



UL 61800-5-1

STANDARD FOR SAFETY

Adjustable Speed Electrical Power
Drive Systems – Part 5-1: Safety
Requirements – Electrical, Thermal and
Energy

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UL Standard for Safety for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1

Second Edition, Dated June 24, 2022

Summary of Topics

This new edition of ANSI/UL 61800-5-1 dated June 24, 2022 includes changes in requirements to the following:

- Alternate Means of Providing Installation Manual (Internet);***
- Primary Rechargeable Battery Back-up;***
- VFD Output Conductor Protection.***

Please note that the national difference document incorporates all of the U.S. national differences for UL 61800-5-1. UL 61800-5-1 is based on IEC 61800-5-1, second edition (published July 2007).

The requirements are substantially in accordance with Proposal(s) on this subject dated October 15, 2021 and November 20, 2020.

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JUNE 24, 2022



ANSI/UL 61800-5-1-2022

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UL 61800-5-1

**Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1:
Safety Requirements – Electrical, Thermal and Energy**

Second Edition

June 24, 2022

This ANSI/UL Standard for Safety consists of the Second Edition.

The most recent designation of ANSI/UL 61800-5-1 as an American National Standard (ANSI) occurred on June 24, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at <https://csds.ul.com>.

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Bibliography

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Preface (UL)

This UL Standard is based on IEC Publication 61800-5-1: edition 2.1, Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, as revised by Amendment 1. IEC publication 61800-5-1 is copyrighted by the IEC.

This edition has been issued to satisfy UL Standards policy.

Efforts have been made to synchronize the UL edition number with that of the corresponding IEC standard with which this standard is harmonized.

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Note – Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

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NATIONAL DIFFERENCES

GENERAL

National Differences from the text of International Electrotechnical Commission (IEC) Publication 61800-5-1, Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy copyright 2016 are indicated by notations (differences) and are presented in bold text.

There are five types of National Differences as noted below. The difference type is noted on the first line of the National Difference in the standard. The standard may not include all types of these National Differences.

DR – These are National Differences based on the **national regulatory requirements**.

D1 – These are National Differences which are based on **basic safety principles and requirements**, elimination of which would compromise safety for consumers and users of products.

D2 – These are National Differences from IEC requirements based on existing **safety practices**. These requirements reflect national safety practices, where empirical substantiation (for the IEC or national requirement) is not available or the text has not been included in the IEC standard.

DC – These are National Differences based on the **component standards** and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE – These are National Differences based on **editorial comments or corrections**.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

Modification / Modify - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.

Deletion / Delete - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

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FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ADJUSTABLE SPEED ELECTRICAL POWER DRIVE SYSTEMS – Part 5-1: Safety requirements – Electrical, thermal and energy

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.

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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.

This Consolidated version of IEC 61800-5-1 bears the edition number 2.1. It consists of the second edition (2007-07) [documents 22G/178/FDIS and 22G/181/RVD] and its amendment 1 (2016-08) [documents 22G/338/FDIS and 22G/342/RVD]. The technical content is identical to the base edition and its amendment.

This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.

International Standard IEC 61800-5-1 has been prepared by subcommittee 22G: Semiconductor power converters for adjustable speed electric drive systems, of IEC technical committee 22: Power electronic systems and equipment.

This second edition constitutes a technical revision.

The major areas of change in this edition are the following:

- a) addition of alphabetical [Table 1](#) in Clause [3](#);
- b) addition of [Table 2](#) in [4.1](#) for relevance to PDS/CDM/BDM;
- c) addition of [Table 4](#) summary of decisive voltage class requirements;
- d) expansion of subclause on protective bonding ([4.3.5.3](#));
- e) clarification of distinction between touch current and protective conductor current;
- f) revision of section on insulation (now [4.3.6](#)) to include solid insulation;
- g) addition of overvoltage categories I and II to HV insulation voltage;
- h) revision of section on Solid insulation (now [4.3.6.8](#))
- i) addition of high-frequency insulation requirements ([4.3.6.9](#), Annex [E](#));
- j) addition of requirements for liquid-cooled PDS ([4.4.5](#));
- k) addition of climatic and vibration tests ([5.2.6](#));
- l) clarification of voltage test procedure to avoid over-stress of basic insulation (5.2.3.2.3);
- m) revision of short-circuit test requirement for large, high-voltage and one-off PDS (now [5.2.3.6](#));
- n) addition of informative Annex [B](#) for overvoltage category reduction.

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

A list of all parts of the IEC 61800 series, published under the general title *Adjustable speed electrical power drive systems*, can be found on the IEC website.

Terms in *italics* in the text are defined in Clause [3](#).

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site 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.

DV.1 DE Modification to replace the eighth paragraph following item (9) of the Foreword:

Words in SMALL ROMAN CAPS in the text are defined in Clause [3](#).

DV.2 DE Modification to add the following:

The numbering system in the standard uses a space instead of a comma to indicate thousands and uses a comma instead of a period to indicate a decimal point. For example, 1 000 means 1,000 and 1,01 means 1.01.

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ADJUSTABLE SPEED ELECTRICAL POWER DRIVE SYSTEMS – Part 5-1: Safety requirements – Electrical, thermal and energy

1 Scope

This part of IEC 61800 specifies requirements for adjustable speed POWER DRIVE SYSTEMS, or their elements, with respect to electrical, thermal and energy safety considerations. It does not cover the driven equipment except for interface requirements. It applies to adjustable speed electric drive systems which include the power conversion, drive control, and motor or motors. Excluded are traction and electric vehicle drives. It applies to d.c. drive systems connected to line voltages up to 1 kV a.c., 50 Hz or 60 Hz and a.c. drive systems with converter input voltages up to 35 kV, 50 Hz or 60 Hz and output voltages up to 35 kV.

Other parts of IEC 61800 cover rating specifications, EMC, functional safety, etc.

The scope of this part of IEC 61800 does not include devices used as component parts of a PDS if they comply with the safety requirements of a relevant product standard for the same environment. For example, motors used in PDS shall comply with the relevant parts of IEC 60034.

Unless specifically stated, the requirements of this International Standard apply to all parts of the PDS, including the CDM/BDM (see [Figure 1](#)).

NOTE In some cases, safety requirements of the PDS (for example, protection against direct contact) can necessitate the use of special components and/or additional measures.

1DV.1 D2 Modification to add the following:

1DV.1.1 This document is only applicable to the power conversion and drive control equipment, servo drives and integral servo drive/motor combinations.

1DV.1.2 This standard applies to drives with an input rating up to and including 1,5 kV a.c. or d.c.

1DV.1.3 A component of a product covered by this standard shall comply with the requirements for that component. See Annex DVA for a list of additional standards covering components used in the products covered by this standard.

1DV.1.4 The scope includes BDM/CDM/PDS intended for connection to photovoltaic (PV) modules with output voltages not exceeding 1.5 kV DC.

1DV.2 DR Modification to add the following:

This equipment is for use in ordinary locations in accordance with Articles 430 and 440 of the National Electrical Code, NFPA 70.

1DV.3 D2 Modification to add the following:

Specifications provided in other parts of the 61800 Series of Standards (for example EMC in part 3) apply only on agreement between the manufacturer and the customer.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE This does not mean that compliance is required with all clauses of the referenced documents, but rather that this international standard makes a reference that cannot be understood in the absence of the referenced document.

IEC 60034 (all parts), *Rotating electrical machines*

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

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

IEC 60050-111, *International Electrotechnical Vocabulary (IEV) – Chapter 111: Physics and chemistry*

IEC 60050-151, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*

IEC 60050-161, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

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

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

IEC 60050-442, *International Electrotechnical Vocabulary (IEV) – Part 442: Electrical accessories*

IEC 60050-551, *International Electrotechnical Vocabulary (IEV) – Part 551: Power electronics*

IEC 60050-601, *International Electrotechnical Vocabulary (IEV) – Chapter 601: Generation, transmission and distribution of electricity – General*

IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60068-2-2:1974, *Environmental testing – Part 2: Tests. Tests B: Dry heat*

IEC 60068-2-6, *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-78, *Environmental testing – Part 78: Tests – Test Cab: Damp heat, steady state*

IEC 60112:2003, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60204-11, *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*

IEC 60309, *Plugs, socket-outlets and couplers for industrial purposes*

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

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-4-41:2005/AMD1:—¹

IEC 60364-5-54:2002, *Electrical installations of buildings – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements, protective conductors and protective bonding conductors*

IEC 60417, *Graphical symbols for use on equipment*

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

IEC 60617, *Graphical symbols for diagrams*

IEC 60664-1:1992, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*²

Amendment 1 (2000)

Amendment 2 (2002)

IEC 60664-3:2003, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coatings to achieve insulation coordination of printed board assemblies*

IEC 60664-4:2005, *Insulation coordination for equipment within low-voltage systems – Part 4: Consideration of high-frequency voltage stress*

IEC 60695-2-10, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-13, *Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignitability test method for materials*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60695-11-20, *Fire hazard testing – Part 11-20: Test flames – 500 W flame test methods*

IEC 60755, *General requirements for residual current operated protective devices*

IEC 60947-4-1:2009, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

IEC 60947-4-1:2009/AMD1:2012

IEC 60947-7-1:2002, *Low-voltage switchgear and control gear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

IEC 60947-7-2:2002, *Low-voltage switchgear and controlgear – Part 7-2: Ancillary equipment – Protective conductor terminal blocks for copper conductors*

IEC 60990:1999, *Methods of measurement of touch current and protective conductor current*

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

IEC 61800-1, *Adjustable speed electrical power drive systems – Part 1: General requirements – Rating specifications for low voltage adjustable speed d.c. power drive systems*

IEC 61800-2, *Adjustable speed electrical power drive systems – Part 2: General requirements – Rating specifications for low voltage adjustable frequency a.c. power drive systems*

IEC 61800-4, *Adjustable speed electrical power drive systems – Part 4: General requirements – Rating specifications for a.c. power drive systems above 1 000 V a.c. and not exceeding 35 kV*

IEC 62020, *Electrical accessories – Residual current monitors for household and similar uses (RCMs)*

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

ISO 3864 (all parts), *Graphical symbols – Safety colours and safety signs*

ISO 7000:2004, *Graphical symbols for use on equipment – Index and synopsis*

¹ Under preparation. Stage at the time of publication: IEC DEC 60364-4-41:2016.

² There exists a consolidated edition 1.2 (2002) including IEC 60664-1:1992 and its Amendments 1 and 2.

2DV D2 Modification to add the following:

See Annex [DVA](#) for USA Normative References and Component Standards. See Annex [DVB](#) for IEC Normative References that do not apply and for IEC Normative References replaced by USA Standards.

3 Terms and definitions

For the purposes of this international standard, the terms and definitions given in IEC 60050-111, IEC 60050-151, IEC 60050-161, IEC 60050-191, IEC 60050-441, IEC 60050-442, IEC 60050-551, IEC 60050-601, IEC 60664-1, IEC 61800-1, IEC 61800-2, IEC 61800-3 and IEC 61800-4 (some of which are repeated below for convenience), and the following definitions apply.

[Table 1](#) provides an alphabetical cross-reference listing of terms.

Table 1
Alphabetical list of terms

Term	Term number	Term	Term number	Term	Term number
adjacent circuit	3.1	(earth) leakage current	3.16	protective screening	3.31
basic drive module (BDM)	3.2	live part	3.17	protective separation	3.32
basic insulation	3.3	low-voltage PDS	3.18	reinforced insulation	3.33
CDM (complete drive module)	3.4	open-type (product)	3.19	routine test	3.34

Table 1 Continued on Next Page

Table 1 Continued

Term	Term number	Term	Term number	Term	Term number
closed electrical operating area	3.5	power drive system (PDS)	3.20	safety ELV (SELV) circuit	3.35
commissioning test	3.6	protective ELV (PELV) circuit	3.21	sample test	3.36
decisive voltage class (DVC)	3.7	prospective short-circuit current	3.22	supplementary insulation	3.37
double insulation	3.8	protective bonding	3.23	system voltage	3.38
extra low voltage (ELV)	3.9	protective class 0	3.24	temporary overvoltage	3.39
electrical breakdown	3.10	protective class I	3.25	touch current	3.40
expected lifetime	3.11	protective class II	3.26	type test	3.41
functional insulation	3.12	protective class III	3.27	user terminal	3.42
high-voltage PDS	3.13	protective earthing (PE)	3.28	working voltage	3.43
installation	3.14	protective earthing conductor	3.29	zone of equipotential bonding	3.44
integrated PDS	3.15	protective impedance	3.30		

Table 1DV DE Modification to add the following terms to Table 1:

AMBIENT TEMPERATURE	3.1ADV
CONTROL CIRCUIT	3.6ADV
GROUP INSTALLATION	3.12ADV
INSULATED LIVE PART	3.14ADV
SLASH VOLTAGE RATING	3.36ADV
STRAIGHT VOLTAGE RATING	3.36BDV
SURROUNDING AIR TEMPERATURE RATING	3.37ADV

3.1

ADJACENT CIRCUIT

circuit having no galvanic connection to the circuit under consideration

NOTE A protective impedance is not considered to be a galvanic connection.

