### 11.2.2 Physical separation or grouping

Non-electrical parts and devices, not directly associated with the electrical equipment, shall not be located within enclosures containing controlgear. Devices such as solenoid valves should be separated from the other electrical equipment (for example in a separate compartment).

Control devices mounted in the same location and connected to the power circuits, or to both power and control circuits, should be grouped separately from those connected only to the control circuits.

Terminals shall be separated into groups for:

– power circuits;
– control circuits of the machine;
– other control circuits, fed from external sources (for example for interlocking).

The groups may be mounted adjacently, provided that each group can be readily identified (for example by markings, by use of different sizes, by use of barriers or by colours).

When arranging the location of devices (including interconnections), the clearances and creepage distances specified for them by the supplier shall be maintained, taking into account the external influences or conditions of the physical environment.

### 11.2.3 Heating effects

The temperature rise inside electrical equipment enclosures shall not exceed the ambient temperature specified by the component manufacturers.

NOTE 1 IEC TR 60890 can be used for the calculation of temperature rise inside enclosures.

Heat generating components (for example heat sinks, power resistors) shall be so located that the temperature of each component in the vicinity remains within the permitted limit.

NOTE 2 Information on the selection of insulating materials to resist thermal stresses is given in IEC 60216 and IEC 60085.

ensure the degree of protection specified for the equipment. Openings for cable entries shall be easy to re-open on site. A suitable opening may be provided in the base of enclosures within the machine so that moisture due to condensation can drain away.

There shall be no opening between enclosures containing electrical equipment and compartments containing coolant, lubricating or hydraulic fluids, or those into which oil, other liquids, or dust can penetrate. This requirement does not apply to electrical devices specifically designed to operate in oil (for example electromagnetic clutches) nor to electrical equipment in which coolants are used.

Where there are holes in an enclosure for mounting purposes, means may be necessary to ensure that after mounting, the holes do not impair the required protection.

Equipment that, in normal or abnormal operation, can attain a surface temperature sufficient to cause a risk of fire or 〚C〉 detrimental 〈C〛 effect to an enclosure material shall:

– be located within an enclosure that will withstand, without risk of fire or harmful effect, such temperatures as can be generated; and
– be mounted and located at a sufficient distance from adjacent equipment so as to allow safe dissipation of heat (see also 11.2.3); or
– be otherwise screened by material that can withstand, without risk of fire or harmful effect, the heat emitted by the equipment.

NOTE A warning label in accordance with 16.2.2 can be necessary.

### 11.5 Access to electrical equipment

Doors in gangways and for access to electrical operating areas shall:

– be at least 0,7 m wide and 2,0 m high;
– open outwards;
– have a means (for example panic bolts) to allow opening from the inside without the use of a key or tool.

NOTE Further information is given in IEC 60364-7-729.

## 12 Conductors and cables

### 12.1 General requirements

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

These requirements do not apply to the integral wiring of assemblies, subassemblies, and devices that are manufactured and tested in accordance with their relevant IEC standard (for example IEC 61800 series).

### 12.2 Conductors

Conductors should be of copper. Where aluminium conductors are used, the cross-sectional area shall be at least 16 $mm^2$.

To ensure adequate mechanical strength, the cross-sectional area of conductors should not be less than as shown in Table 5. However, conductors with smaller cross-sectional areas or other constructions than shown in Table 5 may be used in equipment provided adequate mechanical strength is achieved by other means and proper functioning is not impaired.

NOTE Classification of conductors is given in Table D.4.

**Table 5 – Minimum cross-sectional areas of copper conductors**

| Location | Application | Type of conductor, cable | | | | |
|---|---|---|---|---|---|---|
| | | Single core | | Multicore | | |
| | | Flexible Class 5 or 6 | Solid (class 1) or stranded (class 2) | Two core, shielded | Two core not shielded | Three or more cores, shielded or not |
| Wiring outside (protecting) enclosures | Power circuits, fixed | 1,0 | 1,5 | 0,75 | 0,75 | 0,75 |
| | Power circuits, subjected to frequent movements | 1,0 | – | 0,75 | 0,75 | 0,75 |
| | Control circuits | 1,0 | 1,0 | 0,2 | 0,5 | 0,2 |
| | Data communication | – | – | – | – | 0,08 |
| Wiring inside enclosures [a)] | Power circuits (connections not moved) | 0,75 | 0,75 | 0,75 | 0,75 | 0,75 |
| | Control circuits | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 |
| | Data communication | – | – | – | – | 0,08 |

NOTE All cross-sections in $mm^2$.

[a)] Except special requirements of individual standards, see also 12.1.

Class 1 and class 2 conductors are primarily intended for use between rigid, non-moving parts where vibration is not considered to be likely to cause damage.

All conductors that are subject to frequent movement (for example one movement per hour of machine operation) should have flexible stranding of class 5 or class 6.

### 12.3 Insulation

Where the insulation of conductors and cables can constitute hazards due for example to the propagation of a fire or the emission of toxic or corrosive fumes, guidance from the cable supplier shall be sought. It is important to give special attention to the integrity of a circuit having a safety-related function.

The insulation of cables and conductors used, shall be suitable for a test voltage:

– not less than 2 000 V AC for a duration of 5 min for operation at voltages higher than 50 V AC or 120 V DC, or

– not less than 500 V AC for a duration of 5 min for PELV circuits (see IEC 60364-4-41, class III equipment).

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

### 12.4 Current-carrying capacity in normal service

The current-carrying capacity depends on several factors, for example insulation material, number of conductors in a cable, design (sheath), methods of installation, grouping and ambient temperature.

NOTE 1 Detailed information and further guidance can be found in IEC 60364-5-52, in some national standards or given by the manufacturer.

One typical example of the current-carrying capacities for PVC insulated wiring between enclosures and individual items of equipment under steady-state conditions is given in Table 6.

NOTE 2 For specific applications where the correct cable dimensioning can depend on the relationship between the period of the duty cycle and the thermal time constant of the cable (for example starting against high-inertia load, intermittent duty), the cable manufacturer can provide information.

**Table 6 – Examples of current-carrying capacity ($I_Z$) of PVC insulated copper conductors or cables under steady-state conditions in an ambient air temperature of +40 °C for different methods of installation**

| | Installation method (see D.2.2) | | | |
|---|---|---|---|---|
| | B1 | B2 | C | E |
| Cross-sectional area mm$^2$ | Current-carrying capacity $I_z$ for three phase circuits A | | | |
| 0,75 | 8,6 | 8,5 | 9,8 | 10,4 |
| 1,0 | 10,3 | 10,1 | 11,7 | 12,4 |
| 1,5 | 13,5 | 13,1 | 15,2 | 16,1 |
| 2,5 | 18,3 | 17,4 | 21 | 22 |
| 4 | 24 | 23 | 28 | 30 |
| 6 | 31 | 30 | 36 | 37 |
| 10 | 44 | 40 | 50 | 52 |
| 16 | 59 | 54 | 66 | 70 |
| 25 | 77 | 70 | 84 | 88 |
| 35 | 96 | 86 | 104 | 110 |
| 50 | 117 | 103 | 125 | 133 |
| 70 | 149 | 130 | 160 | 171 |
| 95 | 180 | 156 | 194 | 207 |
| 120 | 208 | 179 | 225 | 240 |
| | Control circuit pairs | | | |
| 0,20 | 4,5 | 4,3 | 4,4 | 4,4 |
| 0,5 | 7,9 | 7,5 | 7,5 | 7,8 |
| 0,75 | 9,5 | 9,0 | 9,5 | 10 |

NOTE 1 The values of the current-carrying capacity of Table 6 are based on:

– one symmetrical three-phase circuit for cross-sectional areas 0,75 mm$^2$ and greater;

– one control circuit pair for cross-sectional areas between 0,2 mm$^2$ and 0,75 mm$^2$.

Where more loaded cables/pairs are installed, derating factors for the values of Table 6 can be found in Tables D.2 or D.3.

NOTE 2 For ambient temperatures other than 40 °C, correction factors for current-carrying capacities are provided in Table D.1.

NOTE 3 These values are not applicable to flexible cables wound on drums (see 12.6.3).

NOTE 4 Current-carrying capacities of other cables are provided in IEC 60364-5-52.

## 12.5 Conductor and cable voltage drop

The voltage drop from the point of supply to the load in any power circuit cable shall not exceed 5 % of the nominal voltage under normal operating conditions. In order to conform to this requirement, it can be necessary to use conductors having a larger cross-sectional area than that derived from Table 6.

### 12.7.4 Removable current collectors with a disconnector function

Removable current collectors having a disconnector function shall be so designed that the protective conductor circuit is interrupted only after the live conductors have been disconnected, and the continuity of the protective conductor circuit is re-established before any live conductor is reconnected (see also 8.2.3).

