UL 61800-5-1

STANDARD FOR SAFETY

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

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

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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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.

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.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

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5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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 categoruies 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.

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

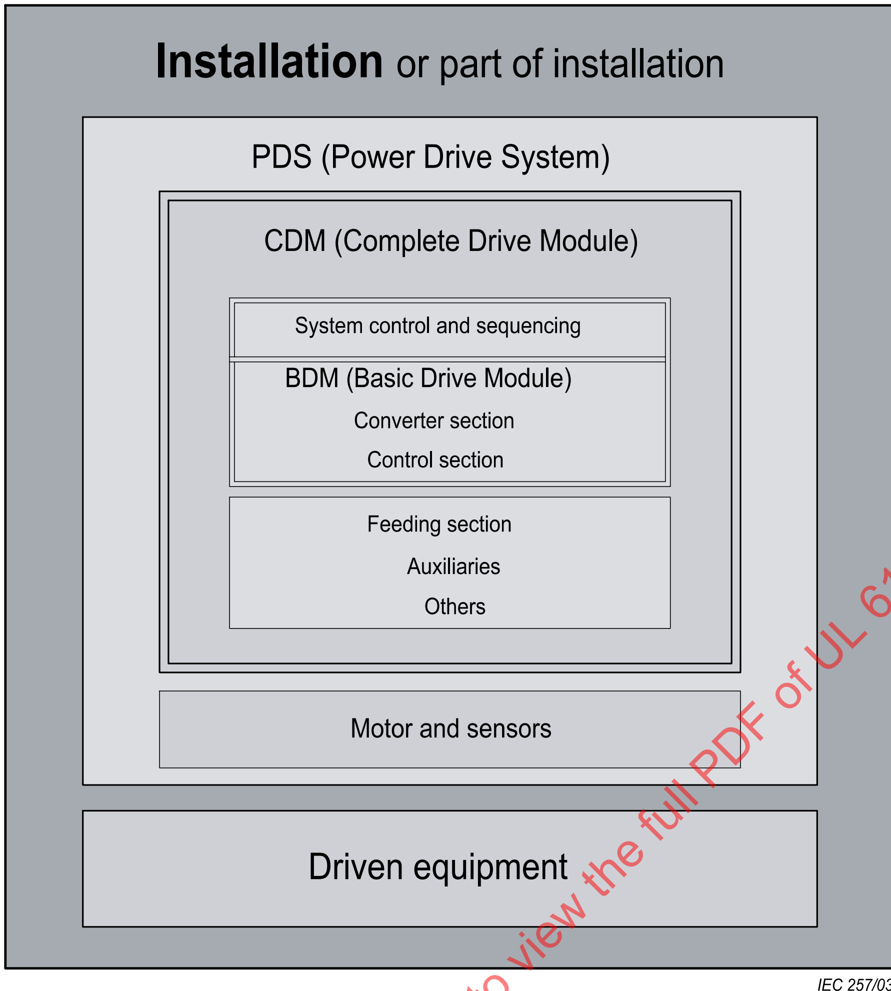

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Figure 1

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.) U_{ACL}	a.c. voltage (peak) U_{ACPL}	d.c. voltage (mean) 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 × √2 × 1 000 V = 4 242 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.