3.1ADV D2 Addition:

AMBIENT TEMPERATURE

the temperature of the room or chamber in which the equipment under test is located

3.2

BASIC DRIVE MODULE (BDM)

drive module, consisting of a converter section and a control section for speed, torque, current or voltage, etc. (see [Figure 1](#))

3.3

BASIC INSULATION

insulation applied to LIVE PARTS to provide basic protection against electrical shock

[IEV 826-12-14, modified]

3.4

COMPLETE DRIVE MODULE

CDM

drive system, without the motor and the sensors which are mechanically coupled to the motor shaft, consisting of, but not limited to, the BDM, and extensions such as feeding section and auxiliaries (see [Figure 1](#))

3.5

CLOSED ELECTRICAL OPERATING AREA

room or location for electrical equipment to which access is restricted to skilled or instructed persons by the opening of a door or the removal of a barrier by the use of a key or tool and which is clearly marked by appropriate warning signs

3.6

COMMISSIONING TEST

test on a device or equipment performed on site, to prove the correctness of installation and operation

[IEV 151-16-24, modified]

3.6ADV D2 Addition:

CONTROL CIRCUIT

a circuit that carries the electric signals directing the performance of a controller, and does not carry the main power circuit (see IEEE Standards Dictionary of Electrical and Electronic Terms). A CONTROL CIRCUIT is mostly limited to 15 A.

3.6BDV D2 Addition:

COMMON DC BUS CONDUCTOR

The conductors between the output of a CONVERTER SECTION and the DC TAP CONDUCTORS of a modular drive assembly. COMMON DC BUS CONDUCTORS may have INTERNAL CONNECTIONS, EXTERNAL CONNECTIONS, or be modular DC bus conductors.

3.6CDV D2 Addition:

COMMON DC BUS CONDUCTOR, MODULAR

An assembly to which the CONVERTER SECTION and INVERTER SECTIONS are connected or “plugged in” and that include integral connections for the sections and the conductors between the sections. A MODULAR DRIVE SYSTEM using this assembly does not incorporate DC TAP CONDUCTORS. The connections for MODULAR COMMON DC BUS CONDUCTORS are INTERNAL CONNECTIONS.

3.6DDV D2 Addition:

CONVERTER OVERLOAD PROTECTION

Circuitry integral to the converter that acts to protect the converter and associated conductors under overload conditions by reducing current flow through the converter. The

overload protection circuitry is usually comprised of hardware, firmware and software components.

3.6EDV D2 Addition:

CONVERTER SECTION (DC SUPPLY)

An AC/DC converter that supplies DC power to modular INVERTER SECTIONS via COMMON DC BUS CONDUCTORS. The CONVERTER SECTION may consist of a simple rectifier construction or it may also contain a DC/AC converter, to return regenerative energy to the supply circuit.

3.6FDV D2 Addition:

DC TAP CONDUCTORS

The conductors between the COMMON DC BUS CONDUCTORS and the input of the INVERTER SECTIONS. DC TAP CONDUCTORS may have INTERNAL OR EXTERNAL CONNECTIONS.

3.7

DECISIVE VOLTAGE CLASS

DVC

classification of voltage range used to determine the protective measures against electric shock

3.8

DOUBLE INSULATION

insulation comprising both BASIC INSULATION and SUPPLEMENTARY INSULATION

[IEV 826-12-16]

NOTE BASIC and SUPPLEMENTARY INSULATION are separate, each designed for basic protection against electric shock.

3.9

EXTRA LOW VOLTAGE

ELV

any voltage not exceeding 50 V a.c. r.m.s. and 120 V d.c.

NOTE 1 R.M.S. ripple voltage of not more than 10 % of the d.c. component.

NOTE 2 In this international standard, protection against electric shock is dependent on the DECISIVE VOLTAGE CLASSIFICATION. DVC A and B are contained in the voltage range of ELV.

3.10

ELECTRICAL BREAKDOWN

failure of insulation under electric stress when the discharge completely bridges the insulation, thus reducing the voltage between the electrodes almost to zero

[IEC 60664-1:1992, definition 1.3.20]

3.11

EXPECTED LIFETIME

minimum duration for which the safety performance characteristics are valid at rated conditions of operation

3.11ADV D2 Addition:**EXTERNAL CONNECTIONS**

Connections between two or more modules of a MODULAR DRIVE SYSTEM in which the conductors are not entirely contained within the same end product enclosure as the two components that are being connected.

3.12

FUNCTIONAL INSULATION

insulation between conductive parts within a circuit, which is necessary for the proper functioning of the circuit, but which does not provide protection against electric shock

3.12ADV D2 Addition:**GROUP INSTALLATION**

A motor branch circuit for two or more motors, or one or more motors with other loads and protected by a circuit breaker or a single set of fuses.

3.13

HIGH-VOLTAGE PDS

product with rated supply voltage between 1 kV and 35 kV a.c., 50 Hz or 60 Hz

NOTE These products fall into the scope of IEC 61800-4

3.13DV D2 Modification:

Equipment operating at more than 600 Vac is considered high-voltage equipment with respect to the requirements in the National Electrical Code.

3.14

INSTALLATION

equipment or equipments including at least the PDS and the driven equipment (see [Figure 1](#))

NOTE The word "installation" is also used in this international standard to denote the process of installing a PDS/CDM/BDM. In these cases, the word does not appear in italics.

3.14ADV D2 Addition:**INSULATED LIVE PART**

An electrically LIVE PART that is provided with complete protection against electric shock and does not rely upon other parts for insulation

3.15

INTEGRATED PDS

PDS where motor and CDM/BDM are mechanically integrated into a single unit

3.15ADV D2 Addition:

INTERNAL CONNECTIONS

Connections between two or more modules of a MODULAR DRIVE SYSTEM in which the conductors are entirely contained within the same end product enclosure as the modules that are being connected.

3.15BDV D2 Addition:

INVERTER SECTION

A DC/AC inverter intended to drive a motor load.

3.16

(EARTH) LEAKAGE CURRENT

current flowing from the LIVE PARTS of the INSTALLATION to earth, in the absence of an insulation fault

[IEV 442-01-24]

3.17

LIVE PART

conductor or conductive part intended to be energized in normal use, including a neutral conductor but not a protective earth neutral

3.17ADV D2 Addition:

LOAD WIRE

A wire between the output of an INVERTER SECTION and the motor controlled by the inverter.

3.18

LOW-VOLTAGE PDS

product with rated supply voltage up to 1 000 V a.c., 50 Hz or 60 Hz

NOTE These products fall into the scope of IEC 61800-1 or IEC 61800-2.

3.18DV D2 Modification:

Equipment operating at more than 600 Vac is not considered low-voltage equipment with respect to the requirements in the National Electrical Code.

3.18ADV D2 Addition:

MODULAR DRIVE SYSTEM

A MODULAR DRIVE SYSTEM is an arrangement of a single converter and two or more INVERTER SECTIONS which are sold by the same company and intended to be used together to control multiple motors, but where a single inverter controls a single motor. The CONVERTER AND INVERTER SECTIONS of a MODULAR DRIVE SYSTEM are designed to facilitate field connection (field wiring), however they may also be supplied as a factory-assembled system. The

CONVERTER AND INVERTER SECTIONS of a MODULAR DRIVE SYSTEM may be designed to connect together using any of the following methods: printed wiring board(s), factory-made wiring harness(es) / cabling, field wiring, or busbars. Connections between converter and inverters may be internal or external. MODULAR DRIVE SYSTEMS often support a variety of configurations and ratings.

3.18BDV D2 Addition:

MULTIPLE MOTOR APPLICATION

An application in which a CDM/BDM directly controls more than one motor. This can apply to a single CDM/BDM with a single motor output connection for connection of multiple motors or a single CDM/BDM with multiple individual motor output connections.

3.19

OPEN TYPE (PRODUCT)

(product) intended for incorporation within enclosure or assembly which will provide access protection

3.19ADV D2 Addition:

OVERALL ASSEMBLY

An arrangement of a single converter and multiple inverter modules, with or without motors as shown in [Figure DVG.1](#), in a suitable enclosure or several enclosures mechanically attached and electrically connected together. The OVERALL ASSEMBLY forming a MODULAR DRIVE SYSTEM can be either factory assembled or assembled in the field as per the instruction manual using factory supplied sections or parts and with or without factory supplied electrical connections for field wiring. Where the system is in more than one enclosure and the enclosures are to be mechanically attached in the field, the conductors between enclosures are contained within the final assembly of enclosures and do not become part of the installation (building) or machine wiring as per the instruction manual.

3.20

POWER DRIVE SYSTEM

PDS

system for the speed control of an electric motor, including the CDM and motor but not the driven equipment (see [Figure 1](#))

3.20ADV D2 Addition:

PRIMARY CIRCUIT CONDUCTOR

The conductors connecting the AC input of the CONVERTER SECTION to the load side of the branch circuit protective device.

3.21

PROTECTIVE ELV (PELV) CIRCUIT

electrical circuit with the following characteristics:

- the voltage does not continuously exceed ELV under single fault as well as normal conditions;
- protective separation from circuits other than PELV or SELV;
- provisions for earthing of the PELV CIRCUIT, or its accessible conductive parts, or both

3.22

PROSPECTIVE SHORT-CIRCUIT CURRENT

current which flows when the supply conductors to the circuit are short-circuited by a conductor of negligible impedance located as near as possible to the supply terminals of the PDS/CDM/BDM

3.23

PROTECTIVE BONDING

electrical connection of conductive parts for safety purposes

3.24

PROTECTIVE CLASS 0

equipment in which protection against electric shock relies only upon BASIC INSULATION

NOTE Equipment of this class becomes hazardous in the event of a failure of the BASIC INSULATION.

3.25

PROTECTIVE CLASS I

equipment in which protection against electric shock does not rely on BASIC INSULATION only, but which includes an additional safety precaution in such a way that means are provided for the connection of accessible conductive parts to the PROTECTIVE (EARTHING) CONDUCTOR in the fixed wiring of the INSTALLATION, so that accessible conductive parts cannot become live in the event of a failure of the BASIC INSULATION

3.26

PROTECTIVE CLASS II

equipment in which protection against electric shock does not rely on BASIC INSULATION ONLY, but in which additional safety precautions such as SUPPLEMENTARY INSULATION or REINFORCED INSULATION are provided, there being no provision for PROTECTIVE EARTHING or reliance upon installation conditions

3.27

PROTECTIVE CLASS III

equipment in which protection against electric shock relies on supply at ELV and in which voltages higher than those of ELV are not generated and there is no provision for PROTECTIVE EARTHING

[see IEC 61140, subclause 7.4]

3.28

PROTECTIVE EARTHING (PE)

earthing of a point in a system, or equipment, for protection against electric shock in case of a fault

3.29

PROTECTIVE EARTHING CONDUCTOR

protective conductor provided for PROTECTIVE EARTHING

[IEV 195-02-11]

3.30

PROTECTIVE IMPEDANCE

impedance connected between LIVE PARTS and accessible conductive parts, of such value that the current, in normal use and under likely fault conditions, is limited to a safe value, and which is so constructed that its reliability is maintained throughout the life of the equipment

[IEV 442-04-24, modified]

3.31

PROTECTIVE SCREENING

separation of circuits from hazardous live-parts by means of an interposed conductive screen, connected to the means of connection for a PROTECTIVE EARTHING CONDUCTOR

3.32

PROTECTIVE SEPARATION

separation between circuits by means of basic and supplementary protection (BASIC INSULATION plus SUPPLEMENTARY INSULATION or PROTECTIVE SCREENING) or by an equivalent protective provision (for example, REINFORCED INSULATION)

3.32ADV D2 Addition:**RATED VOLTAGE**

the nominal rms voltage for which the power conversion equipment is designed to operate.

3.33

REINFORCED INSULATION

single insulation system, applied to LIVE PARTS, which provides a degree of protection against electric shock equivalent to DOUBLE INSULATION under the conditions specified in the relevant IEC standard

[IEC 60664-1: 1992, definition 1.3.17.5]

3.34

ROUTINE TEST

test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

[IEV 151-16-17]

3.35

SAFETY ELV (SELV) CIRCUIT

electrical circuit with the following characteristics:

- the voltage does not exceed ELV;
- PROTECTIVE SEPARATION from circuits other than SELV or PELV;
- no provisions for earthing of the SELV CIRCUIT, or its accessible conductive parts;
- BASIC INSULATION of the SELV CIRCUIT from earth and from PELV CIRCUITS

3.36

SAMPLE TEST

test on a number of devices taken at random from a batch

[IEV 151-16-20, modified]

3.36ADV D2 Addition:**SLASH VOLTAGE RATING**

A rating with two RATED VOLTAGES separated by a slash, for example, 460Y/267 volts or 480Y/277 volts. Equipment with a slash voltage rating is investigated for use in a circuit with these characteristics: the source is solidly grounded, the nominal voltage between any two circuit conductors does not exceed the higher RATED VOLTAGE, and the nominal voltage between any circuit conductor and the grounded enclosure, grounded parts, and exposed dead metal parts does not exceed the lower RATED VOLTAGE.