### 12.7.5 Clearances in air

Clearances between the respective conductors, and between adjacent systems, of conductor wires, conductor bars, slip-ring assemblies and their current collectors shall be suitable for at least a rated impulse voltage of an overvoltage category III in accordance with IEC 60664-1.

### 12.7.6 Creepage distances

Creepage distances between the respective conductors, between adjacent systems of conductor wires, conductor bars and slip-ring assemblies, and their current collectors shall be suitable for operation in the intended environment, for example open air, inside buildings, protected by enclosures.

In abnormally dusty, moist or corrosive environments, the following creepage distance requirements apply:

– unprotected conductor wires, conductor bars, and slip-ring assemblies shall be equipped with insulators with a minimum creepage distance of 60 mm;

– enclosed conductor wires, insulated multipole conductor bars and insulated individual conductor bars shall have a minimum creepage distance of 30 mm.

The manufacturer's recommendations shall be followed regarding special measures to prevent a gradual reduction in the insulation values due to unfavourable ambient conditions (for example deposits of conductive dust, chemical attack).

### 12.7.7 Conductor system sectioning

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

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

Conductor wires, conductor bars and slip-ring assemblies in power circuits shall be grouped separately from those in control circuits.

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

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

Where conductor bars are installed in a common metal enclosure, the individual sections of the enclosure shall be bonded together and connected to the protective bonding circuit. Metal covers of conductor bars laid underground or underfloor shall also be bonded together and connected to the protective bonding circuit.

Exception: Where it is impracticable to provide terminals in a junction box (for example on mobile machines, on machines having long flexible cables; cable connections exceeding a length which is not practical to be supplied by the cable manufacturer on one cable drum), splices or joints may be used.

Where it is necessary to connect and disconnect cables and cable assemblies, sufficient extra length shall be provided for that purpose.

The terminations of cables shall be adequately supported to prevent mechanical stresses at the terminations of the conductors.

Wherever practicable, the protective conductor shall be placed close to the associated live conductors in order to decrease the impedance of the loop.

#### 13.1.3 Conductors of different circuits

Conductors of different circuits may be laid side by side, may occupy the same duct (for example conduit, cable trunking system), or may be in the same multiconductor cable or in the same plug/socket combination provided that the arrangement does not impair the proper functioning of the respective circuits and:

- where those circuits operate at different voltages, the conductors are separated by suitable barriers or;
- the conductors are insulated for the highest voltage to which any of the conductors can be subjected, for example line to line voltage for unearthed systems and phase to earth voltage for earthed systems.

#### 13.1.4 AC circuits – Electromagnetic effects (prevention of eddy currents)

Conductors of AC circuits installed in ferromagnetic enclosures shall be arranged so that all conductors of each circuit, including the protective conductor of each circuit, are contained in the same enclosure. Where such conductors enter a ferrous enclosure, they shall be arranged such that the conductors are not individually surrounded by ferromagnetic material.

Single-core cables armoured with steel wire or steel tape should not be used for AC circuits.

NOTE 1 The steel wire or steel tape armour of a single-core cable is regarded as a ferromagnetic enclosure. For single-core wire armoured cables, the use of aluminium armour is recommended.

NOTE 2 Derived from IEC 60364-5-52.

#### 13.1.5 Connection between pick-up and pick-up converter of an inductive power supply system

The cable between the pick-up and the pick-up converter shall be:

– as short as practicable;

– adequately protected against mechanical damage.

NOTE The output of the pick-up can be a current source, therefore damage to the cable can result in a high voltage hazard.

### 13.2 Identification of conductors

#### 13.2.1 General requirements

Each conductor shall be identifiable at each termination in accordance with the technical documentation.

It is recommended (for example to facilitate maintenance) that conductors be identified by number, alphanumeric, colour (either solid or with one or more stripes), or a combination of

Where identification by colour is used, bare conductors used as neutral conductors shall be either coloured by a stripe, 15 mm to 100 mm wide in each compartment or unit and at each accessible location, or coloured throughout their length.

### 13.2.4 Identification by colour

Where colour-coding is used for identification of conductors (other than the protective conductor (see 13.2.2) and the neutral conductor (see 13.2.3)), the following colours may be used:

BLACK, BROWN, RED, ORANGE, YELLOW, GREEN, BLUE (including LIGHT BLUE), VIOLET, GREY, WHITE, PINK, TURQUOISE.

NOTE This list of colours is derived from IEC 60757.

It is recommended that, where colour is used for identification, the colour be used throughout the length of the conductor either by the colour of the insulation or by colour markers at regular intervals and at the ends or accessible location.

For safety reasons, the colour GREEN or the colour YELLOW should not be used where there is a possibility of confusion with the bicolour combination GREEN-AND-YELLOW (see 13.2.2).

Colour identification using combinations of those colours listed above may be used provided there can be no confusion and that GREEN or YELLOW is not used except in the bicolour combination GREEN-AND-YELLOW.

Where colour-coding is used for identification of conductors, it is recommended that they be colour-coded as follows:

– BLACK: AC and DC power circuits;
– RED: AC control circuits;
– BLUE: DC control circuits;
– ORANGE: excepted circuits in accordance with 5.3.5.

Exceptions to the above are permitted where insulation is not available in the colours recommended (for example in multiconductor cables).

## 13.3 Wiring inside enclosures

Conductors inside enclosures shall be supported where necessary to keep them in place. Non-metallic ducts shall be permitted only when they are made with a flame-retardant insulating material (see the IEC 60332 series).

It is recommended that electrical equipment mounted inside enclosures be designed and constructed in such a way as to permit modification of the wiring from the front of the enclosure (see also 11.2.1). Where that is not practicable and control devices are connected from the rear of the enclosure, access doors or swingout panels shall be provided.

Connections to devices mounted on doors or to other movable parts shall be made using flexible conductors in accordance with 12.2 and 12.6 to allow for the frequent movement of the part. The conductors shall be anchored to the fixed part and to the movable part independently of the electrical connection (see also 8.2.3 and 11.2.1).

Conductors and cables that do not run in ducts shall be adequately supported.

Terminal blocks or plug/socket combinations shall be used for control wiring that extends beyond the enclosure. For plug/socket combinations, see also 13.4.5 and 13.4.6.

Power cables and cables of measuring circuits may be directly connected to the terminals of the devices for which the connections were intended.

### 13.4 Wiring outside enclosures

#### 13.4.1 General requirements

The means of introduction of cables or ducts with their individual glands, bushings, etc., into an enclosure shall ensure that the degree of protection is not reduced (see 11.3).

Conductors of a circuit shall not be distributed over different multi-core cables, conduits, cable ducting systems or cable trunking systems. This is not required where a number of multi-core cables, forming one circuit, are installed in parallel. Where multi-core cables are installed in parallel, each cable shall contain one conductor of each phase and the neutral if any.

#### 13.4.2 External ducts

Conductors and their connections external to the electrical equipment enclosure(s) shall be enclosed in suitable ducts (i.e. conduit or cable trunking systems) as described in 13.5 except for suitably protected cables that may be installed without ducts and with or without the use of cable trays or cable support means. Where devices such as position switches or proximity switches are supplied with a dedicated cable, their cable need not be enclosed in a duct when the cable is suitable for the purpose, sufficiently short, and so located or protected, that the risk of damage is minimized.

Fittings used with ducts or cables shall be suitable for the physical environment.

Flexible conduit or flexible multiconductor cable shall be used where it is necessary to employ flexible connections to pendant push-button stations. The weight of the pendant stations shall be supported by means other than the flexible conduit or the flexible multiconductor cable, except where the conduit or cable is specifically designed for that purpose.

#### 13.4.3 Connection to moving elements of the machine

The design of connections to moving parts shall take into account the foreseeable frequency of movement and shall be made using conductors in accordance with 12.2 and 12.6. Flexible cable and flexible conduit shall be so installed as to avoid excessive flexing and straining, particularly at the fittings.

Cables subject to movement shall be supported in such a way that there is no mechanical strain on the connection points nor any sharp flexing. When this is achieved by the provision of a loop, it shall have sufficient length to provide for a bending radius of the cable as specified by the cable manufacturer or if no such specification is given, at least 10 times the diameter of the cable.

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

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

All sharp edges, flash, burrs, rough surfaces, or threads with which the insulation of the conductors can come in contact shall be removed from ducts and fittings. Where necessary, additional protection consisting of a flame-retardant, oil-resistant insulating material shall be provided to protect conductor insulation.

Drain holes of 6 mm diameter are permitted in cable trunking systems, connection boxes, and other boxes used for wiring purposes that can be subject to accumulations of oil or moisture.

In order to prevent confusion of conduits with oil, air, or water piping, it is recommended that the conduits be either physically separated or suitably identified.

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

Cable trays that are partially covered should not be considered to be ducts or cable trunking systems (see 13.5.6), and the cables used shall be of a type suitable for installation on open cable trays.

It is recommended that the dimensions and arrangement of ducts be such as to facilitate the insertion of the conductors and cables.