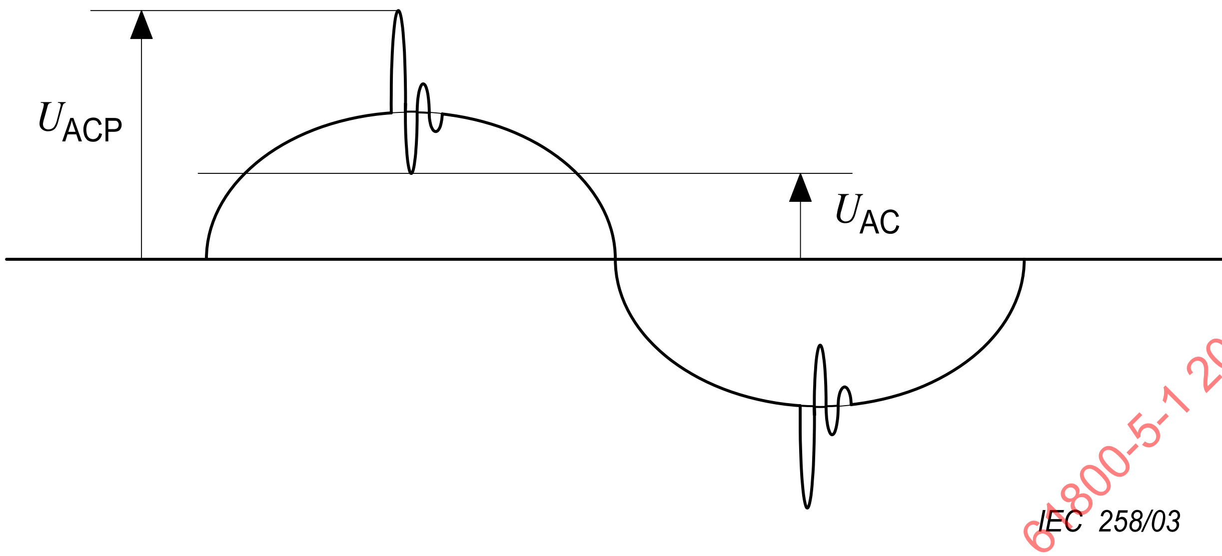
‡ It is permitted to use BASIC INSULATION for the circuit of higher voltage if protection against direct contact is applied to the considered circuit by BASIC or SUPPLEMENTARY INSULATION for the circuit of higher voltage.

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)



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Key

U_{AC} r.m.s. voltage

U_{ACP} recurring peak voltage

Figure 2

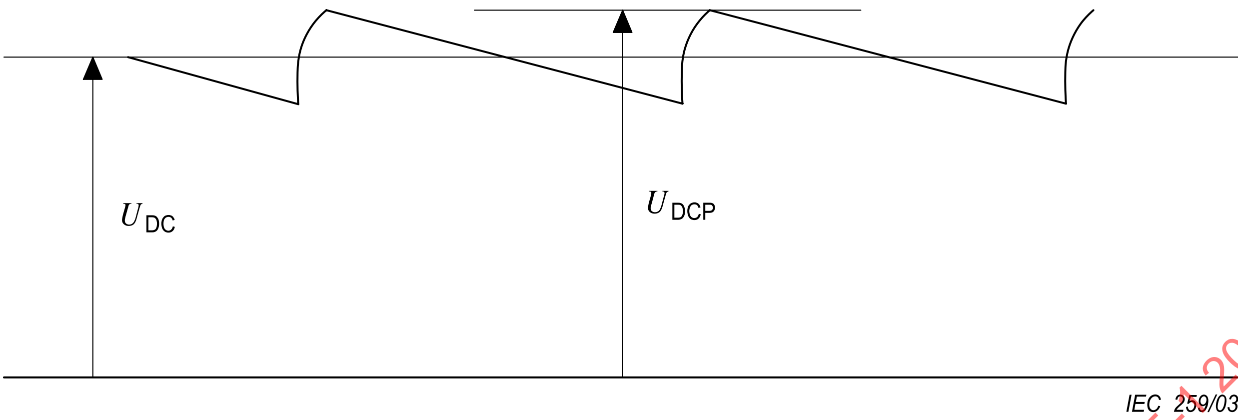
Typical waveform for a.c. WORKING VOLTAGE

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)