3.36BDV D2 Addition:**STRAIGHT VOLTAGE RATING**

a rating with one RATED VOLTAGE, for example, 460 volts or 480 volts. Equipment with a straight voltage rating is investigated for use in a circuit with these characteristics: the nominal voltage between any two circuit conductors and between any one circuit conductor and the grounded enclosure, grounded parts, and exposed dead metal parts does not exceed the RATED VOLTAGE.

3.37**SUPPLEMENTARY INSULATION**

independent insulation applied in addition to BASIC INSULATION in order to provide protection against electric shock in the event of a failure of BASIC INSULATION

[IEC 60664-1: 1992, definition 1.3.17.3]

NOTE BASIC and SUPPLEMENTARY INSULATION are separate, each designed for basic protection against electric shock.

3.37ADV D2 Addition:**SURROUNDING AIR TEMPERATURE RATING**

a rating assigned to OPEN TYPE equipment that refers to the maximum AMBIENT TEMPERATURE of air immediately surrounding the equipment inside of the ultimate enclosure

3.38**SYSTEM VOLTAGE**

voltage used to determine insulation requirements

NOTE See [4.3.6.2.1](#) for further consideration of SYSTEM VOLTAGE.

3.39**TEMPORARY OVERVOLTAGE**

overvoltage at the supply frequency of relatively long duration

[IEC 60664-1:1992, definition 1.3.7.1, modified]

3.40**TOUCH CURRENT**

electric current passing through a human body or through an animal body when it touches one or more accessible parts of an electrical installation or electrical equipment

[IEV 826-11-12]

3.41**TYPE TEST**

test of one or more devices made to a certain design to show that the design meets certain specifications

[IEV 151-16-16, modified]

3.42**USER TERMINAL**

terminal provided for external connection to the PDS/CDM/BDM

3.43**WORKING VOLTAGE**

voltage, at rated supply conditions (without tolerances) and worst case operating conditions, which occurs by design in a circuit or across insulation

NOTE The WORKING VOLTAGE can be d.c. or a.c. Both the r.m.s. and recurring peak values are used.

3.44**ZONE OF EQUIPOTENTIAL BONDING**

zone where all simultaneously accessible conductive parts are electrically connected to prevent hazardous voltages appearing between them

NOTE For equipotential bonding, it is not necessary for the parts to be earthed.

3.45**ELECTRONIC MOTOR OVERLOAD PROTECTION**

PDS/CDM/BDM circuitry which protects a motor during overload conditions by reducing current to the motor

Note 1 to entry: The protection circuitry is usually a combination of hardware and software.

Note 2 to entry: This protection is typically achieved through an algorithm based on the I^2t of the current to the motor.

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3.46

ELECTRONIC POWER OUTPUT SHORT-CIRCUIT PROTECTION CIRCUITRY

circuitry integral to PDS/CDM/BDM that acts to significantly reduce current flow to the power output upon sensing a short-circuit condition

Note 1 to entry: The protection circuitry is usually a combination of hardware and software.

3.47

THERMAL MEMORY

ability of an overload protective system to approximate the heating and cooling of a protected motor during operation

3.48

THERMAL MEMORY RETENTION

ability to retain a representation of the thermal state of a motor prior to shutdown or loss of power

Note 1 to entry: Typically, this information will be used by the overload protective system to approximate the thermal state of the motor upon restart.

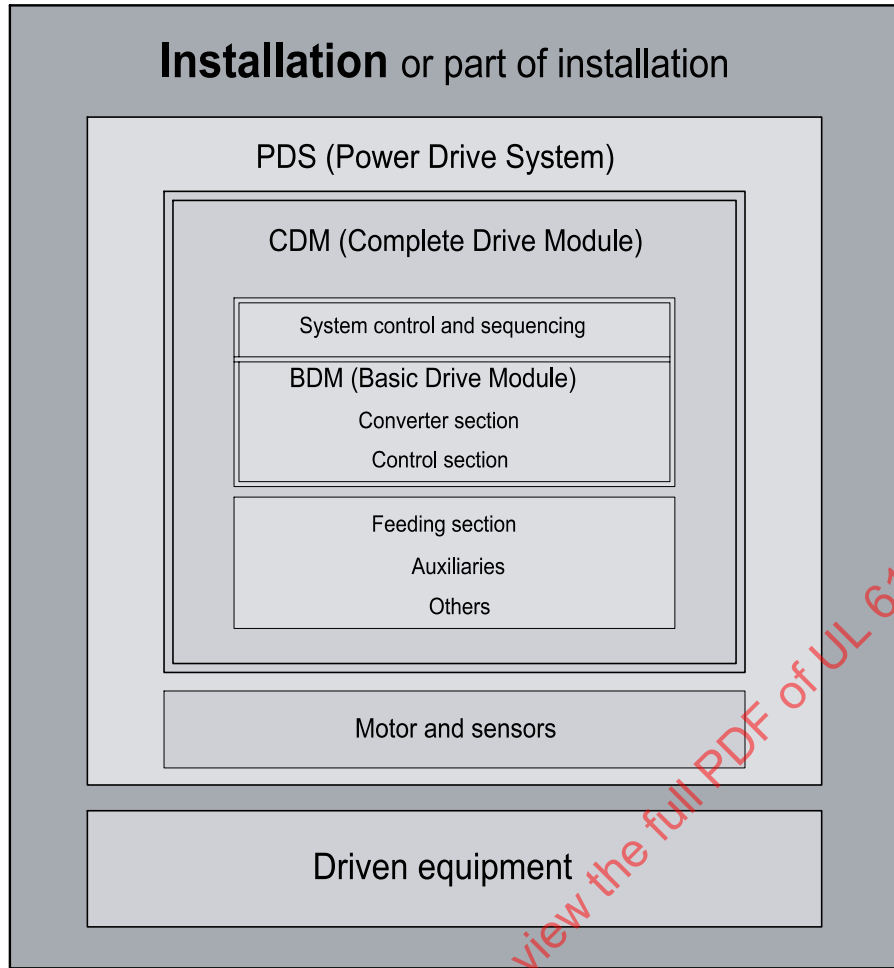
Note 2 to entry: This may include an ongoing reduction of the thermal representation to reflect cooling of the motor during shutdown or loss of power.

3.46

TRIP

controlled rapid reduction or elimination of the transfer of energy to any device or process initiated by a detected fault or abnormal operating condition

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IEC 257/03

su0059

Figure 1
PDS hardware configuration within an INSTALLATION

4 Protection against electric shock, thermal, and energy hazards

4.1 General

This Clause 4 defines the minimum requirements for the design and construction of a PDS, to ensure its safety during installation, normal operating conditions and maintenance for the EXPECTED LIFETIME of the PDS. Consideration is also given to minimising hazards resulting from reasonably foreseeable misuse.

[Table 2](#) shows the application of the requirements of this Clause 4 to PDS, CDM or BDM.

Table 2
Relevance of requirements to PDS/CDM/BDM

Sub-clause	Title	PDS ^a	CDM/BDM
4.2	(Protection against electric shock, thermal, and energy hazards) – Fault conditions	A	A
4.3.1	DECISIVE VOLTAGE CLASSIFICATION –	A	A
4.3.2	PROTECTIVE SEPARATION	A	A
4.3.3	Protection against direct contact	A	C
4.3.4	Protection in case of direct contact	A	C
4.3.5.1	(Protection against indirect contact) – General	A	A
4.3.5.2	Insulation between LIVE PARTS and accessible conductive parts	A	C
4.3.5.3	PROTECTIVE BONDING CIRCUIT	A	C
4.3.5.4	PROTECTIVE EARTHING CONDUCTOR	A	A
4.3.5.5	Means of connection for the PROTECTIVE EARTHING CONDUCTOR	A	A
4.3.5.6	Special features in equipment for PROTECTIVE CLASS II	A	C
4.3.6	Insulation	A	A
4.3.7	Enclosures	A	C
4.3.8	Wiring and connections	A	A
4.3.9	Output short-circuit requirements	A	A
4.3.10	Residual current-operated protective (RCD) or monitoring (RCM) device compatibility	A	C
4.3.11	Capacitor discharge	A	A
4.3.12	Access conditions for HIGH-VOLTAGE PDS	A	C
4.4	Protection against thermal hazards	A	A
4.4.3	Flammability of enclosure materials	A	C
4.4.5	Specific requirements for liquid cooled PDS	A	A
4.5	Protection against energy hazards	A	A
4.5.2	Mechanical energy hazards	A	C
4.6	Protection against environmental stresses	A	A
A Requirement always relevant.			
C Requirement relevant unless CDM or BDM is incorporated into an assembly that provides the required protection.			
^a INTEGRATED PDS shall meet the requirement for PDS.			

4.1DV.1 DR Modification to add the following:

Power conversion equipment shall be constructed so that it complies with the rules for INSTALLATION and use of such equipment as given in the National Electrical Code, ANSI/NFPA 70.

4.1DV.2 D2 *Modification to add the following:*

4.1DV.2.1 Power conversion equipment shall employ materials that are evaluated for the use.

4.1DV.2.2 The acceptability of insulating materials is to be determined with respect to properties such as flammability, arc-resistance, and similar properties, based on an operating temperature equal to the measured temperature adjusted to the minimum anticipated end use ambient of 40 °C (104 °F), unless the equipment is marked in accordance with [6.3.3](#) for a higher end use ambient.

4.1DV.2.3 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. This applies to all springs and other parts upon which proper mechanical operation may depend other than the following items:

- 1) Bearings, thermal elements, sliding surfaces of a hinge, or shaft, and the like, where such protection is impracticable;
- 2) Small parts of iron or steel, such as washers, screws, bolts, and the like, that are not current carrying, if the corrosion of such parts would not be likely to result in a risk of fire, electric shock, or injury to persons; and
- 3) Parts made of stainless steel that are polished or treated.

4.1DV.3 D2 *Modification to add the following:*

For Isolated Secondary Circuits the requirements in Annex [DVC](#) can be used to determine if any of the requirements for risk of electric shock, thermal or energy hazards may be waived.

4.2 Fault conditions

PDS shall be designed to avoid operating modes or sequences that can cause a fault condition or component failure leading to a hazard, unless other measures to prevent the hazard are provided by the INSTALLATION.

Protection against thermal hazards and electric shock shall be maintained in single fault conditions as well as under normal conditions.

Circuit analysis shall be performed to identify components (including insulation systems) whose failure would result in a thermal or electric shock hazard. The analysis shall include the effect of short-circuit and open-circuit conditions of the component. The analysis need not include power semiconductor devices if equivalent testing is accomplished during short-circuit tests, or components which have been determined to have an insignificant probability of failure during the EXPECTED LIFETIME of the PDS. See [5.2.3.6.4](#) for test.

NOTE It is possible that no critical components will be revealed by the analysis. In this case, no component failure testing is required.

Consideration shall be given to potential safety hazards associated with major component parts of the PDS, such as motor rotating parts and flammability of transformer and capacitor oils.

4.2DV.1 D2 Modification to add the following:

4.2DV.1.1 Critical components

4.2DV.1.1.1 The use of probability of failure for waiving circuit analysis on components is not applicable. The circuit analysis shall be used to identify critical components with respect to resulting thermal or electric shock hazard. Further analysis shall be used to determine the components to be subjected to the test in [5.2.3.6.4](#).

4.2DV.1.1.2 The breakdown of components testing is not required for:

- a) Components in Class 2, limited voltage/current secondary, or limiting impedance circuits as defined in Annex [DVC](#) if the analysis of [4.2](#) reveals that a fault of components within these circuits will not lead to a hazard within a circuit that is not Class 2, limited voltage/current, or limiting impedance; and;
- b) Components complying with the requirements applicable to the component where those requirements address the failure mode under evaluation for the circuit conditions in which the component is used within the drive.

4.2DV.2 D2 Modification to add the following:

4.2DV.2.1 Contactor overload

4.2DV.2.1.1 A contactor in a power circuit shall be suitable for controlling the connected load, including making, carrying and breaking the overload current that can be delivered by the equipment. A contactor with lower ratings may be used when it is interlocked or sequenced such that in normal operation the contactor does not make or break load current and meets the requirements of [5.2.4.5.5DV](#).

4.2DV.3 D2 Modification to add the following:

4.2DV.3.1 Current limiting control

4.2DV.3.1.1 Power conversion equipment incorporating a current limiting control is to be tested in accordance with [5.2.4.5.6DV](#).

4.3 Protection against electric shock

4.3.1 DECISIVE VOLTAGE CLASSIFICATION

4.3.1.1 Use of DECISIVE VOLTAGE CLASS (DVC)

Protective measures against electric shock depend on the DECISIVE VOLTAGE CLASSIFICATION of the circuit according to [Table 3](#), which correlates the limits of the WORKING VOLTAGE within the circuit with the DVC. The DVC in turn determines the minimum required level of protection for the circuit.