### 13.5.2 Rigid metal conduit and fittings

Rigid metal conduit and fittings shall be of galvanized steel or of a corrosion-resistant material suitable for the conditions. [C〉 Where galvanic action is possible between dissimilar metals metal these combinations shall not be used. 〈C]

Conduits shall be securely held in place and supported at each end.

Fittings shall be compatible with the conduit and appropriate for the application. Fittings should be threaded unless structural difficulties prevent assembly. Where threadless fittings are used, the conduit shall be securely fastened to the equipment.

Conduit bends shall be made in such a manner that the conduit shall not be damaged and the internal diameter of the conduit shall not be effectively reduced.

### 13.5.3 Flexible metal conduit and fittings

A flexible metal conduit shall consist of a flexible metal tubing or woven wire armour. It shall be suitable for the expected physical environment.

Fittings shall be compatible with the conduit and appropriate for the application.

### 13.5.4 Flexible non-metallic conduit and fittings

Flexible non-metallic conduit shall be resistant to kinking and shall have physical characteristics similar to those of the sheath of multiconductor cables.

The conduit shall be suitable for use in the expected physical environment.

Fittings shall be compatible with the conduit and appropriate for the application.

### 13.5.5 Cable trunking systems

Cable trunking systems external to enclosures shall be rigidly supported and clear of all moving parts of the machine and of sources of contamination.

Covers shall be shaped to overlap the sides; gaskets shall be permitted. Covers shall be attached to cable trunking systems by suitable means. On horizontal cable trunking systems, the cover shall not be on the bottom unless specifically designed for such installation.

NOTE Requirements for cable trunking and ducting systems for electrical installations are given in the IEC 61084 series.

Where the cable trunking system is furnished in sections, the joints between sections shall fit tightly but need not be gasketed.

The only openings permitted shall be those required for wiring or for drainage. Cable trunking systems shall not have opened but unused knockouts.

#### 13.5.6 Machine compartments and cable trunking systems

The use of compartments or cable trunking systems within the column or base of a machine to enclose conductors is permitted provided the compartments or cable trunking systems are isolated from coolant or oil reservoirs and are entirely enclosed. Conductors run in enclosed compartments and cable trunking systems shall be so secured and arranged that they are not subject to damage.

#### 13.5.7 Connection boxes and other boxes

Connection boxes and other boxes used for wiring purposes shall be accessible for maintenance. Those boxes shall provide protection against the ingress of solid bodies and liquids, taking into account the external influences under which the machine is intended to operate (see 11.3).

Those boxes shall not have opened but unused knockouts nor any other openings and shall be so constructed as to exclude materials such as dust, flyings, oil, and coolant.

#### 13.5.8 Motor connection boxes

Motor connection boxes shall enclose only connections to the motor and motor-mounted devices (for example brakes, temperature sensors, plugging switches, tachometer generators).

## 14 Electric motors and associated equipment

### 14.1 General requirements

Electric motors should conform to the relevant parts of IEC 60034 series.

The protection requirements for motors and associated equipment are given in 7.2 for overcurrent protection, in 7.3 for protection of motors against overheating, and in 7.6 for overspeed protection.

As many controllers do not switch off the supply to a motor when it is at rest, care shall be taken to ensure compliance with the requirements of 5.3, 5.4, 5.5, 7.5, 7.6 and 9.4. Motor control equipment shall be located and mounted in accordance with Clause 11.

### 14.2 Motor enclosures

Enclosures for motors should be in accordance with IEC 60034-5.

The degree of protection shall be dependent on the application and the physical environment (see 4.4). All motors shall be adequately protected from mechanical damage.

# 15 Socket-outlets and lighting

## 15.1 Socket-outlets for accessories

Where the machine or its associated equipment is provided with socket-outlets that are intended to be used for accessory equipment (for example hand-held power tools, test equipment), the following apply:

– the socket-outlets should conform to IEC 60309-1. Where that is not practicable, they should be clearly marked with the voltage and current ratings;

– the continuity of the protective bonding circuit to the socket-outlet shall be ensured;

– all unearthed conductors connected to the socket-outlet shall be protected against overcurrent and, when required, against overload in accordance with 7.2 and 7.3 separately from the protection of other circuits;

– where the power supply to the socket-outlet is not disconnected by the supply disconnecting device for the machine or the section of the machine, the requirements of 5.3.5 apply;

– where fault protection is provided by automatic disconnection of supply, the disconnection time shall be in accordance with Table A.1 for TN systems or Table A.2 for TT systems;

– circuits supplying socket-outlets with a current rating not exceeding 20 A shall be provided with residual current protection (RCDs) with a rated operating current not exceeding 30 mA.

## 15.2 Local lighting of the machine and of the equipment

### 15.2.1 General

The ON/OFF switch shall not be incorporated in the lampholder or in the flexible connecting cord.

Stroboscopic effects from lights shall be avoided by the selection of appropriate luminaires.

Where fixed lighting is provided in an enclosure, electromagnetic compatibility should be taken into account using the principles outlined in 4.4.2.

### 15.2.2 Supply

The nominal voltage of the local lighting circuit shall not exceed 250 V between conductors. A voltage not exceeding 50 V between conductors is recommended.

Lighting circuits shall be supplied from one of the following sources (see also 7.2.6):

– a dedicated isolating transformer connected to the load side of the supply disconnecting device. Overcurrent protection shall be provided in the secondary circuit;

– a dedicated isolating transformer connected to the line side of the supply disconnecting device. That source shall be permitted for maintenance lighting circuits in control enclosures only. Overcurrent protection shall be provided in the secondary circuit (see also 5.3.5);

– a circuit of the electrical equipment of the machine for lighting, with dedicated overcurrent protection;

– an isolating transformer connected to the line side of the supply disconnecting device, provided with a dedicated primary disconnecting means (see 5.3.5) and secondary overcurrent protection, and mounted within the control enclosure adjacent to the supply disconnecting device;

– an externally supplied lighting circuit (for example factory lighting supply). This shall be permitted in control enclosures only, and for the machine work light(s) where their total power rating is not more than 3 kW;

- details of the interconnections of the electrical components subject to replacement (for example by circuit diagrams and/or connection tables);
- information on required special devices or tools;
- information on spare parts;
- information on possible residual risks, indication of whether any particular training is required and specification of any necessary personal protective equipment;
- where applicable, instructions to restrict availability of key(s) or tool(s) to skilled or instructed persons only;
- settings (DIP-switches, programmable parameter values, etc);
- information for validation of safety related control functions after repair or modification, and for periodic testing where necessary;

g) information on handling, transportation and storage as appropriate (for example dimensions, weight, environmental conditions, possible ageing constraints);

h) information for proper disassembly and handling of components (for example for recycling or disposal).

## 18 Verification

### 18.1 General

The extent of verification will be given in the dedicated product standard for a particular machine. Where there is no dedicated product standard for the machine, the verifications shall always include the items a), b), c) and h) and may include one or more of the items d) to g):

a) verification that the electrical equipment complies with its technical documentation;

b) verification of continuity of the protective bonding circuit (Test 1 of 18.2.2);

c) in case of fault protection by automatic disconnection of supply, conditions for protection by automatic disconnection shall be verified according to 18.2;

d) insulation resistance test (see 18.3);

e) voltage test (see 18.4);

f) protection against residual voltage (see 18.5);

g) verification that the relevant requirements of 8.2.6 are met;

h) functional tests (see 18.6).

When these tests are performed, it is recommended that they follow the sequence listed above. 〚C〉 Where the sequence cannot be followed verification a) and b) shall be conducted first. 〈C〛

When the electrical equipment is modified, the requirements stated in 18.7 shall apply.

For verifications that include measurement, measuring equipment in accordance with the IEC 61557 series is recommended.

The results of the verification shall be documented.

### 18.2 Verification of conditions for protection by automatic disconnection of supply

#### 18.2.1 General

The conditions for automatic disconnection of supply (see 6.3.3) shall be verified by tests.

Test 1 verifies the continuity of the protective bonding circuit.

Test 2 verifies the conditions for protection by automatic disconnection of the supply in TN systems.

For TN-systems, those test methods are described in 18.2.2 and 18.2.3; their application for different conditions of supply are specified in 18.2.4.

For TT systems, see Clause A.2.

For IT systems, see IEC 60364-6.

Where RCDs are used in the electrical equipment, their function shall be verified in accordance with the manufacturer's instructions. The test procedure and test interval shall be specified in the maintenance instructions.

### 18.2.2 Test 1 – Verification of the continuity of the protective bonding circuit

The resistance between the PE terminal (see 5.2 and Figure 4) and relevant points that are part of the protective bonding circuit shall be measured with a current between at least 0,2 A and approximately 10 A derived from an electrically separated supply source (for example SELV, see 414 of IEC 60364-4-41:2005) having a maximum no-load voltage of 24 V AC or DC.