4.3.1.2 Limits of DVC

Table 3
Summary of the limits of the DECISIVE VOLTAGE CLASSES

DVC	Limits of WORKING VOLTAGE V			Subclause
	a.c. voltage (r.m.s.)	a.c. voltage (peak)	d.c. voltage (mean)	
	U_{ACL}	U_{ACPL}	U_{DCL}	
A ^a	25	35,4	60	4.3.4.2 , 4.3.4.4
B	50	71	120	4.3.5.3.1 a), b)
C	1 000	4 500 ^b	1 500	
D	>1 000	>4 500	>1 500	

^a For equipment having only one DVC A circuit, the r.m.s. and peak voltage limits are 30 V and 42,4 V respectively.

^b The value of 4 500 V allows all LOW-VOLTAGE PDS to be covered by [Table 7](#) (possible reflections up to $3 \times \sqrt{2} \times 1\,000\text{ V} = 4\,242\text{ V}$).

4.3.1.3 Requirements for protection

[Table 4](#) shows the requirements for the application of BASIC INSULATION OR PROTECTIVE SEPARATION, dependent on the DVC of the circuit under consideration and of ADJACENT CIRCUITS.

Table 4
Protection requirements for considered circuit

DVC of considered circuit	Protection required against direct contact	Insulation to earthed parts	Insulation to accessible conductive parts that are not earthed	Insulation to ADJACENT CIRCUIT of DVC:			
				A	B	C	D
A	No	a*	a	f*	b	p‡	p
B	Yes	b	p		b	p‡	p
C	Yes	b	p			b	p
D	Yes	b	p				b

a Insulation is not necessary for safety, but may be required for functional reasons.

* If the considered circuit is designated as a SELV CIRCUIT, BASIC INSULATION is required from earth and from PELV CIRCUITS.

f FUNCTIONAL INSULATION for circuit of higher voltage.

b BASIC INSULATION for circuit of higher voltage.

p PROTECTIVE SEPARATION for circuit of higher voltage.

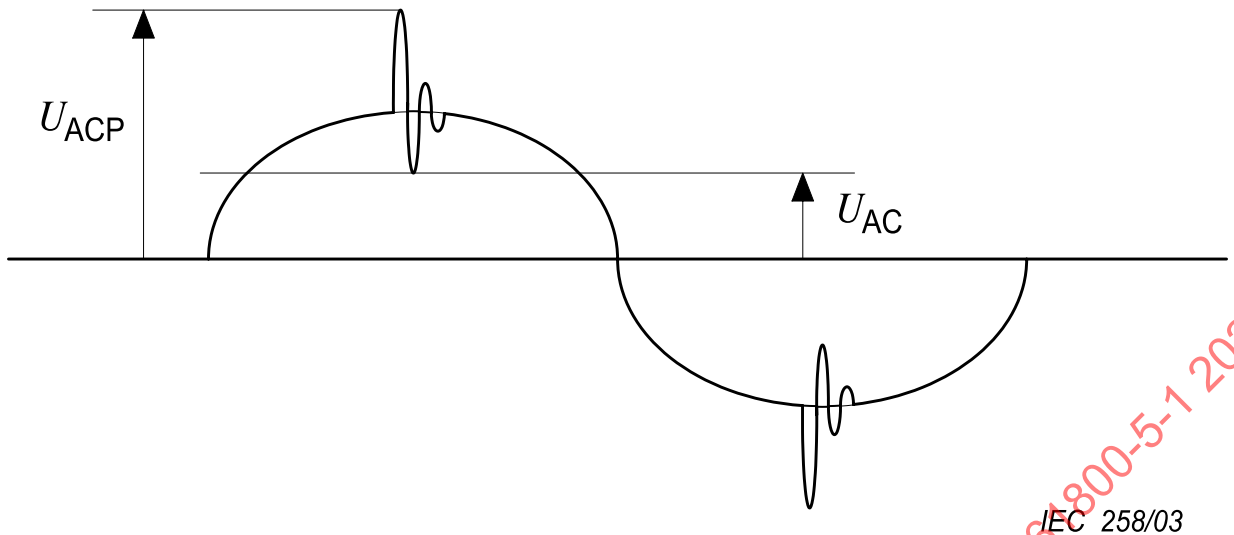
‡ It is permitted to use BASIC INSULATION for the circuit of higher voltage if protection against direct contact is applied to the considered circuit by BASIC or SUPPLEMENTARY INSULATION for the circuit of higher voltage.

4.3.1.4 Circuit evaluation

4.3.1.4.1 General

The DVC of a given circuit is evaluated by the method set out below, three cases of waveforms being considered.

4.3.1.4.2 A.C. WORKING VOLTAGE (see [Figure 2](#))



su0067

Key

U_{AC} r.m.s. voltage

U_{ACP} recurring peak voltage

Figure 2

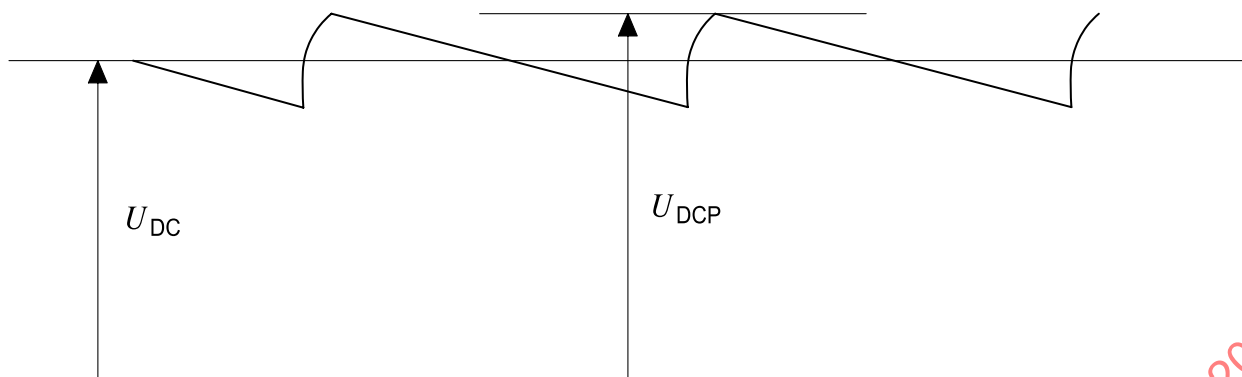
Typical waveform for a.c. WORKING VOLTAGE

The WORKING VOLTAGE has an r.m.s. value U_{AC} and a recurring peak value U_{ACP} .

The DVC is that of the lowest voltage row of [Table 3](#) for which both of the following conditions are satisfied.

- $U_{AC} \leq U_{ACL}$
- $U_{ACP} \leq U_{ACPL}$

4.3.1.4.3 D.C. WORKING VOLTAGE (see [Figure 3](#))



IEC 259/03

su0068

Key

U_{DC} mean voltage

U_{DCP} recurring peak voltage

Figure 3

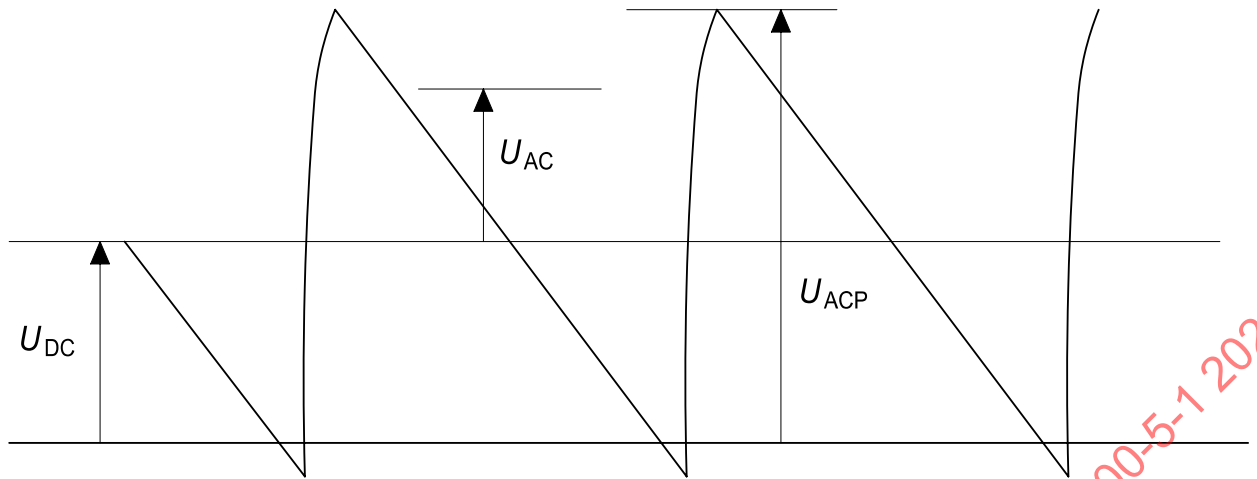
Typical waveform for d.c. WORKING VOLTAGE

The WORKING VOLTAGE has a mean value U_{DC} and a recurring peak value U_{DCP} , caused by a ripple voltage of r.m.s. value not greater than 10 % of U_{DC} .

The DVC is that of the lowest voltage row of [Table 3](#) for which both of the following conditions are satisfied.

- $U_{DC} \leq U_{DCL}$
- $U_{DCP} \leq 1,17 \times U_{DCL}$

4.3.1.4.4 Pulsating WORKING VOLTAGE (see [Figure 4](#))



IEC 260/03

su0069

Key

U_{DC} mean voltage

U_{DCP} recurring peak voltage

Figure 4

Typical waveform for pulsating WORKING VOLTAGE

The WORKING VOLTAGE has a mean value U_{DC} and a recurring peak value U_{ACP} , caused by a ripple voltage of r.m.s. value U_{AC} greater than 10 % of U_{DC} .

The DVC is that of the lowest voltage row of [Table 3](#) for which both of the following conditions are satisfied.

- $U_{AC}/U_{ACL} + U_{DC}/U_{DCL} \leq 1$
- $U_{ACP}/U_{ACPL} + U_{DC}/(1,17 \times U_{DCL}) \leq 1$

4.3.2 PROTECTIVE SEPARATION

PROTECTIVE SEPARATION shall be achieved by application of materials resistant to degradation, as well as by special constructive measures; and

- by DOUBLE or REINFORCED INSULATION,

or

- by PROTECTIVE SCREENING, i.e. by a conductive screen connected to earth by PROTECTIVE BONDING of the PDS, or connected to the protective earth conductor itself, whereby the screen is separated from LIVE PARTS by at least BASIC INSULATION,

or

- by PROTECTIVE IMPEDANCE according to [4.3.4.3](#) comprising limitation of discharge energy and of current, or by limitation of voltage according to [4.3.4.4](#).

The PROTECTIVE SEPARATION shall be fully and effectively maintained under all conditions of intended use of the PDS.

4.3.3 Protection against direct contact

4.3.3.1 General

Protection against direct contact is employed to prevent persons from touching LIVE PARTS which do not meet the requirements of [4.3.4](#). It shall be provided by one or more of the measures given in [4.3.3.2](#) and [4.3.3.3](#).

For INTEGRATED PDS the motor shall meet the requirements of IEC 60034-5. For the BDM the protection shall be provided by one or more of the measures given in [4.3.3.2](#) and [4.3.3.3](#).

4.3.3.1DV DC Modification:

In the US, motor requirements are provided in UL 2111 and the UL 1004 series of standards.

4.3.3.2 Protection by means of insulation of LIVE PARTS

LIVE PARTS shall be completely surrounded with insulation if their WORKING VOLTAGE is greater than the maximum limit of DVC A or if they do not have PROTECTIVE SEPARATION from ADJACENT CIRCUITS of DVC C or D. The insulation shall be rated according to the impulse voltage, TEMPORARY OVERVOLTAGE or WORKING VOLTAGE (see [4.3.6.2.1](#)), whichever gives the most severe requirement. It shall not be possible to remove the insulation without the use of a tool.

Any conductive part which is not separated from the LIVE PARTS by at least BASIC INSULATION is considered to be a LIVE PART. A metallic accessible part is considered to be conductive if its surface is bare or is covered by an insulating layer which does not comply with the requirements of BASIC INSULATION.

As an alternative to solid or liquid insulation, a clearance according to [4.3.6.4](#), shown by L_1 and L_2 in [Figure 5](#), may be provided.

The grade of insulation – BASIC, DOUBLE or REINFORCED – depends on:

- the DVC of the LIVE PARTS or ADJACENT CIRCUITS,

and

- the connection of conductive parts to earth by PROTECTIVE BONDING.

Examples of insulation configurations are given in [Figure 5](#), which also shows the requirements for apertures.