The resistance measured shall be in the expected range according to the length, the cross sectional area and the material of the related protective conductors and protective bonding conductor(s).

Earthed PELV supplies can produce misleading results in this test and therefore shall not be used.

NOTE Larger currents used for the continuity test increases the accuracy of the test result, especially with low resistance values, i.e. larger cross sectional areas and/or lower conductor lengths.

### 18.2.3 Test 2 – Fault loop impedance verification and suitability of the associated overcurrent protective device

The connections of each power supply including the connection of the associated protective conductor to the PE terminal of the machine, shall be verified by inspection.

The conditions for the protection by automatic disconnection of supply in accordance with 6.3.3 and Annex A shall be verified by both:

a) verification of the fault loop impedance by:
   - calculation, or
   - measurement in accordance with A.1.4, and

b) confirmation that the setting and characteristics of the associated overcurrent protective device are in accordance with the requirements of Annex A, and where a power drive system (PDS) is used, confirmation that the setting and characteristics of the protective device(s) associated with a PDS are in accordance with the converter manufacturer's and protective device manufacturer's instructions.

### 18.2.4 Application of the test methods for TN-systems

When Test 2 of 18.2.3 is carried out by measurement, it shall always be preceded by Test 1 of 18.2.2.

NOTE A discontinuity of the protective bonding circuit can cause a hazardous situation for the tester or other persons, or damage to the electrical equipment during the loop impedance test.

The tests that are necessary for machines of different status are specified in Table 9.

– disconnect these devices, or

– reduce the test voltage to a value lower than the voltage protection level of the surge protection devices, but not lower than the peak value of the upper limit of the supply (phase to neutral) voltage.

### 18.4 Voltage tests

〖C〉 When voltage tests are performed, tests and test equipment shall be in accordance with EN 61180. 〈C〗

The test voltage shall be at a nominal frequency of 50 Hz or 60 Hz.

The maximum test voltage shall have a value of twice the rated supply voltage of the equipment or 1 000 V, whichever is the greater. The maximum test voltage shall be applied between the power circuit conductors and the protective bonding circuit for at least 1 s. The requirements are satisfied if no disruptive discharge occurs.

Components and devices that are not rated to withstand the test voltage and surge protection devices which are likely to operate during the test shall be disconnected during testing.

Components and devices that have been voltage tested in accordance with their product standards may be disconnected during testing.

### 18.5 Protection against residual voltages

Where appropriate, tests shall be performed to ensure compliance with 6.2.4.

### 18.6 Functional tests

The functions of electrical equipment shall be tested.

### 18.7 Retesting

Where a portion of the machine or its associated equipment is changed or modified, the need for re-verification and testing of the electrical equipment shall be considered.

Particular attention should be given to the possible adverse effects that retesting can have on the equipment (for example overstressing of insulation, disconnection/reconnection of devices).

# Annex A
(normative)

# Fault protection by automatic disconnection of supply

## A.1 Fault protection for machines supplied from TN-systems

### A.1.1 General

The provisions in the Annex A are derived from IEC 60364-4-41:2005, and IEC 60364-6:2006.

Fault protection shall be provided by an overcurrent protective device that automatically disconnects the supply to the circuit or equipment in the event of a fault between a live part and an exposed conductive part or a protective conductor in the circuit or equipment, within a sufficiently short disconnecting time. A disconnecting time not exceeding 5 s is considered sufficiently short for machines that are neither hand-held nor portable.

Where this disconnecting time cannot be assured, supplementary protective bonding shall be provided in accordance with A.1.3 that can prevent a prospective touch voltage from exceeding 50 V AC or 120 V ripple-free DC between simultaneously accessible conductive parts.

NOTE The use of supplementary protective bonding does not preclude the need to disconnect the supply for other reasons, for example protection against fire, thermal stresses in equipment, etc.

For circuits which supply, through socket-outlets or directly without socket-outlets, Class 1 hand-held equipment or portable equipment (for example socket-outlets on a machine for accessory equipment, see 15.1) Table A.1 specifies the maximum disconnecting times that are considered sufficiently short.

**Table A.1 – Maximum disconnecting times for TN systems**

| System | 50 V < $U_0$ ≤ 120 V s | | 120 V < $U_0$ ≤ 230 V s | | 230 V < $U_0$ ≤ 400 V s | | $U_0$ > 400 V s | |
|---|---|---|---|---|---|---|---|---|
| | AC | DC | AC | DC | AC | DC | AC | DC |
| TN | 0,8 | NOTE 1 | 0,4 | 5 | 0,2 | 0,4 | 0,1 | 0,1 |

$U_0$ is the nominal AC or DC line to earth voltage.

NOTE 1 Disconnection may be required for reasons other than protection against electric shock.

NOTE 2 For voltages which are within the tolerance band stated in IEC 60038, the disconnecting time appropriate to the nominal voltage applies.

NOTE 3 For intermediate values of voltage, the next higher value in the above table is to be used.

### A.1.2 Conditions for protection by automatic disconnection of the supply by overcurrent protective devices

The characteristics of overcurrent protective devices and the circuit impedances shall be such that, if a fault of negligible impedance occurs anywhere in the electrical equipment between a line conductor and a protective conductor or exposed conductive part, automatic disconnection of the supply will occur within the specified time (i.e. ≤ 5 s or ≤ values in accordance with Table A.1). The following general condition fulfils this requirement:

### A.1.4 Verification of conditions for protection by automatic disconnection of the supply

#### A.1.4.1 General

The effectiveness of the measures for fault protection by automatic disconnection of supply in accordance with A.1.2 is verified as follows:

– verification of the characteristics of the associated protective device by visual inspection of the nominal current setting for circuit-breakers and the current rating for fuses, and;

– measurement of the fault loop impedance ($Z_s$). See Figure A.1.

Exception: Verification of the continuity of the protective conductors may replace the measurement where the calculations of the fault loop impedance are available and when the arrangement of the installations permits the verification of the length and cross-sectional area of the conductors.

Where a power drive system (PDS) is used, the disconnection time for fault protection shall meet the relevant requirements of this Annex A at the incoming supply terminals of the basic drive module (BDM) of the PDS. See Figure A.2.

#### A.1.4.2 Measurement of the fault loop impedance

Where measurement of the fault loop impedance is performed, it is recommended that the measuring equipment comply with IEC 61557-3. The information about the accuracy of the measuring results, and the procedures to be followed given in the documentation of the measuring equipment shall be considered.

Measurement shall be performed when the machine is connected to a supply having the same frequency as the nominal frequency of the supply at the intended installation.

NOTE Figure A.1 illustrates a typical arrangement for measuring the fault loop impedance on a machine.

If it is not practicable for the motor to be connected during the test, the two line conductors not used in the test may be opened, for example, by removing fuses.

The measured value of the fault loop impedance shall be in accordance with A.1.2.

## A.2 Fault protection for machines supplied from TT-systems

### A.2.1 Connection to earth

All exposed-conductive-parts and all extraneous-conductive-parts shall be bonded to the protective bonding circuit.

**Exception:** see 8.2.5.

In addition to the requirements of 5.2, provision for additional earthing of machine elements and/or the PE conductor of the electrical equipment may be provided.

NOTE In a TT system, the neutral point or the mid-point of the power supply system is earthed, or where a neutral point or mid-point is not available or not accessible, a line conductor is earthed (derived from IEC 60364-4-41:2005, 411.5.1).

### A.2.2 Fault protection for TT systems

#### A.2.2.1 General

Generally in TT systems, RCDs shall be used for fault protection. Alternatively, overcurrent protective devices may be used for fault protection provided a suitably low value of $Z_s$ is permanently and reliably assured. $Z_s$ is the impedance of the fault loop.

NOTE In some countries the use of overcurrent protective devices is not permitted as the means of fault protection in TT systems.

Where automatic disconnection of supply is used as a measure for fault protection, the electrical equipment designer may either:

a) use in the design calculations a value of earth electrode resistance or earth fault loop impedance measured in accordance with IEC 60364-6 or declared by the intended user of the equipment (see Annex B); or

b) for series-manufactured machines, specify a value of the earth electrode resistance or earth fault loop impedance suitable for the intended installations;

and shall state in the installation instructions the value of earth electrode resistance or earth fault loop impedance used for the design of the electrical equipment, specifying that this is the maximum value to which the machine can be connected.

Where a power drive system (PDS) is used, the disconnection time for fault protection shall meet the relevant requirements of this Annex A at the incoming supply terminals of the basic drive module (BDM) of the PDS. See Figure A.4.

#### A.2.2.2 Protection by residual current protective device (RCD)

Where a residual current protective device (RCD) is used for fault protection, the following conditions shall be fulfilled:

a) disconnection time as required by Table A.2, and

b) $R_A \times I_{\Delta n} \leq 50$ V

where:

$R_A$ is the sum of the resistances of the earth electrode and the protective conductor for each exposed conductive-part,

$I_{\Delta n}$ is the rated residual operating current of the RCD.

Exception: a disconnection time not exceeding 1 s is permitted for distribution circuits and for circuits not covered by Table A.2.

NOTE 1 Fault protection is provided in this case also if the fault impedance is not negligible.

NOTE 2 Where discrimination between RCDs is necessary, information is given in 535.3 of IEC 60364-5-53:2001.

NOTE 3 The disconnection times in accordance with Table A.2 relate to prospective residual fault currents significantly higher than the rated residual operating current of the RCD (typically 5 $I_{\Delta n}$).

NOTE 4 The definition of $R_A$ is extracted from IEC 60364-4-41. In this part of IEC 60204, the term "earth electrode" in the definition of $R_A$ is considered to mean the "earth-return path" as defined by IEC 60050-195:1998, 195-02-30.

### A.2.2.3 Protection by overcurrent protective devices

Where an overcurrent protective device is used the following condition shall be fulfilled:

$$Z_s \times I_a \leq U_o$$

where:

$Z_s$ is the impedance of the fault loop comprising:

the source,

the line conductor up to the point of the fault,

the protective conductor of each exposed-conductive-part,

the earthing conductor,

the earth electrode of the installation and the earth electrode of the source;

$I_a$ is the current causing the automatic operation of the disconnecting device within the time specified in Table A.2.

Exception: a disconnection time not exceeding 1 s is permitted for circuits not covered by Table A.2.

$U_o$ is the nominal AC or DC line to earth voltage.

The maximum disconnection times stated in Table A.2 shall be applied to circuits not exceeding 32 A. Maximum disconnection times shall not exceed 1 s for circuits 32 A or greater.

**Table A.2 – Maximum disconnecting time for TT-systems**

| System | 50 V < $U_o$ ≤ 120 V s | | 120 V < $U_o$ ≤ 230 V s | | 230 V < $U_o$ ≤ 400 V s | | $U_o$ > 400 V s | |
|---|---|---|---|---|---|---|---|---|
| | AC | DC | AC | DC | AC | DC | AC | DC |
| TT | 0,3 | NOTE | 0,2 | 0,4 | 0,07 | 0,2 | 0,04 | 0,1 |
| Where in TT systems the disconnection is achieved by an overcurrent protective device and all extraneous-conductive-parts will be connected to the protective bonding circuit, the maximum disconnection times specified in Table A.1 may be used.<br>$U_o$ is the nominal AC or DC line to earth voltage. | | | | | | | | |
| NOTE Disconnection can be required for reasons other than protection against electric shock. | | | | | | | | |

### A.2.3 Verification of protection by automatic disconnection of supply using a residual current protective device

Fault protection in a TT system by automatic disconnection of supply using a residual current protective device shall be verified by the following:

- inspection of the rated residual current for tripping value, and the disconnecting time value of the residual current protective device, and

# Annex B
(informative)

## Enquiry form for the electrical equipment of machines

The use of this enquiry form can facilitate an exchange of information between the user and supplier on basic conditions and additional user requirements to enable suitable design, application and utilization of the electrical equipment of the machine (see 4.1) particularly when the conditions on site can deviate from those generally expected.

Annex B can also serve as an internal checklist for serial manufactured machines.

| | | | | |
|---|---|---|---|---|
| Name of manufacturer/supplier | | | | |
| Name of end user | | | | |
| Tender/order number | | | Date | |
| Type of machine | Type designation | | Serial number | |
| **1. Special conditions (see Clause 1)** | | | | |
| a) Is the machine to be used in the open air? | Yes/No | | If yes, specification | |
| b) Will the machine use, process or produce explosive or flammable material? | Yes/No | | If yes, specification | |
| c) Is the machine for use in potentially explosive or flammable atmospheres? | Yes/No | | If yes, specification | |
| d) Can the machine present special hazards when producing or consuming certain materials? | Yes/No | | If yes, specification | |
| e) Is the machine for use in mines? | Yes/No | | If yes, specification | |
| **2. Electrical supplies and related conditions (see 4.3)** | | | | |
| a) Anticipated voltage fluctuations (if more than ±10 %) | | | | |
| b) Anticipated frequency fluctuations (if more than ±2 %) | Continuous | | Short time | |
| c) Indicate possible future changes in electrical equipment that will require an increase in the electrical supply requirements | | | | |
| d) Specify voltage interruptions in supply if longer than specified in Clause 4 where electrical equipment has to maintain operation under such conditions | | | | |
| **3. Physical environment and operating conditions (see 4.4)** | | | | |
| a) Electromagnetic environment (see 4.4.2) | Residential, commercial or light industrial environment | | Industrial environment | |
| Special EMC conditions or requirements | | | | |
| b) Ambient temperature range | | | | |
| c) Humidity range | | | | |
| d) Altitude | | | | |
| e) Special environmental conditions (for example corrosive atmospheres, dust, wet environments) | | | | |
| f) Radiation | | | | |
| g) Vibration, shock | | | | |

| | | | | |
|---|---|---|---|---|
| h) Special installation and operation requirements (for example flame-retardant cables and conductors) | | | | |
| i) Transportation and storage (for example, temperatures outside the range specified in 4.5) | | | | |
| k) restrictions related to size, weight or point load | | | | |
| **4. Incoming electrical supplies** | | | | |
| Specify for each source of supply: | | | | |
| a) Nominal voltage (V) | AC | | DC | |
| | If AC, number of phases | | Frequency (Hz) | |
| Value of the supply source impedance (Ω) at the point of connection to the electrical equipment | | | | |
| Prospective short-circuit current (kA r.m.s.) at the point of connection to the electrical equipment (see also item 2) | | | | |
| b) Type of distribution system (see IEC 60364-1) | TN (system with one point directly earthed, with a protective conductor (PE) directly connected to that point); specify if the earthed point is the neutral point (centre of the star) or another point | | TT (system with one point directly earthed but the protective conductor (PE) of the machine not connected to that earth point of the system) | |
| | IT (system that is not directly earthed) | | | |
| In the case of IT systems, is insulation monitoring/fault location to be provided by the supplier of the electrical equipment? | Yes | | No | |
| c) Is the electrical equipment to be connected to a neutral (N) supply conductor? (See 5.1) | Yes | | No | |
| Maximum current (A) allowed | | | | |
| d) Supply disconnecting device | | | | |
| Is disconnection of the neutral (N) conductor required? | Yes | | No | |
| Is a removable link for disconnecting the neutral (N) required? | Yes | | No | |
| Type of supply disconnecting device to be provided | | | | |
| e) Cross sectional area and material of external protective (PE) conductor | | | | |
| f) Is an RCD provided in the installation? | Yes/No | | If yes, type and rated residual operating current | |
| **5. Protection against electric shock (see Clause 6)** | | | | |
| a) For which of the following classes of persons is access to the interior of enclosures required during normal operation of the equipment? | Electrically skilled persons | | Electrically instructed persons | |
| b) Are locks with removable keys to be provided for securing the doors? (see 6.2.2) | Yes | | No | |
| Type of locking device | | | | |
| Basic lock unit (except key cylinder) to be supplied and installed by | | | | |
| Key cylinder to be supplied and installed by | | | | |

| | | | | |
|---|---|---|---|---|
| **6. Protection of equipment (see Clause 7)** | | | | |
| a) Will the user or the supplier of the electrical equipment provide supply conductors and the overcurrent protection for the supply conductors? (see 7.2.2) | | | | |
| Type and rating of overcurrent protective devices | | | | |
| b) Largest (kW) three-phase AC motor that may be started direct-on-line | | | | |
| c) May the number of motor overload detection devices be reduced? (see 7.3.2) | Yes | | No | |
| d) Is overvoltage protection to be provided? | Yes/No | | If yes, specification | |
| **7. Operation** | | | | |
| For cableless control systems, specify the time delay before automatic machine shutdown is initiated in the absence of a valid signal. | | | | |
| **8. Operator interface and machine-mounted control devices (see Clause 10)** | | | | |
| Special colour preferences (for example to align with existing machinery): | Start | | Stop | |
| | Other | | | |
| **9. Controlgear** | | | | |
| Degree of protection of enclosures (see 11.3) or special conditions: | | | | |
| **10. Wiring practices (see Clause 13)** | | | | |
| Is there a specific method of identification to be used for the conductors? (see 13.2.1) | Yes | | No | |
| Type | | | | |
| **11. Accessories and lighting (see Clause 15)** | | | | |
| a) Is a particular type of socket-outlet required? | Yes | | No | |
| If yes, which type? | | | | |
| b) Where the machine is equipped with local lighting: | Highest permissible voltage (V) | | If lighting circuit voltage is not obtained directly from the power supply, state preferred voltage | |
| **12. Marking, warnings and reference designations (see Clause 16)** | | | | |
| a) Functional identification (see 16.3) | | | | |
| Specifications: | | | | |
| b) Inscriptions/special markings | On electrical equipment? | | In which language? | |
| c) Specific local regulations that must be complied with | Yes | | No | |
| If yes, which one? | | | | |
| **13. Technical documentation (see Clause 17)** | | | | |
| a) Technical documentation (see 17.1) | On what media/ | | In which language? | |
| | File format? | | | |
| b) Instructions for use (see 17.1) | On what media? | | In which language? | |
| | File format? | | | |

| | | | | |
|---|---|---|---|---|
| c) Size, location and purpose of ducts, open cable trays or cable supports to be provided by the user | | | | |
| d) Indicate if special limitations on the size or weight affect the transport of a particular machine or controlgear assemblies to the installation site: | Maximum dimensions | | Maximum weight | |
| e) In the case of specially built machines, is a certificate of operating tests with the loaded machine to be supplied? | Yes | | No | |
| f) In the case of other machines, is a certificate of operating type tests on a loaded prototype machine to be supplied? | Yes | | No | |