Type of insulation	Insulation configuration		
	a Accessible parts conductive and connected to earth by <i>protective bonding</i>	b Accessible parts not conductive	c Accessible parts conductive, but NOT connected to earth by <i>protective bonding</i>
1) Solid or liquid			
2) Totally or partially by air clearance			
3) Insulation for adjacent circuits: Circuit A: lower voltage circuit Circuit C: higher voltage circuit; upper row - DVC C only, lower row - DVC C or D			
4) Requirements for apertures in enclosures			
A <i>live part</i>	L_1 <i>clearance for basic insulation</i>	T <i>test finger (Clause 12 of IEC 60529)</i>	
B <i>basic insulation for circuit A</i>	L_2 <i>clearance for reinforced insulation</i>	Z <i>supplementary insulation for circuit A</i>	
Bc <i>basic insulation for circuit C</i>	M <i>conductive part</i>	Zc <i>supplementary insulation for circuit C</i>	
C <i>adjacent circuit</i>	R <i>reinforced insulation for circuit A</i>	* <i>also applies to plastic screws</i>	
D <i>double insulation for circuit A</i>	Rc <i>reinforced insulation for circuit C</i>	F <i>functional insulation for circuit A</i>	
I <i>insulation less than B</i>	S <i>surface of equipment</i>		
NOTE 1: In column c a plastic screw is treated like a metal screw because a user could replace it with a metal screw during the life of the equipment.			
NOTE 2: In row 4), the insertion of the test finger is considered to represent the first fault.			

Figure 5
Examples for protection against direct contact

Three cases are considered:

Case a): Accessible parts are conductive and are connected to earth by PROTECTIVE BONDING.

- BASIC INSULATION is required between accessible parts and the LIVE PARTS. The relevant voltage is that of the LIVE PARTS (see [Figure 5](#), cells 1)a), 2)a), 3)a)).

Cases b) and c): Accessible parts are non-conductive (case b)) or conductive but not connected to earth by PROTECTIVE BONDING (case c)). The required insulation is:

- DOUBLE or REINFORCED INSULATION between accessible parts and LIVE PARTS of DVC C or D. The relevant voltage is that of the LIVE PARTS (see [Figure 5](#), cells 1)b), 1)c), 2)b), 2)c)).

- SUPPLEMENTARY INSULATION between accessible parts and LIVE PARTS of circuits of DVC A or B which are separated by BASIC INSULATION from ADJACENT CIRCUITS of DVC C. The relevant voltage is the highest voltage of the ADJACENT CIRCUITS (see [Figure 5](#), upper cells 3)b), 3)c)).

- BASIC INSULATION between accessible parts and LIVE PARTS of circuits of DVC B which have PROTECTIVE SEPARATION from ADJACENT CIRCUITS of DVC C or D. The relevant voltage is that of the LIVE PARTS (see [Figure 5](#), lower cells 3)b), 3)c)).

4.3.3.3 Protection by means of enclosures and barriers

LIVE PARTS of DVC B, C or D shall be arranged in enclosures or located behind enclosures or barriers, which meet at least the requirements of the Protective Type IPXXB according to 15.1 of IEC 60529. The top surfaces of enclosures or barriers which are accessible when the equipment is energized shall meet at least the requirements of the Protective Type IP3X with regard to vertical access only. See [5.2.2.3](#) for test. It shall only be possible to open enclosures or remove barriers with the use of a tool or after de-energization of these LIVE PARTS.

Where the enclosure is required to be opened and the PDS energised during installation or maintenance:

a) accessible LIVE PARTS of DVC B, C or D shall be protected to at least IPXXA;

b) LIVE PARTS of DVC B, C or D that are likely to be touched when making adjustments shall be protected to at least IPXXB;

c) it shall be ensured that persons are aware that LIVE PARTS of DVC B, C or D are accessible.

OPEN TYPE sub-assemblies and devices do not require protective measures against direct contact.

Products containing circuits of DVC A, B or C, intended for installation in CLOSED ELECTRICAL OPERATING AREAS, as defined in [3.5](#), need not have protective measures against direct contact.

Products containing circuits of DVC D, intended for installation within a CLOSED ELECTRICAL OPERATING AREA, have additional requirements (see [4.3.12](#)).

4.3.3.3DV.1 D2 Modification:

It is permitted to open enclosures or remove barriers without the use of a tool and without de-energization of LIVE PARTS of DVC A, B or C circuits.

4.3.3.3DV.2 D2 Modification:

Accessibility of LIVE PARTS of DVC B or C circuits, excluding isolated secondary circuits of DVC B that have been investigated to Annex [DVC](#) which do not require protection against direct contact as indicated by [Table DVC.1](#), shall be determined in accordance with Annex [DVD](#).

4.3.4 Protection in case of direct contact

4.3.4.1 General

Protection in case of direct contact is required to ensure that contact with LIVE PARTS does not produce a shock hazard.

The protection against direct contact according to [4.3.3](#) is not required if the circuit contacted is separated from all other circuits according to [4.3.1.3](#), and:

- is of DVC A and complies with [4.3.4.2](#),

or

- is current limited via a PROTECTIVE IMPEDANCE according to [4.3.4.3](#),

or

- is limited in voltage according to [4.3.4.4](#).

See Annex [A](#) for examples of these measures.

NOTE The requirements of these subclauses apply to the entire circuit including power supplies and any associated peripheral devices.

Compliance with PROTECTIVE SEPARATION requirements shall be verified according to [5.2.1](#), [5.2.2](#), and [5.2.3](#) as appropriate.

4.3.4.1DV D2 Modification to add the following:

Protection in case of direct contact according to [4.3.3](#) is not required if the circuit is an isolated secondary circuit investigated to Annex [DVC](#) and does not require protection against direct contact as indicated by [Table DVC.1](#).

4.3.4.2 Protection using DVC A

Unearthed circuits of DVC A, and earthed circuits of DVC A used within a ZONE OF EQUIPOTENTIAL BONDING (see [3.44](#)), do not require protection in case of direct contact.

Earthed circuits of DVC A that are not within a ZONE OF EQUIPOTENTIAL BONDING require additional protection in case of direct contact, by one of the measures given in [4.3.4.3](#) or [4.3.4.4](#), in order to provide protection in cases where the earth reference potentials of the DVC A circuits are not the same. The instruction manual shall provide information concerning the use of these circuits (see [6.3.6.5](#)).

4.3.4.3 Protection by means of PROTECTIVE IMPEDANCE

The connection of accessible LIVE PARTS to circuits of DVC B, C or D, or to earthed circuits of DVC A not used within a ZONE OF EQUIPOTENTIAL BONDING, shall only be made through PROTECTIVE IMPEDANCES (unless [4.3.4.4](#) applies).

The same constructional provisions as those for PROTECTIVE SEPARATION shall be applied for the construction and arrangement of a PROTECTIVE IMPEDANCE. The current value stated below shall not be exceeded in the event of failure of a single component. The stored charge available between simultaneously accessible parts protected by the PROTECTIVE IMPEDANCE shall not exceed 50 μC .

The PROTECTIVE IMPEDANCES shall be designed so that the current available through them to earth at the accessible LIVE PART does not exceed a value of 3,5 mA a.c. or 10 mA d.c. See [5.2.3.4](#) for test.

The PROTECTIVE IMPEDANCES shall be designed and tested to withstand the impulse voltages and TEMPORARY OVERVOLTAGES for the circuits to which they are connected. See [5.2.3.1](#) and [5.2.3.2](#) for tests.

4.3.4.3DV D2 Modification:

Impulse voltage testing is not required.

4.3.4.4 Protection by means of limited voltages

This type of protection implies a voltage division technique from a circuit protected against direct contact, resulting in a voltage to earth not greater than that of DVC A.

This circuit shall be designed so that, even in the event of failure of a single component in the voltage division circuit, the voltage across output terminals as well as the voltage to earth will not become greater than that of DVC A. The same constructional measures as in PROTECTIVE SEPARATION shall be employed in this case.

This type of protection shall not be used in case of PROTECTIVE CLASS II, because it relies on protective earth being connected.

4.3.5 Protection against indirect contact

4.3.5.1 General

Protection against indirect contact is required to prevent shock currents which can result from accessible conductive parts during an insulation failure. This protection shall comply with the requirements for PROTECTIVE CLASS I, CLASS II or CLASS III.

That part of a PDS which meets the requirements of [4.3.5.2](#), [4.3.5.3](#) and [4.3.5.3.2](#) is defined as PROTECTIVE CLASS I.

That part of a PDS which meets the requirements of [4.3.5.6](#) is defined as PROTECTIVE CLASS II.

That part of a PDS which meets the requirements of SELV is defined as PROTECTIVE CLASS III.

PROTECTIVE CLASS 0 is only acceptable for parts of the PDS when instructions are provided to meet the requirements of [4.3.3.3](#) (CLOSED ELECTRICAL OPERATING AREAS) (see [6.3.6.5](#)). In the case of HIGH-VOLTAGE PDS, special requirements exist (see [4.3.12](#)).

4.3.5.1DV D2 *Modification:*

Protection by means of CLASS II methods are not applicable.

4.3.5.2 Insulation between LIVE PARTS and accessible conductive parts

Accessible conductive parts of equipment shall be separated from LIVE PARTS at least by BASIC INSULATION or by clearances as in [4.3.6.4](#).

4.3.5.3 PROTECTIVE BONDING circuit

4.3.5.3.1 General

Other than in a) or b) below, PROTECTIVE BONDING shall be provided between accessible conductive parts of equipment and the means of connection for the PROTECTIVE EARTHING CONDUCTOR:

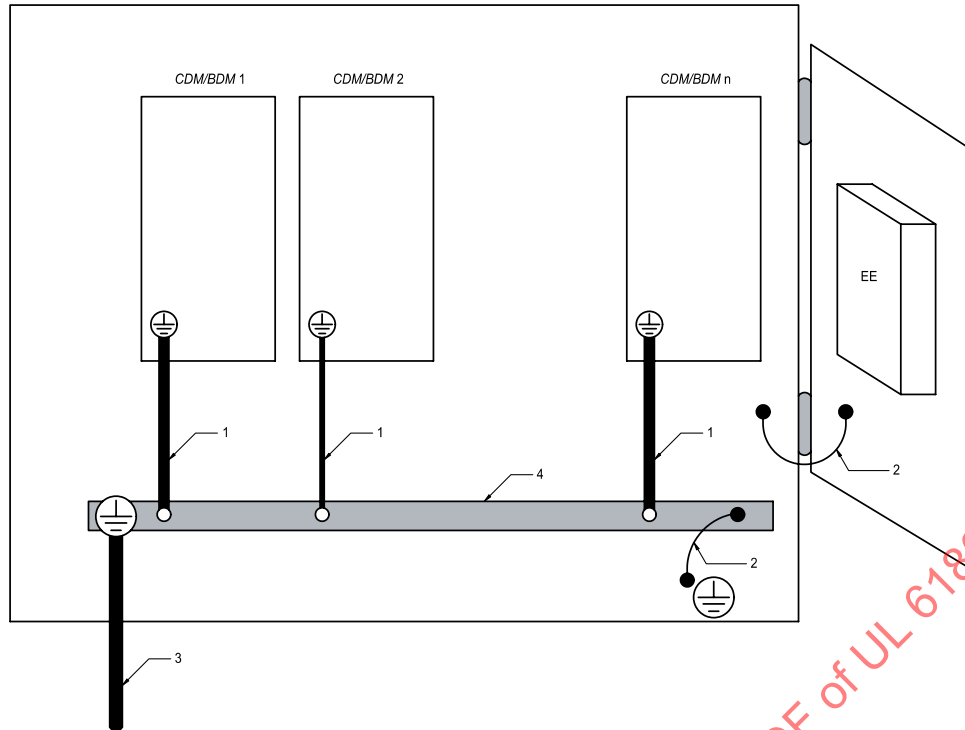
a) when accessible conductive parts are protected by one of the measures in [4.3.4.2](#) to [4.3.4.4](#);

b) when accessible conductive parts are separated from LIVE PARTS using DOUBLE or REINFORCED INSULATION.

NOTE Some examples of such parts are magnetic cores, screws, rivets, nameplates and cable clamps.

[Figure 6](#) shows an example CDM/BDM assembly and its associated PROTECTIVE BONDING.

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- 1 CDM/BDM PROTECTIVE EARTHING CONDUCTOR (dimensioned according to CDM/BDM requirements)
- 2 PROTECTIVE BONDING
- 3 PDS PROTECTIVE EARTHING CONDUCTOR (dimensioned according to PDS requirements) to INSTALLATION earthing point
- 4 EARTH bar
- EE other ELECTRICAL equipment (bonded as relevant for that equipment)

Figure 6

Example of PROTECTIVE BONDING

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Electrical contact to the means of connection of the PROTECTIVE EARTHING CONDUCTOR shall be achieved by one or more of the following means:

- through direct metallic contact;
- through other accessible conductive parts which are not removed when the PDS/CDM/BDM is used as intended;
- through a dedicated PROTECTIVE BONDING conductor;
- through other metallic components of the PDS/CDM/BDM.

NOTE When painted surfaces (in particular powder painted surfaces) are joined together, then a separate connection should be made for reliable contact.

Where electrical equipment is mounted on lids, doors, or cover plates, continuity of the PROTECTIVE BONDING circuit shall be ensured and it is recommended that a dedicated conductor be used. Otherwise fastenings, hinges or sliding contacts designed and maintained to have a low resistance shall be used.

Metal ducts of flexible or rigid construction and metallic sheaths shall not be used as protective conductors.

For HIGH-VOLTAGE PDS, metal ducts and metal sheathing of all connecting cables (e.g. cable armouring, lead sheath) shall be connected to earth by the PROTECTIVE BONDING circuit. If only one end of such ducting or sheathing is so connected, it shall not be possible to touch the other end. This shall be connected to earth by the PROTECTIVE BONDING circuit via an impedance to limit any induced voltage to a maximum of 50 V a.c.