# Annex C
(informative)

## Examples of machines covered by this part of IEC 60204

The following list shows examples of machines whose electrical equipment should conform to this part of IEC 60204. The list is not intended to be exhaustive but is consistent with the definition of machinery (3.1.40). This part of IEC 60204 need not be applied to machines that are household and similar domestic appliances within the scope of the IEC 60335 series of standards.

Metalworking machinery

- metal cutting machines
- metal forming machines

Plastics and rubber machinery

- injection moulding machines
- extrusion machines
- blow moulding machines
- thermoset moulding machines
- size reduction machines

Wood machinery

- woodworking machines
- laminating machines
- sawmill machines

Assembly machines

Material handling machines

- robots
- conveyors
- transfer machines
- storage and retrieval machines

Textile machines

Refrigeration and air-conditioning machines

Food machinery

- dough breaks
- mixing machines
- pie and tart machines
- meat processing machines

Printing, paper and board machinery

- printing machines
- finishing machines, guillotines, folders
- reeling and slitting machines
- folder box gluing machines
- paper and board making machines

Inspecting/testing machinery

- co-ordinate measuring machines
- in-process gauging machines

Compressors

Packaging machinery

- palletizers/depalletizers
- wrapping and shrink-wrapping machines

Laundry machines

Heating and ventilating machines

Leather/imitation leather goods and footwear machinery

- cutting and punching machines
- roughing, scouring, buffing, trimming and brushing machines
- footwear moulding machines
- lasting machines

Hoisting machinery (see IEC 60204-32)

- cranes
- hoists

Machinery for transportation of persons

- escalators
- ropeways for transportation of persons, for example chairlifts, ski lifts
- passenger lifts

Power-operated doors

Leisure machinery

- fairground and amusement rides

Pumps

Agriculture and forestry machines

Construction and building materials machinery

- tunnelling machines
- concrete batching machines
- brick-making machines
- stone, ceramic and glass-making machines

Transportable machinery

- wood working machines
- metal working machines

Mobile machinery

- lifting platforms
- fork lift trucks
- construction machines

Machines for hot metal processing

Tanning machinery

- multi-roller machines
- bandknife machines
- hydraulic tanning machines

Mining and quarrying machines

# Annex D
(informative)

# Current-carrying capacity and overcurrent protection of conductors and cables in the electrical equipment of machines

## D.1 General

The purpose of this Annex A is to provide additional information on the selection of conductor sizes where the conditions given for Table 6 (see Clause 12) have to be modified (see notes to Table 6).

## D.2 General operating conditions

### D.2.1 Ambient air temperature

The current carrying capacity for PVC insulated conductors given in Table 6 is related to an ambient air temperature of +40 °C. For other ambient air temperatures, the correction factors are given in Table D.1.

The correction factors for rubber insulated cables are given by the manufacturer.

**Table D.1 – Correction factors**

| Ambient air temperature | Correction factor |
|---|---|
| °C | |
| 40 | 1,00 |
| 45 | 0,91 |
| 50 | 0,82 |
| 55 | 0,71 |
| 60 | 0,58 |
| NOTE The correction factors are derived from IEC 60364-5-52.<br>The maximum temperature under normal conditions for PVC 70 °C. | |

### D.2.2 Methods of installation

In machines, the methods of conductor and cable installation between enclosures and individual items of the equipment shown in Figure D.1 are assumed to be typical (the letters used are in accordance with IEC 60364-5-52):

– Method B1: using conduits (3.1.9) and cable trunking systems (3.1.6) for holding and protecting conductors or single core cables;

– Method B2: same as B1 but used for multicore cables;

– Method C: multicore cables installed in free air, horizontal or vertical without gap between cables on walls;

– Method E: multicore cables in free air, horizontal or vertical laid on open cable trays (3.1.5).

$I_n$ is the nominal current of the protective device;

NOTE 1 For adjustable protective devices, the nominal current $I_n$ is the current setting selected.

$I_2$ is the minimum current ensuring effective operation of the protective device within a specified time (for example 1 h for protective devices up to 63 A).

The current $I_2$ ensuring effective operation of the protective device is given in the product standard or may be provided by the manufacturer.

NOTE 2 For motor circuit conductors, overload protection for conductor(s) can be provided by the overload protection for the motor(s) whereas the short-circuit protection is provided by short-circuit protective devices.

Where a device that provides both overload and short-circuit protection is used in accordance with Clause D.3 for conductor overload protection, it does not ensure complete protection in all cases (for example overload with currents less than $I_2$), nor will it necessarily result in an economical solution. Therefore, such a device can be unsuitable where overloads with currents less than $I_2$ are likely to occur.

## D.4 Overcurrent protection of conductors

All conductors are required to be protected against overcurrent (see 7.2) by protective devices inserted in all live conductors so that any short-circuit current flowing in the cable is interrupted before the conductor has reached the maximum allowable temperature.

NOTE Information on neutral conductors can be found in 7.2.3, third paragraph.

**Table D.5 – Maximum allowable conductor temperatures under normal and short-circuit conditions**

| Type of insulation | Maximum temperature under normal conditions<br>°C | Ultimate short-time conductor temperature under short-circuit conditions [a)]<br>°C |
|---|---|---|
| Polyvinyl chloride (PVC) | 70 | 160 |
| Rubber | 60 | 200 |
| Cross-linked polyethylene (XLPE) | 90 | 250 |
| Ethylene propylene compound (EPR) | 90 | 250 |
| Silicone rubber (SiR) | 180 | 350 |
| NOTE For ultimate short-time conductor temperatures greater than 200 °C, neither tinned nor bare copper conductors are suitable. Silver-plated or nickel-plated copper conductors are suitable for use above 200 °C. | | |
| [a)] These values are based on the assumption of adiabatic behaviour for a period of not more than 5 s. | | |

In practice, the requirements of 7.2 are fulfilled when the protective device at a current $I$ causes the interruption of the circuit within a time that in no case exceeds the time $t$ where $t < 5$ s.

The value of the time $t$ in seconds can be calculated using the following formula:

$$t = (k \times S/I)^2$$

where:

$S$ is the cross-sectional area in square millimetres;

$I$ is the effective short-circuit current in amperes expressed for AC as the r.m.s. value;

$k$ is the factor shown for copper conductors when insulated with the following material:

PVC 115

| | |
|---|---|
| Rubber | 141 |
| SiR | 132 |
| XLPE | 143 |
| EPR | 143 |

## D.5 Effect of harmonic currents on balanced three-phase systems

In case of circuits feeding single phase loads with load current including harmonics, the neutral conductor of the circuit might be additionally loaded and a reduction of the current carrying capacity of that cable might be necessary. For reference see IEC 60364-5-52:2009, Annex E.

# Annex E
(informative)

## Explanation of emergency operation functions

NOTE The concepts below are included here to give the reader an understanding of these terms even though in this part of IEC 60204 only two of them are used.

- **Emergency operation**

  Emergency operation includes separately or in combination:

  – emergency stop;

  – emergency start;

  – emergency switching off;

  – emergency switching on.

- **Emergency stop**

  An emergency operation intended to stop a process or a movement that has become hazardous.

- **Emergency start**

  An emergency operation intended to start a process or a movement to remove or to avoid a hazardous situation.

- **Emergency switching off**

  An emergency operation intended to switch off the supply of electrical energy to all or a part of an installation where a risk of electric shock or another risk of electrical origin is involved.

- **Emergency switching on**

  An emergency operation intended to switch on the supply of electrical energy to a part of an installation that is intended to be used for emergency situations.