The PROTECTIVE BONDING circuit shall not incorporate a switching device, an overcurrent device (e.g. switch, fuse) or means of current detection for such devices.

4.3.5.3.1DV.1 D1 Modification:

Item b) is not applicable.

4.3.5.3.1DV.2 D2 Modification to add the following:

4.3.5.3.1DV.2.1 Bonding

4.3.5.3.1DV.2.1.1 Other than as noted in [4.3.5.3.1DV.2.1.2](#) and [4.3.5.3.1DV.2.1.3](#), an enclosure made of insulating material, either wholly or in part, shall have bonding means to provide continuity of grounding between all conduit openings. The bonding means shall be either completely assembled on the product or provided as separate parts for field INSTALLATION.

4.3.5.3.1DV.2.1.2 A bonding means required in [4.3.5.3.1DV.2.1.1](#) is not required for an enclosure that is intended to be connected to a single conduit. Enclosures shall be marked in accordance with [6.3.6.6DV.3](#).

4.3.5.3.1DV.2.1.3 A bonding means required in [4.3.5.3.1DV.2.1.1](#) is not required to be provided with each enclosure when such means is available in the form of a kit from the manufacturer and the equipment complies with the marking requirements in [6.3.6.6DV.2](#).

4.3.5.3.1DV.2.1.4 Other than as noted in [4.3.5.3.1DV.2.1.5](#), the continuity of a conduit system shall be provided by metal-to-metal contact not relying on a polymeric material.

4.3.5.3.1DV.2.1.5 The continuity of the grounding system is not prohibited from relying on the integrity of the polymeric enclosure when samples have been subjected to the creep test requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. Overcurrent Tests shall be conducted at 200 percent of the rated current of the branch circuit-protective device.

4.3.5.3.1DV.2.1.6 A separate bonding conductor whether in a plastic or metal enclosure shall be copper, a copper alloy, or other material determined to be usable as an electrical conductor. Ferrous metal parts in the grounding path shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. A separate bonding conductor shall:

- a) Be protected from mechanical damage or be located within the confines of the outer enclosure or frame; and
- b) Not be secured by a removable fastener used for any purpose other than bonding unless the bonding conductor is unable to be omitted after removal and replacement of the fastener.

4.3.5.3.1DV.2.1.7 Other than as noted in [4.3.5.3.1DV.2.1.8](#), the size of a separate component bonding conductor shall not be less than the applicable size specified in [Table 4.3.5.3.1DV.1](#) or the size of the conductor supplying the component, whichever is smaller.

4.3.5.3.1DV.2.1.8 A bonding conductor is not required to be as large as specified in [4.3.5.3.1DV.2.1.7](#) when:

- a) It does not open when carrying, for the time specified in [Table 4.3.5.3.1DV.2](#). A current equal to twice the branch-circuit overcurrent-device rating – see [4.3.5.3.1DV.2.1.9](#) – and not less than 40 A; and
- b) None of three samples of the bonding conductor opens during a limited-shortcircuit test with a current as specified in [Table 4.3.5.3.1DV.3](#) when in series with a fuse as described in [4.3.5.3.1DV.2.1.9](#).

Table 4.3.5.3.1DV.1
Size of Bonding Conductor

Maximum rating or setting of automatic overcurrent device in circuit ahead of equipment, A	Minimum size of bonding conductor ^a	
	Copper wire AWG (mm ²)	Aluminum wire AWG or kcmil (mm ²)
15	14 (2,1)	12 (3,3)
20	12 (3,3)	10 (5,3)
30	10 (5,3)	8 (8,4)
40	10 (5,3)	8 (8,4)
60	10 (5,3)	8 (8,4)
100	8 (8,4)	6 (13,3)
200	6 (13,3)	4 (21,2)

Table 4.3.5.3.1DV.1 Continued on Next Page

Table 4.3.5.3.1DV.1 Continued

Maximum rating or setting of automatic overcurrent device in circuit ahead of equipment, A	Minimum size of bonding conductor ^a			
	Copper wire AWG (mm ²)		Aluminum wire AWG or kcmil (mm ²)	
300	4	(21,2)	2	(33,6)
400	3	(26,7)	1	(42,4)
500	2	(33,6)	1/0	(53,5)
600	1	(42,2)	2/0	(67,4)
800	1/0	(53,5)	3/0	(85,0)
1 000	2/0	(67,4)	4/0	(107,0)
1 200	3/0	(85,0)	250	(127,0)

^a Or equivalent cross-sectional area.

Table 4.3.5.3.1DV.2
Duration of Current Flow for Bonding-Conductor Test

Overcurrent device rating, A	Minimum duration of current flow, min
30 or less	1
31 – 60	4
61 – 100	6

Table 4.3.5.3.1DV.3
Bonding Conductor Short-Circuit Test Capacity

Controller rating		V	Circuit capacity, A
hp	(kW output)		
1/2	(0,373)	0 – 250	200
1/2	(0,373)	251 – 600	1 000
over 1/2 to 1	(0,374 – 0,746)	0 – 600	1 000
over 1 to 3	(0,747 – 2,24)	0 – 250	2 000
over 3 to 7-1/2	(2,25 – 5,59)	0 – 250	3 500
over 7-1/2 to 50	(5,60 – 37,3)	0 – 250	5 000
over 1 to 50	(0,747 – 37,3)	251 – 600	5 000
over 50 to 200	(37,4 – 149)	0 – 600	10 000
over 200	(over 150)	0 – 600	a

^a See [Table 4.3.9DV.1](#).

4.3.5.3.1DV.2.1.9 The circuit for the test required by [4.3.5.3.1DV.2.1.8](#) is to have a power factor of 0,9 – 1,0 and is to be limited to the current specified in [Table 4.3.5.3.1DV.3](#). The open-circuit voltage of the test circuit is to be 100 to 105 percent of the specified voltage. The circuit is to be connected through a nonrenewable fuse that conducts twice its rated current for at least 12 s. The fuse rating is to be that of the branch-circuit overcurrent device to which the equipment is intended to be connected and not less than 20 A. One test is to be performed on each of three samples of the bonding conductor.

4.3.5.3.2 Rating of protective bonding

PROTECTIVE BONDING shall withstand the highest thermal and dynamic stresses that can occur to the PDS/CDM/BDM item(s) concerned when they are subjected to a fault connecting to accessible conductive parts.

The PROTECTIVE BONDING shall remain effective for as long as a fault to the accessible conductive parts persists or until an upstream protective device removes power from the part.

NOTE In cases where the PROTECTIVE BONDING is routed through conductors of low cross-section (for example, PWB tracks), particular care should be taken to ensure that no undetected damage to the bonding circuit can occur in the event of a fault.

These conditions will be satisfied if the cross-section of the PROTECTIVE BONDING conductor is the same as that for the PROTECTIVE EARTHING CONDUCTOR according to [4.3.5.4](#). For testing, see [5.2.3.9](#).

Alternatively, PROTECTIVE BONDING may be designed to meet the impedance requirements of [4.3.5.3.3](#).

4.3.5.3.3 PROTECTIVE BONDING impedance

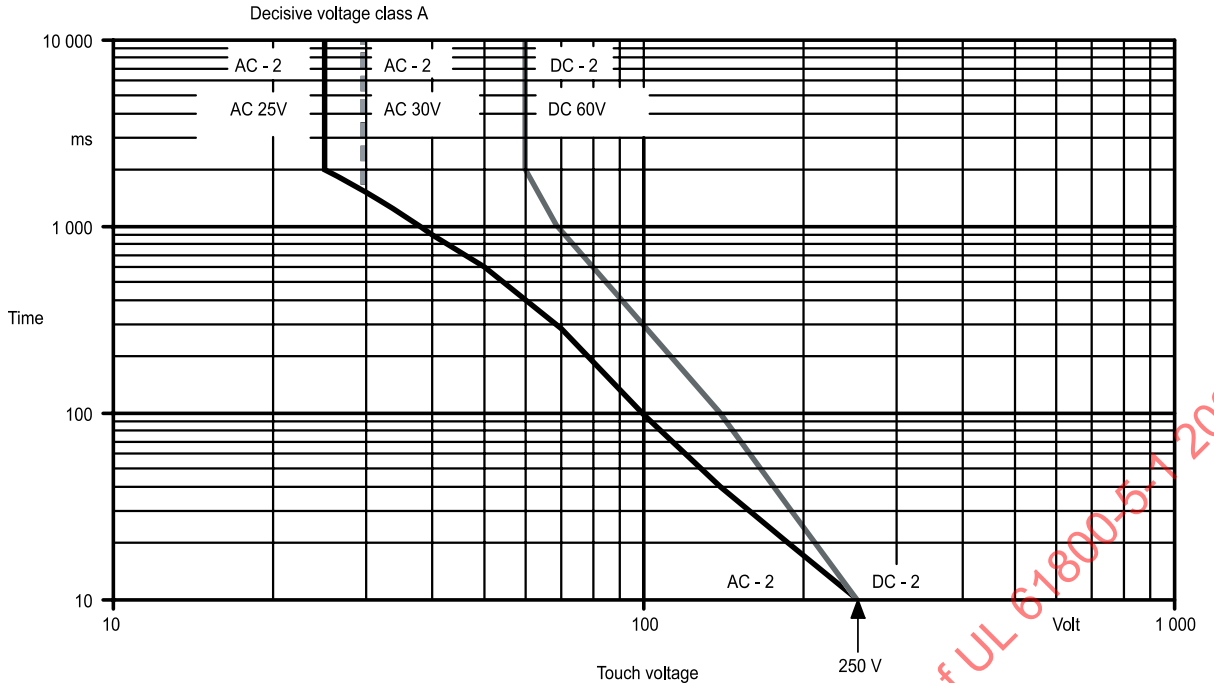
The impedance of the PROTECTIVE BONDING shall be sufficiently low that:

- during normal operation, no voltage exceeding continuously 5 V a.c. or 12 V d.c. can persist between the accessible conductive parts and the means of connection for the PROTECTIVE EARTHING CONDUCTOR,

and

- under fault conditions, no voltage exceeding AC-2 or DC-2 in [Figure 7](#) can persist between accessible conductive parts and the means of connection for the PROTECTIVE EARTHING CONDUCTOR until an upstream protective device removes power from the part. The upstream protective device considered for this requirement shall have the characteristics required by the installation manual according to [6.3.7](#).

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NOTE The dashed line of AC-2 applies if only a single DVC A circuit is present; the solid line applies if more than one DVC A circuit is present.

Figure 7
Voltage limits under fault conditions

For testing, see [5.2.3.9](#).

4.3.5.4 PROTECTIVE EARTHING CONDUCTOR

A PROTECTIVE EARTHING CONDUCTOR shall be connected at all times when power is supplied to the PDS/CDM/BDM, unless the PDS/CDM/BDM complies with the requirements of PROTECTIVE CLASS II (see [4.3.5.6](#)). Unless local wiring regulations state otherwise, the PROTECTIVE EARTHING CONDUCTOR cross-sectional area shall be determined from [Table 5](#) or by calculation according to 543.1 of IEC 60364-5-54.

If the PROTECTIVE EARTHING CONDUCTOR is routed through a plug and socket, or similar means of disconnection, it shall not be possible to disconnect it unless power is simultaneously removed from the part to be protected.

Table 5
PROTECTIVE EARTHING CONDUCTOR cross-section

Cross-sectional area of phase conductors of the PDS/CDM/BDM S (mm ²)	Minimum cross-sectional area of the corresponding PROTECTIVE EARTHING CONDUCTOR S _p (mm ²)
S ≤ 16	S
16 < S ≤ 35	16

Table 5 Continued on Next Page

Table 5 Continued

Cross-sectional area of phase conductors of the PDS/CDM/BDM S (mm ²)	Minimum cross-sectional area of the corresponding PROTECTIVE EARTHING CONDUCTOR S _p (mm ²)
35 < S	S/2
The values in Table 5 are valid only if the PROTECTIVE EARTHING CONDUCTOR is made of the same metal as the phase conductors. If this is not so, the cross-sectional area of the PROTECTIVE EARTHING CONDUCTOR shall be determined in a manner which produces a conductance equivalent to that which results from the application of Table 5 .	

The cross-sectional area of every PROTECTIVE EARTHING CONDUCTOR which does not form part of the supply cable or cable enclosure shall, in any case, be not less than:

- 2,5 mm² if mechanical protection is provided,

or

- 4 mm² if mechanical protection is not provided. For cord-connected equipment, provisions shall be made so that the PROTECTIVE EARTHING CONDUCTOR in the cord shall, in the case of failure of the strain-relief mechanism, be the last conductor to be interrupted.

For special system topologies, such as 6-phase motors, the PDS designer shall verify the PROTECTIVE EARTHING CONDUCTOR cross-section required.

4.3.5.4DV.1 DR Modification to add the following:

The PROTECTIVE EARTHING CONDUCTOR shall be sized as specified in Article 250.122 and Table 250.122 of the National Electrical Code, ANSI/NFPA 70.

4.3.5.4DV.2 D2 Modification:

For cord connected equipment, it shall not be possible to disconnect the PROTECTIVE EARTHING CONDUCTOR before power is removed.

4.3.5.4DV.3 D2 Modification:

For the internal grounding and bonding conductor color, see [4.3.8.3DV](#).

4.3.5.5 Means of connection for the PROTECTIVE EARTHING CONDUCTOR

4.3.5.5DV DR Modification to add the following:

4.3.5.5DV.1 Means for grounding shall be provided as follows:

- a) Fixed equipment shall be provided with a means of attachment of a terminal or the equivalent for connecting an equipment grounding conductor. The terminal shall be sized to receive a grounding conductor as specified in Section 250.122 and Table 250.122 of the National Electrical Code, ANSI/NFPA 70;

b) Portable equipment shall be provided with a power-supply cord with a grounding conductor. The grounding conductor shall be connected to the grounding blade of a grounding attachment plug and shall be connected to the frame or enclosure of the equipment. The surface of the insulation on the grounding conductor shall be green with or without one or more yellow stripes.

4.3.5.5DV.2 A wire binding screw intended for the connection of a field-installed equipment grounding conductor shall have a green colored head that is hexagonal, slotted, or both.

4.3.5.5DV.3 A pressure wire connector intended for connection of a field-installed equipment grounding conductor shall be plainly identified, such as being marked “G,” “GR,” “GRD,” “Ground,” “Grounding,” or similar designation, or with the grounding symbol (IEC Publication 417, Symbol 5019).

4.3.5.5DV.4 A terminal for an equipment grounding conductor shall have no other function.

4.3.5.5DV.5 Grounding means provided in the form of a kit meets the requirement of [4.3.5.5DV.1\(a\)](#). When the grounding means is not provided on the equipment as shipped, the equipment shall be marked in accordance with [6.3.6.4DV.1.12](#).

4.3.5.5.1 General

Every PDS or PDS element (motor, converter, transformer) requiring connection to earth by PROTECTIVE BONDING shall have a means of connection for the PROTECTIVE EARTHING CONDUCTOR, located near the terminals for the respective live conductors. The means of connection shall be corrosion-resistant and shall be suitable for the connection of cables according to [Table 5](#) and of cables in accordance with the wiring rules applicable at the INSTALLATION. The means of connection for the PROTECTIVE EARTHING CONDUCTOR shall not be used as a part of the mechanical assembly of the equipment or for other connections. A separate means of connection shall be provided for each PROTECTIVE EARTHING CONDUCTOR.

For HIGH-VOLTAGE PDS, protective shields of high voltage cables shall have provision for connection to earth by PROTECTIVE BONDING in accordance with IEC 60204-11 and IEC 61800-4. The PROTECTIVE BONDING concept shall be by agreement between the supplier and user and consistent with local requirements in the area of INSTALLATION.

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

See [6.3.6.6](#) for marking requirements.

4.3.5.5.2 TOUCH CURRENT in case of failure of PROTECTIVE EARTHING CONDUCTOR

The requirements of this subclause shall be satisfied to maintain safety in case of damage to or disconnection of the PROTECTIVE EARTHING CONDUCTOR.

For plug-connected single phase PDS/CDM/BDM, not using an industrial connector according to IEC 60309, the TOUCH CURRENT (measured in accordance with [5.2.3.5](#)) shall not exceed 3,5 mA a.c. or 10 mA d.c.

For all other PDS/CDM/BDM, one or more of the following measures shall be applied, unless the TOUCH CURRENT (measured in accordance with [5.2.3.5](#)) can be shown to be less than 3,5 mA a.c. or 10 mA d.c.

a) A fixed connection and:

- a cross-section of the PROTECTIVE EARTHING CONDUCTOR of at least 10 mm² Cu or 16 mm² Al,
- or
- automatic disconnection of the supply in case of discontinuity of the PROTECTIVE EARTHING CONDUCTOR;
- or
- provision of an additional terminal for a second PROTECTIVE EARTHING CONDUCTOR of the same cross-sectional area as the original PROTECTIVE EARTHING CONDUCTOR,

b) connection with an industrial connector according to IEC 60309 and a minimum PROTECTIVE EARTHING CONDUCTOR cross-section of 2,5 mm² as part of a multi-conductor power cable. Adequate strain relief shall be provided.

For marking requirements, see [6.3.6.7](#).

4.3.5.5.2DV D2 Modification by replacing 4.3.5.5.2 with the following:

For all cord-connected portable and stationary equipment, rated for a nominal 120-, 208, or 240-V supply, employing a standard grounded, 3-wire attachment plug rated 20 A or less, the maximum permitted LEAKAGE CURRENT is 3,5 mA, measured in accordance with [5.2.3.5DV](#).

4.3.5.6 Special features in equipment for PROTECTIVE CLASS II

If equipment is designed to use DOUBLE or REINFORCED INSULATION between LIVE PARTS and accessible surfaces in accordance with [4.3.3.2](#), then the design is considered to meet PROTECTIVE CLASS II, if the following also apply.

- Equipment designed to PROTECTIVE CLASS II shall not have means of connection for the PROTECTIVE EARTHING CONDUCTOR. However this does not apply if a PROTECTIVE EARTHING CONDUCTOR is passed through the equipment to equipment series-connected beyond it. In the latter event, the PROTECTIVE EARTHING CONDUCTOR and its means for connection shall be insulated with BASIC INSULATION from the accessible surface of the equipment and from circuits which employ PROTECTIVE SEPARATION, extra-low voltage, PROTECTIVE IMPEDANCE and limited discharging energy, according to [4.3.4](#). This BASIC INSULATION shall correspond to the rated voltage of the series-connected equipment.
- Metal-encased equipment of PROTECTIVE CLASS II may have provision on its enclosure for the connection of an equipotential bonding conductor.
- Equipment of PROTECTIVE CLASS II may have provision for the connection of an earthing conductor for functional reasons or for the damping of overvoltages; it shall, however, be insulated as though it is a LIVE PART.
- Equipment of PROTECTIVE CLASS II shall be marked according to [6.3.6.6](#).

4.3.5.6DV DR Deletion:

The use of class II methods are not applicable. (National Electrical Code, ANSI/NFPA 70 Article 250.112).

4.3.6 Insulation

4.3.6.1 General

4.3.6.1.1 Influencing factors

This subclause gives minimum requirements for insulation, based on the principles of IEC 60664 and IEC 60071.

Manufacturing tolerances shall be taken into account during design and installation of the PDS.

For INTEGRATED PDS the motor insulation system shall meet the requirements of the relevant part of IEC 60034. The CDM/BDM shall comply with the requirements of [4.3.6](#).

Insulation shall be selected after consideration of the following influences:

- pollution degree;
- overvoltage category;
- supply earthing system;
- insulation voltage;
- location of insulation;
- type of insulation;

Verification of insulation shall be made according to [5.2.2.1](#), [5.2.3.1](#), [5.2.3.2](#), and [5.2.3.3](#).

4.3.6.1.1DV D2 Modification:

The motor insulation system shall meet the requirements of the UL 1004 series of standards.

4.3.6.1.2 Pollution degree

Insulation, especially when provided by clearances and creepage distances, is affected by pollution which occurs during the EXPECTED LIFETIME of the PDS. The micro-environmental conditions for insulation shall be applied according to [Table 6](#).

Table 6
Definitions of pollution degrees

Pollution degree	Description
1	No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
2	Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation is to be expected, when the PDS is out of operation.

Table 6 Continued on Next Page

Table 6 Continued

Pollution degree	Description
3	Conductive pollution or dry non-conductive pollution occurs, which becomes conductive due to condensation, which is to be expected.
4	The pollution generates persistent conductivity caused, for example by conductive dust or rain or snow.

In accordance with IEC 61800-1, IEC 61800-2 and IEC 61800-4, a standard PDS shall be designed for pollution degree 2. For safety, pollution degree 3 shall be assumed in determining the insulation. Thereby the PDS is usable for pollution degree 1, 2 and 3 environments.

The insulation may be determined according to pollution degree 2 if one of the following applies:

a) instructions are provided with the PDS indicating that it shall be installed in a pollution degree 2 environment,

or

b) the specific installation application of the PDS is known to be a pollution degree 2 environment,

or

c) the PDS enclosure or coatings applied within the PDS according to [4.3.6.8.4.2](#) or [4.3.6.8.6](#) provide adequate protection against what is expected in pollution degree 3 and 4 (conductive pollution and condensation).

If operation in pollution degree 4 is required, protection shall be provided by means of a suitable enclosure.

4.3.6.1.2DV.1 D2 Modification:

Item b) is not applicable.

4.3.6.1.2DV.2 D2 Modification to add the following:

Pollution degree 1 is obtainable by the encapsulation or hermetic sealing of the product. Typical constructions that meet this requirement are:

a) The use of conformal coating on printed wiring board foil traces that complies with the requirements for Conformal Coatings in the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C;

b) The use of any potting material or encapsulation, such as epoxy;

c) The use of silicone rubber at a thickness of at least 1/32 in (0,8 mm);

d) The use of a case or enclosure that is hermetically sealed against the entrance of an external atmosphere by means of fusion – such as from soldering, brazing, welding, or the fusion of glass to metal.

4.3.6.1.2DV.3 D2 Modification to add the following:

Pollution degree 2 is obtainable by reducing possibilities of conductive pollution and reducing possibilities of condensation or high humidity at the creepage distances:

a) Typical constructions that reduce the possibility of conductive pollution are:

- 1) The use of an un-ventilated enclosure; or
- 2) The use of a ventilated enclosure when all ventilation openings are filtered.

b) Typical constructions that reduce the effects of condensation or high humidity are:

- 1) The use of a ventilated enclosure;
- 2) The continuous application of heat through the use of heaters;
- 3) The application of heat through continuous energization of the equipment, with interruptions such that cooling to the point of condensation does not occur; or
- 4) The use of any coatings, such as solder masking, on printed wiring board foil traces.

4.3.6.1.3 Overvoltage category

The concept of overvoltage categories (based on IEC 60364-4-44 and IEC 60664-1) is used for equipment energized from the supply mains. Four categories are considered:

- category IV applies to equipment permanently connected at the origin of an INSTALLATION (upstream of the main distribution board). Examples are electricity meters, primary overcurrent protection equipment and other equipment connected directly to outdoor open lines;
- category III applies to equipment permanently connected in fixed INSTALLATIONS (downstream of, and including, the main distribution board). Examples are switchgear and other equipment in an industrial INSTALLATION;
- category II applies to equipment not permanently connected to the fixed INSTALLATION. Examples are appliances, portable tools and other plug-connected equipment;
- category I applies to equipment connected to a circuit where measures have been taken to reduce transient overvoltages to a low level.

Annex B shows examples of overvoltage category considerations for insulation requirements.

NOTE For PDS not intended to be powered from the supply mains, the appropriate overvoltage category should be determined as required by the application.

4.3.6.1.3DV D2 D2 Modification to add the following:

PDS shall be evaluated at least as Overvoltage Category III.

4.3.6.1.4 Supply earthing systems

IEC 60364-1 describes the three following basic types of earthing system.

- TN system: has one point directly earthed, the accessible conductive parts of the INSTALLATION being connected to that point by protective conductors. Three types of TN system, TN-C, TN-S and TN-C-S, are defined according to the arrangement of the neutral and protective conductors. A corner-earthed system is a TN system with one phase earthed.
- TT system: has one point directly earthed, the accessible conductive parts of the INSTALLATION being connected to earth electrodes electrically independent of the earth electrodes of the power system. A corner-earthed system is a TT system with one phase earthed.
- IT system: has all LIVE PARTS isolated from earth or one point connected to earth through an impedance, the accessible conductive parts of the INSTALLATION being earthed independently or collectively to the earthing system.

In a PDS designed for operation on a corner-earthed system, the

- insulation between phases of the mains supply, including the earthed phase, may be designed for functional insulation according to clause [4.3.6.3](#), and
- circuits within the PDS/CDM/BDM directly connected to any phase of a corner-earthed system shall be separated from earthed parts by at least basic insulation.

4.3.6.1.4DV DR *Modification:*

4.3.6.1.4DV.1 The use of a TT system is not applicable.

4.3.6.1.4DV.2 PDS/CDM/BDM intended for connection to TN corner earthed systems shall be investigated for a STRAIGHT VOLTAGE RATING according to [6.2DV.2.1.5\(a\)](#).

4.3.6.1.4DV.3 PDS/CDM/BDM intended for connection only to TN non-corner earthed systems, TN high-leg delta earthed systems, or IT systems shall be investigated for a SLASH VOLTAGE RATING according to [6.2DV.2.1.5\(b\)](#).

4.3.6.1.5 Insulation voltages

[Table 7](#) and [Table 8](#) use the SYSTEM VOLTAGE of the circuit under consideration and overvoltage category to define the impulse voltage. The SYSTEM VOLTAGE is also used to define the TEMPORARY OVERVOLTAGE.