# Annex F
(informative)

## Guide for the use of this part of IEC 60204

This part of IEC 60204 gives a large number of general requirements that may or may not be applicable to the electrical equipment of a particular machine. A simple reference without any qualification to the complete standard IEC 60204-1 is therefore not sufficient. Choices need to be made to cover all requirements of this part of IEC 60204. A technical committee preparing a product family or a dedicated product standard (type C in ISO and CEN), and the supplier of a machine for which no product family or dedicated product standard exists, should use this part of IEC 60204:

a) by reference; and

b) by selection of the most appropriate option(s) from the requirements given in the relevant clauses; and

c) by modification of certain clauses, as necessary, where the particular requirements for the equipment of the machine are adequately covered by other relevant standards,

providing the options selected and the modifications made do not adversely affect the level of protection required for that machine according to the risk assessment.

When applying the three principles a), b) and c) listed above, it is recommended that:

– reference be made to the relevant clauses and subclauses of this standard:
  - that are complied with, indicating where relevant the applicable option;
  - that have been modified or extended for the specific machine or equipment requirements; and
– reference be made directly to the relevant standard, for those requirements for the electrical equipment that are adequately covered by that standard.

Specific expertise can be necessary to:

– perform the necessary risk assessment of the machine;
– read and understand all of the requirements of this part of IEC 60204;
– choose the applicable requirements from this part of IEC 60204 where alternatives are given;
– identify alternative or additional particular requirements that differ from or are not included in the requirements of this part of IEC 60204, and that are determined by the machine and its use; and
– specify precisely those particular requirements.

Figure 1 of this part of IEC 60204 is a block diagram of a typical machine and can be used as the starting point of this task. It indicates the Clauses and Subclauses dealing with particular requirements/equipment. However, this part of IEC 60204 is a complex document and Table F.1 can help identify the application options for a particular machine and gives reference to other relevant standards.

$$R = R1\ [1 + 0{,}003\ 93\ (t - 20)]$$

where:

$R1$ is the resistance at 20 °C;

$R$ is the resistance at a temperature $t$°C.

# Annex H
(informative)

# Measures to reduce the effects of electromagnetic influences

## H.1 Definitions

For the purposes of Annex H only, the following terms and definitions apply.

### H.1.1 apparatus

finished device or combination thereof made commercially available as a single functional unit, intended for the end user and liable to generate electromagnetic disturbance, or the performance of which is liable to be affected by such disturbance

### H.1.2 fixed installation

particular combination of several types of apparatus and, where applicable, other devices, which are assembled, installed and intended to be used permanently at a predefined location

## H.2 General

This Annex H provides recommendations to improve electromagnetic immunity and reduce emission of electromagnetic disturbances.

For EMC purposes, electrical equipment for machinery is deemed to be either apparatus or fixed installations. Where electrical safety and electromagnetic compatibility result in different requirements, electrical safety always has the higher priority.

Electromagnetic Interference (EMI) can disturb or damage process monitoring, control and automation systems. Currents due to lightning, switching operations, short-circuits and other electromagnetic phenomena can cause overvoltages and electromagnetic interference.

These effects can occur for example:

- where large conductive loops exist,
- where different electrical wiring systems are installed in common routes, e.g. power supply, communication, control or signal cables.

Cables carrying large currents with a high rate of change of current (di/dt) can induce overvoltages in other cables, which can influence or damage the connected electrical equipment.

## H.3 Mitigation of electromagnetic interference (EMI)

### H.3.1 General

Consideration should be given, in the design of the electrical equipment to the measures described below for reducing the electromagnetic influences on electrical equipment.

Only electrical equipment which meets the requirements of the appropriate EMC standards, or the EMC requirements of the relevant product standard, should be used.

### H.3.2 Measures to reduce EMI

The following measures reduce electromagnetic interference:

a) The installation of surge protection devices and/or filters for equipment sensitive to electromagnetic influences is recommended to improve electromagnetic compatibility with regard to conducted electromagnetic phenomena;

b) Conductive sheaths (e.g. armouring, screens) of cables should be bonded to the protective bonding circuit;

c) Inductive loops should be avoided by selection of common routes for power, signal and data circuits wiring while maintaining circuit separation in accordance with Clause H.4;

d) Power cables should be kept separate from signal or data cables;

e) Where it is necessary for power and signal or data cables to cross each other they should be crossed at right-angles;

f) Use of cables with concentric conductors to reduce currents induced into the protective conductor;

g) Use of symmetrical multicore cables (e.g. screened cables containing separate protective conductors) for the electrical connections between motors and converters;

h) Use of signal and data cables according to the EMC requirements of the manufacturer's instructions;

i) Where screened signal or data cables are used, care should be taken to reduce current flowing through the screens of signal cables, or data cables, which are earthed. It can be necessary to install a by-pass conductor; see Figure H.1;

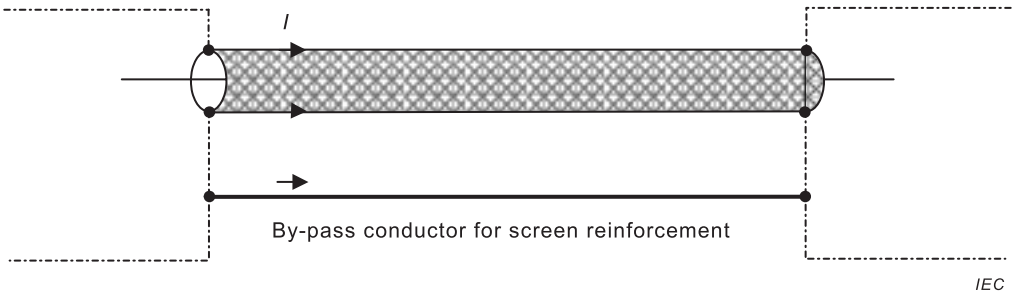



**Figure H.1 – By-pass conductor for screen reinforcement**

NOTE A good equipotential bonding of the components of the machine reduces the need for by-pass conductors.

j) Equipotential bonding connections should have an impedance as low as practicable by being as short as practicable and where applicable braided to conduct higher frequencies;

k) If electronic equipment requires a reference voltage at about earth potential in order to function correctly; this reference voltage is provided by the functional earthing conductor. For equipment operating at high frequencies, the connections shall be kept as short as practicable.

## H.4 Separation and segregation of cables

Power cables and data cables which share the same route should be installed according to the requirements of this Annex H.

Where no other information is available, then the cable separation distance between the power and data cables should be in accordance with Table H.1 and Figure H.2.

| Type of information for the electrical equipment | Recommended standard |
|---|---|
| List of tools | IEC 82079: *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements* |
| Identification systems | IEC 62507-1: *Identification systems enabling unambiguous information interchange – Requirements – Part 1: Principles and methods* |
| NOTE For simple equipment IEC 62023 allows all information to be contained within one single document. | |

## Bibliography

IEC 60034-5, *Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification*

〈C〉 NOTE Harmonized as EN 60034-5. 〈C〉

IEC 60034-11, *Rotating electrical machines – Part 11: Thermal protection*

〈C〉 NOTE Harmonized as EN 60034-11. 〈C〉

IEC 60038:2009, *IEC standard voltages*

〈C〉 NOTE Harmonized as EN 60038:2011 (modified). 〈C〉

IEC 60050, *International Electrotechnical Vocabulary* (available at <http://www.electropedia.org>)

IEC 60073:2002, *Basic and safety principles for man-machine interface, marking and identification – Coding principles for indicators and actuators*

〈C〉 NOTE Harmonized as EN 60073:2002 (not modified). 〈C〉

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

〈C〉 NOTE Harmonized as EN 60085. 〈C〉

IEC 60204-11:2000, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV*

〈C〉 NOTE Harmonized as EN 60204-11:2000 〈C〉

IEC 60204-31:2013, *Safety of machinery – Electrical equipment of machines – Part 31: Particular safety and EMC requirements for sewing machines, units and systems*

〈C〉 NOTE Harmonized as EN 60204-31:2013 (not modified). 〈C〉

IEC 60204-32:2008, *Safety of machinery – Electrical equipment of machines – Part 32: Requirements for hoisting machines*

〈C〉 NOTE Harmonized as EN 60204-32:2008 (not modified). 〈C〉

IEC 60204-33:2009, *Safety of machinery – Electrical equipment of machines – Part 33: Requirements for semiconductor fabrication equipment*

〈C〉 NOTE Harmonized as EN 60204-33:2011 (modified). 〈C〉

IEC 60216 (all parts), *Electrical insulating materials – Thermal endurance properties*

〈C〉 NOTE Harmonized in EN 60216 series. 〈C〉

IEC 60228:2004, *Conductors of insulated cables*

〈C〉 NOTE Harmonized as EN 60228:2005 (not modified). 〈C〉

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*

〈C〉 NOTE Harmonized as EN 60269-1:2007 (not modified). 〈C〉

IEC 60287 (all parts), *Electric cables – Calculation of the current rating*

IEC 60320-1, *Appliance couplers for household and similar general purposes –Part 1: General requirements*

〈C〉 NOTE Harmonized as EN 60320-1. 〈C〉

IEC 60332 (all parts), *Tests on electric and optical fibre cables under fire conditions*