**Table 7
Insulation voltage for low voltage circuits**

Column 1	2	3	4	5	6
SYSTEM VOLTAGE (4.3.6.2.1) (V)	Impulse voltage (V)				TEMPORARY OVERVOLTAGE (crest value / r.m.s.) ^a (V)
	Overvoltage category				
	I	II	III	IV	
≤ 50	330	500	800	1 500	1 770 / 1 250
100	500	800	1 500	2 500	1 840 / 1 300
150	800	1 500	2 500	4 000	1 910 / 1 350
300	1 500	2 500	4 000	6 000	2 120 / 1 500
600	2 500	4 000	6 000	8 000	2 550 / 1 800
1 000	4 000	6 000	8 000	12 000	3 110 / 2 200
Interpolation of SYSTEM VOLTAGE is not permitted when determining the impulse voltage for mains supply. Interpolation of SYSTEM VOLTAGE is permitted when determining the TEMPORARY OVERVOLTAGE for mains supply.					
NOTE The last row only applies to single-phase systems, or to the phase-to-phase voltage in threephase systems.					
SOURCE: IEC 62477-1:2012, Table 9					
^a These values are derived using the formula (1 200 V + SYSTEM VOLTAGE) from IEC 60664-1.					

**Table 8
Insulation voltage for high voltage circuits**

Column 1	2	3	4	5	6
SYSTEM VOLTAGE (4.3.6.2.1) (V)	Impulse voltage (V)				TEMPORARY OVERVOLTAGE (crest value / r.m.s.) (V)
	Overvoltage Category				
	I	II	III	IV	
> 1 000	4 000	6 000	8 000	12 000	4 250 / 3 000
3 600	9 000 ^a	16 000 ^a	20 000 ^b	40 000 ^b	14 150 / 10 000 ^b
7 200	17 500 ^a	29 000 ^a	40 000 ^b	60 000 ^b	28 300 / 20 000 ^b
12 000	29 000 ^a	42 500 ^a	60 000 ^b	75 000 ^b	39 600 / 28 000 ^b
17 500	40 000 ^a	55 000 ^a	75 000 ^b	95 000 ^b	53 750 / 38 000 ^b
24 000	52 000 ^a	75 000 ^a	95 000 ^b	125 000 ^b	70 700 / 50 000 ^b
36 000	75 000 ^a	95 000 ^a	125 000 ^b	145 000 ^b	99 000 / 70 000 ^b
NOTE 1 Interpolation is permitted.					
^a These values have been derived or extrapolated from Tables 4 and 5 of IEC 62103: 2003.					
^b These values have been derived or extrapolated from Table 2 of IEC 60071-1:2006.					
^c This value has been taken from IEC 60146-1-1, Ed. 4 (in preparation).					

4.3.6.2 Insulation to the surroundings

4.3.6.2.1 General

Insulation for BASIC, SUPPLEMENTARY, and REINFORCED INSULATION between a circuit and its surroundings shall be designed according to:

- the impulse voltage,

or

- the TEMPORARY OVERVOLTAGE,

or

- the WORKING VOLTAGE of the circuit.

NOTE 1 For creepage distances, the r.m.s. value of the WORKING VOLTAGE is used. For clearance distances and solid insulation, the recurring peak value of the WORKING VOLTAGE is used, as described in [4.3.6.2.2](#) to [4.3.6.2.4](#).

NOTE 2 Examples of WORKING VOLTAGE with the combination of a.c., d.c. and recurring peaks are on the d.c. link of an indirect voltage source converter, or the damped oscillation of a thyristor snubber, or internal voltages of a switch-mode power supply.

The impulse voltage and TEMPORARY OVERVOLTAGE depend on the SYSTEM VOLTAGE of the circuit, and the impulse voltage also depends on the overvoltage category, as shown in [Table 7](#) (for LOW-VOLTAGE PDS) and [Table 8](#) (for HIGH-VOLTAGE PDS).

The SYSTEM VOLTAGE in column 1 of these tables is:

- For [Table 7](#)

- in TN and TT systems: the r.m.s. value of the rated voltage between a phase and earth;

NOTE A corner-earthed system is a TN system with one phase earthed, in which the SYSTEM VOLTAGE is the r.m.s. value of the rated voltage between a non-earthed phase and earth (i.e. the phase-phase voltage).

- in three-phase IT systems:

- for determination of impulse voltage, the r.m.s. value of the rated voltage between a phase and an artificial neutral point (an imaginary junction of equal impedances from each phase);

NOTE For most systems, this is equivalent to dividing the phase-to-phase voltage by $\sqrt{3}$.

- for determination of TEMPORARY OVERVOLTAGE, the r.m.s. value of the rated voltage between phases;

- in single-phase IT systems: the r.m.s. value of the rated voltage between phases.

- For [Table 8](#): the r.m.s. value of the rated voltage between phases.

NOTE 3 For both tables, when the supply voltage is rectified a.c., the SYSTEM VOLTAGE is the r.m.s. value of the source a.c. before rectification, taking into account the supply earthing system.

NOTE 4 Voltages generated within the PDS by the secondaries of transformers providing galvanic isolation from the supply mains are also considered to be SYSTEM VOLTAGES for the determination of impulse voltages.

NOTE 5 For PDS having series-connected diode bridges (12-pulse, 18-pulse, etc.), the SYSTEM VOLTAGE is the sum of the a.c. voltages at the diode bridges.

4.3.6.2.1DV D2 Modification:

4.3.6.2.1DV.1 For evaluating the clearances and creepage distances between uninsulated LIVE PARTS and the surface on which the equipment is mounted, the mounting surface is evaluated as part of an enclosure, unless any deformation of the enclosure will not reduce the clearances and creepage distances between the mounting surface and any uninsulated LIVE PART.

4.3.6.2.1DV.2 The system voltage for [Table 7](#) and [Table 8](#) shall be according to the higher value given by the following:

- a) The largest RATED VOLTAGE for equipment rated in accordance with [6.2DV.2.1.5\(a\)](#); and
- b) The largest lower RATED VOLTAGE for equipment rated in accordance with [6.2DV.2.1.5\(b\)](#).

4.3.6.2.1DV.3 For BDM/CDM/PDS intended to receive power partially or fully from photovoltaic (PV) modules and panels, the system voltage of [Table 7](#) shall be the larger of the mains voltage or the PV open-circuit line to ground voltage at the PV power input of the BCM/CDM/PDS.

4.3.6.2.2 Circuits connected directly to the supply mains

Insulation between the surroundings and circuits which are connected directly to the supply mains shall be designed according to the impulse voltage, TEMPORARY OVERVOLTAGE, or WORKING VOLTAGE, whichever gives the most severe requirement.

This insulation is normally evaluated to withstand impulses of overvoltage category III, except that overvoltage category IV shall be used when the PDS is connected at the origin of the INSTALLATION. Overvoltage category II may be used for plug-in equipment connected to a supply for non-industrial purposes without special requirements with regard to reliability.

If measures are provided which reduce impulses of overvoltage category IV to values of category III, or values of category III to values of category II, BASIC or SUPPLEMENTARY INSULATION may be designed for the reduced values. If the devices used for this purpose can be damaged by overvoltages or repeated impulses, thus decreasing their ability to reduce impulses, they shall be monitored and an indication of their status provided. For low-voltage applications, IEC 61643-12 provides information on the selection and use of such devices.

The requirements for DOUBLE or REINFORCED INSULATION shall not be reduced when measures to reduce impulses are provided.

NOTE Circuits which are connected to the supply mains via PROTECTIVE IMPEDANCES, according to [4.3.4.3](#), or via means of voltage limitation, according to [4.3.4.4](#), are not regarded as connected directly to the supply mains.

4.3.6.2.2DV D2 Modification to add the following:

PDS shall be evaluated at least as Overvoltage Category III.

4.3.6.2.3 Circuits not connected directly to the supply mains

Insulation between the surroundings and circuits supplied by a transformer providing galvanic isolation from the supply mains shall be designed according to: a) the impulse voltage determined using the transformer secondary voltage as the SYSTEM VOLTAGE; or b) the WORKING VOLTAGE, whichever gives the more severe requirement.

This insulation is normally evaluated to withstand impulses of overvoltage category II, except that overvoltage category III shall be used when the PDS is connected at the origin of the INSTALLATION.

If measures are provided which reduce impulses of overvoltage category III to values of category II, or, for LOW-VOLTAGE PDS only, values of category II to values of category I, BASIC or SUPPLEMENTARY INSULATION may be designed for the reduced value. If the devices used for this purpose can be damaged by overvoltages or repeated impulses, thus decreasing their ability to reduce impulses, they shall be monitored and an indication of their status provided. For low-voltage applications, IEC 61643-12 provides information on the selection and use of such devices.

The requirements for DOUBLE or REINFORCED INSULATION shall not be reduced when measures to reduce impulses are provided.

Insulation between the surroundings and circuits of DVC A or B, supplied by a transformer at a frequency other than that of the supply mains, or supplied by other means providing galvanic isolation from the supply mains, shall be evaluated according to the WORKING VOLTAGE (recurring peak) of the circuit.

4.3.6.2.4 Insulation between circuits

Insulation between two circuits shall be designed according to the circuit having the more severe requirement.

4.3.6.2.4DV.1 DR Modification to add the following.

Conductors of different circuits must be separated, unless all conductors have an insulation rating equal to at least the maximum voltage of any of the circuits. See also [DVC.1.1.3](#).

4.3.6.2.4DV.2 DR Modification to add the following:

4.3.6.2.4DV.2.1 Class 1, Class 2, and Class 3 remote-control, signaling, and power-limited circuits

4.3.6.2.4DV.2.1.1 In the field-wiring area, provisions for wiring for Class 2 and Class 3 circuits must meet the requirements for separation from Class 1 circuits in accordance with Section 725 of the National Electrical Code, ANSI/NFPA 70. See also [DVC.1.1.3](#).

4.3.6.3 FUNCTIONAL INSULATION

For parts or circuits that are not significantly affected by external transients, FUNCTIONAL INSULATION shall be designed according to the WORKING VOLTAGE across the insulation.

For parts or circuits that are significantly affected by external transients, FUNCTIONAL INSULATION shall be designed according to the impulse voltage of overvoltage category II, except that overvoltage category III shall be used when the PDS is connected at the origin of the INSTALLATION.

Where measures are provided which reduce transient overvoltages within the circuit from category III to values of category II, or values of category II to values of category I, FUNCTIONAL INSULATION may be designed for the reduced values.

Where the circuit characteristics can be shown by testing (see [5.2.3.1](#)) to reduce impulse voltages, FUNCTIONAL INSULATION may be designed for the highest impulse voltage occurring in the circuit during the tests.

4.3.6.3DV DE *Modification for clarification:*

Where the circuit analysis required by [4.2](#) shows that failure of the FUNCTIONAL INSULATION could result in a hazard, the FUNCTIONAL INSULATION shall meet the requirements and tests for BASIC INSULATION. See [4.3.6.8.2.3](#) for additional information.

4.3.6.4 Clearance distances

4.3.6.4DV.1 D1 *Modification to add the following:*

4.3.6.4DV.1.1 Measurement considerations

4.3.6.4DV.1.1.1 Clearance distances at field wiring terminals shall comply with the requirements in Annex [DVF](#), unless the design of the field wiring terminals precludes the possibility of reduced clearances due to stray strands or improper wiring INSTALLATION, in which case the requirements of the remainder of this clause are applicable.

4.3.6.4DV.1.1.2 The clearance distances at fuses and fuseholders are to be measured with the fuses having maximum standard dimensions in place, and shall be at least the spacings specified for the clearance and creepage distances to comply with [Table 9](#) and [Table 10](#).

4.3.6.4DV.1.1.3 For an enclosure without conduit openings or knockouts, spacings not less than the minimum specified in Annex [DVF](#) shall be provided between uninsulated LIVE PARTS and a conduit bushing installed at any location to be used during INSTALLATION. A permanent marking on the enclosure, a template, or a full-scale drawing furnished with the equipment is usable to identify such locations.

4.3.6.4DV.1.1.4 For the spacing between an uninsulated LIVE PART and a bushing installed in a knockout, it is to be assumed that a bushing having the dimensions specified in [Table 4.3.6.4DV.1](#) is in place, in conjunction with a single locknut installed on the outside of the enclosure.

Table 4.3.6.4DV.1
Dimensions of Bushings

Trade size of conduit, in	Bushing dimensions, in (mm)			
	Maximum overall diameter		Height	
1/2	1	(25,4)	3/8	(9,5)
3/4	1-15/64	(31,4)	27/64	(10,7)
1	1-19/32	(40,5)	33/64	(13,1)
1-1/4	1-15/16	(49,2)	9/16	(14,3)
1-1/2	2-13/64	(56,0)	19/32	(15,1)
2	2-45/64	(68,7)	5/8	(15,9)
2-1/2	3-7/32	(81,8)	3/4	(19,1)
3	3-7/8	(98,4)	13/16	(20,6)
3-1/2	4-7/16	(113)	15/16	(23,8)
4	4-31/32	(126)	1	(25,4)
5	6-7/32	(158)	1-3/16	(30,2)
6	7-7/32	(183)	1-1/4	(31,8)