〈C〉 NOTE Harmonized in EN 60332 series. 〈C〉

IEC 60335 (all parts), *Household and similar electrical appliances – Safety*

〈C〉 NOTE Harmonized in EN 60335 series. 〈C〉

IEC 60364 (all parts), *Low-voltage electrical installations*

〈C〉 NOTE Harmonized in HD 60364 series. 〈C〉

IEC 60447:2004, *Basic and safety principles for man-machine interface, marking and identification – Actuating principles*

〈C〉 NOTE Harmonized as EN 60447:2004 (not modified). 〈C〉

IEC TR 60755, *General requirements for residual current operated protective devices*

IEC 60757:1983, *Code for designation of colours*

〈C〉 NOTE Harmonized as HD 457 S1:1985 (not modified). 〈C〉

IEC TR 60890, *A method of temperature-rise verification of low-voltage switchgear and controlgear assemblies by calculation*

〈C〉 NOTE Harmonized as CLC/TR 60890. 〈C〉

IEC 60909-0:2001, *Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents*

〈C〉 NOTE Harmonized as EN 60909-0:2001 (not modified). 〈C〉

IEC TR 60909-1:2002, *Short-circuit currents in three-phase a.c. systems – Part 1: Factors for the calculation of short-circuit currents according to IEC 60909-0*

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*

〈C〉 NOTE Harmonized as EN 60947-1:2007 (not modified). 〈C〉

IEC 60947-4-1, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motorstarters – Electromechanical contactors and motor-starters*

〈C〉 NOTE Harmonized as EN 60947-4-1. 〈C〉

IEC 60947-5-2:2007, *Low-voltage switchgear and controlgear – Part 5-2: Control circuit devices and switching elements – Proximity switches*

〈C〉 NOTE Harmonized as EN 60947-5-2:2007 (not modified). 〈C〉

IEC 60947-5-8, *Low-voltage switchgear and controlgear – Part 5-8: Control circuit devices and switching elements – Three-position enabling switches*

〈C〉 NOTE Harmonized as EN 60947-5-8. 〈C〉

IEC 60947-7-1:2009, *Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

〈C〉 NOTE Harmonized as EN 60947-7-1:2009 (not modified). 〈C〉

IEC 61000-5-2:1997, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling*

IEC 61000-6-1:2005, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards: Immunity for residential, commercial and light-industrial environments*

〈C〉 NOTE Harmonized as EN 61000-6-1:2007 (not modified). 〈C〉

IEC 61000-6-2:2005, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

〈C〉 NOTE Harmonized as EN 61000-6-2:2005 (not modified). 〈C〉

IEC 61000-6-3:2006, E*lectromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

〈C〉 NOTE Harmonized as EN 61000-6-3:2007 (not modified). 〈C〉

IEC 61000-6-4:1997, *Electromagnetic compatibility (EMC) – Part 6: Generic standards – Section 4: Emission standard for industrial environments*

〈C〉 NOTE Harmonized as EN 61000-6-4:2001[2] (modified). 〈C〉

IEC 61082-1:2014, *Preparation of documents used in electrotechnology – Part 1: Rules*

〈C〉 NOTE Harmonized as EN 61082-1:2015 (not modified). 〈C〉

IEC 61084 (all parts), *Cable trunking and ducting systems for electrical installations*

〈C〉 [2] Superseded by EN 61000-6-4:2007, which is based on IEC 61000-6-4:2006. 〈C〉

IEC 61175, *Industrial systems, installations and equipment and industrial products –Designation of signals*

〈C〉 NOTE Harmonized as EN 61175. 〈C〉

IEC 61180 (all parts), *High-voltage test techniques for low-voltage equipment*

〈C〉 NOTE Harmonized in EN 61180 series. 〈C〉

IEC TR 61200-53:1994, *Electrical installation guide – Part 53: Selection and erection of electrical equipment – Switchgear and controlgear*

IEC 61355, *Collection of standardized and established document kinds* (available at http://std.iec.ch/iec61355)

IEC 61496-1:2004, *Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests*

〈C〉 NOTE Harmonized as EN 61496-1:2004[3] (modified). 〈C〉

IEC 61506, *Industrial-process measurement and control – Documentation of application software*

IEC 61557 (all parts), *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1500 V d.c. – Equipment for testing, measuring or monitoring of protective measures*

〈C〉 NOTE Harmonized in EN 61557 series. 〈C〉

IEC 61558-2-2, *Safety of power transformers, power supplies, reactors and similar products – Part 2-2: Particular requirements and tests for control transformers and power supplies incorporating control transformers*

〈C〉 NOTE Harmonized as EN 61558-2-2. 〈C〉

IEC 61558-2-16, *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V – Part 2-16: Particular requirements and tests for switch mode power supply units and transformers for switch mode power supply units*

〈C〉 NOTE Harmonized as EN 61558-2-16. 〈C〉

IEC 61643-12:2008, *Low-voltage surge protective devices – Part 12: Surge protective devices connected to low-voltage power distribution systems – Selection and application principles*

〈C〉 NOTE Harmonized as CLC/TS 61643-12:2009 (modified). 〈C〉

IEC 61666, *Industrial systems, installations and equipment and industrial products – Identification of terminals within a system*

〈C〉 NOTE Harmonized as EN 61666. 〈C〉

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

〈C〉 NOTE Harmonized in EN 61800 series. 〈C〉

IEC TR 61912-1:2007, *Low-voltage switchgear and controlgear – Overcurrent protective devices – Part 1: Application of short-circuit ratings*

IEC 62020, *Electrical accessories – Residual current monitors for household and similar uses (RCMs)*

〈C〉 NOTE Harmonized as EN 62020. 〈C〉

IEC 62027:2011, *Preparation of object lists, including parts lists*

〈C〉 NOTE Harmonized as EN 62027:2012 (not modified). 〈C〉

IEC 62305-1:2010, *Protection against lightning – Part 1: General principles*

〈C〉 NOTE Harmonized as EN 62305-1:2011 (modified). 〈C〉

IEC 62305-4:2010, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

〈C〉 NOTE Harmonized as EN 62305-4:2011 (modified). 〈C〉

IEC 62491, *Industrial systems, installations and equipment and industrial products – Labelling of cables and cores*

〈C〉 NOTE Harmonized as EN 62491. 〈C〉

〈C〉

[3] Superseded by EN 61496-1:2013, which is based on IEC 61496-1:2012. 〈C〉

IEC 62507-1, *Identification systems enabling unambiguous information interchange – Requirements – Part 1: Principles and methods*

〈C〉 NOTE Harmonized as EN 62507-1. 〈C〉

IEC 62745[4], *Safety of machinery – Requirements for the interfacing of cableless controllers to machinery*

〈C〉 NOTE Harmonized as EN 62745. 〈C〉

IEC PAS 62569-1, *Generic specification of information on products – Part 1: Principles and methods*

IEC 81346-1:2009, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules*

〈C〉 NOTE Harmonized as EN 81346-1:2009 (not modified). 〈C〉

IEC 81346-2:2009, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 2: Classification of objects and codes for classes*

〈C〉 NOTE Harmonized as EN 81346-2:2009 (not modified). 〈C〉

IEC 82079-1:2012, *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*

〈C〉 NOTE Harmonized as EN 82079-1:2012 (not modified). 〈C〉

IEC Guide 106:1996, *Guide for specifying environmental conditions for equipment performance rating*

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

ISO 7000:2014, *Graphical symbols for use on equipment – Registered symbols*

ISO 12100:2010, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

〈C〉 NOTE Harmonized as EN ISO 12100:2010 (not modified). 〈C〉

ISO 13732-1, *Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces – Part 1:Hot surfaces*

〈C〉 NOTE Harmonized as EN ISO 13732-1. 〈C〉

ISO 13851:2002, *Safety of machinery – Two-hand control devices – Functional aspects and design principles*

ISO 14118:2000, *Safety of machinery – Prevention of unexpected start-up*

ISO 14122-1:2001, *Safety of machinery – Permanent means of access to machinery – Part 1: Choice of fixed means of access between two levels*
ISO 14122-1:2001/AMD1:2010

ISO 14122-2:2001, *Safety of machinery – Permanent means of access to machinery – Part 2: Working platforms and walkways*
ISO 14122-2:2001/AMD1:2010

ISO 14122-3:2001, *Safety of machinery – Permanent means of access to machinery – Part 3: Stairs, stepladders and guard-rails*
ISO 14122-3:2001/AMD1:2010

CENELEC HD 516 S2, *Guide to use of low-voltage harmonized cables*

EN 50160:2010, *Voltage characteristics of electricity supplied by public electricity networks*
EN 50160:2010/AMD1:2015

UL 508A, *UL Standard for Safety for Industrial Control Panels*, second Edition, 2013 revised 2014.

NFPA 79, *Electrical Standard for Industrial Machinery*, 2015 edition.

———————

[4] Under consideration.