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Key

U_{DC} mean voltage

U_{DCP} recurring peak voltage

Figure 3

Typical waveform for d.c. WORKING VOLTAGE

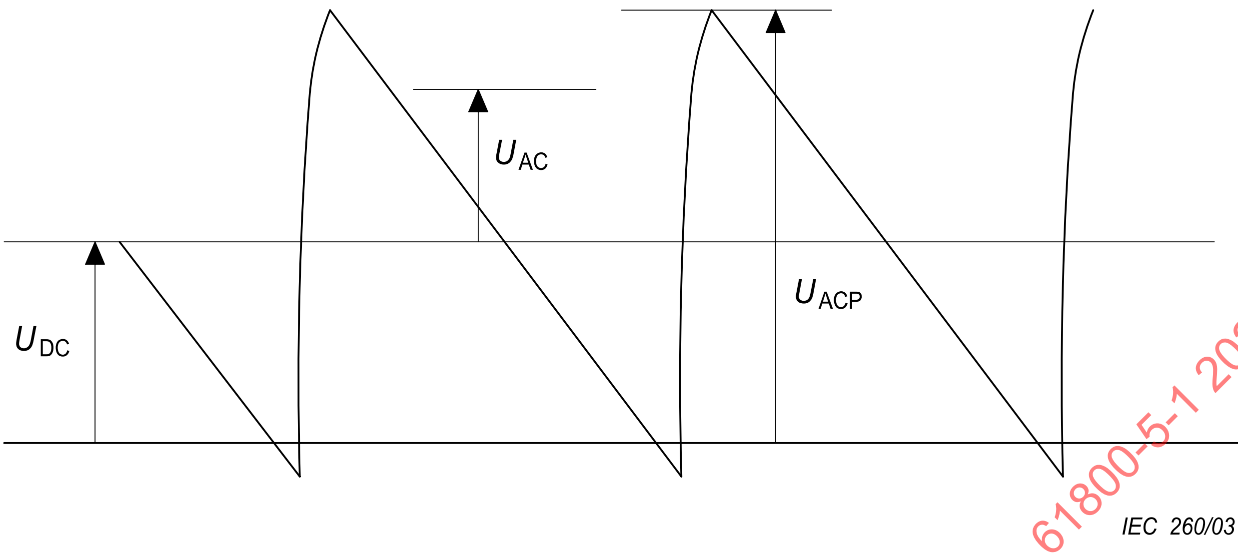
The WORKING VOLTAGE has a mean value U_{DC} and a recurring peak value U_{DCP}, caused by a ripple voltage of r.m.s. value not greater than 10 % of U_{DC}.

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)



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.

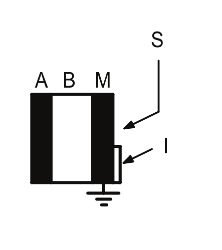
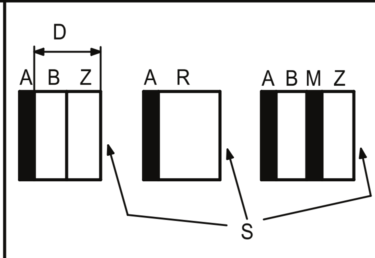
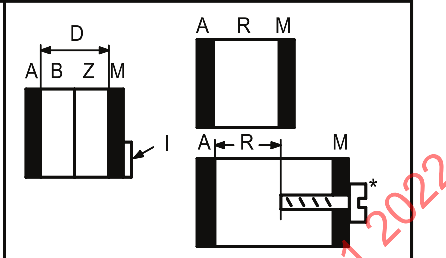
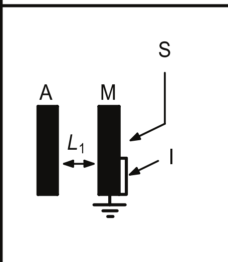
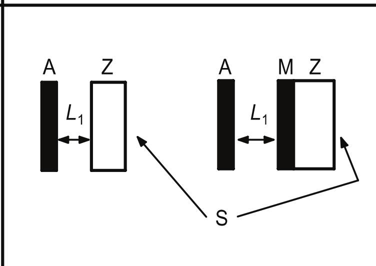
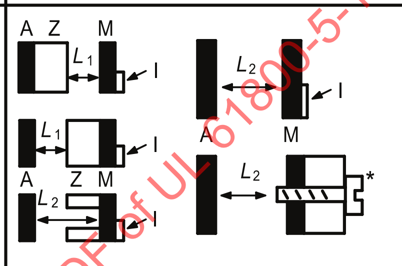
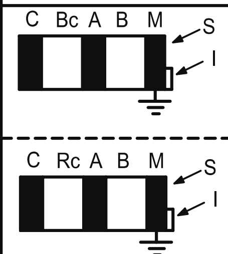
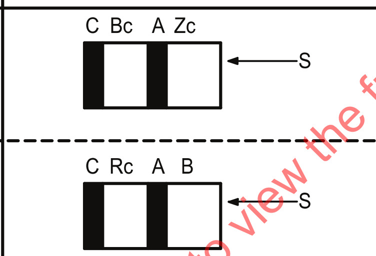
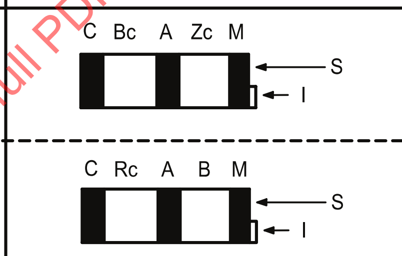
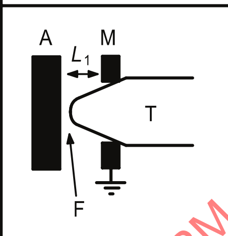
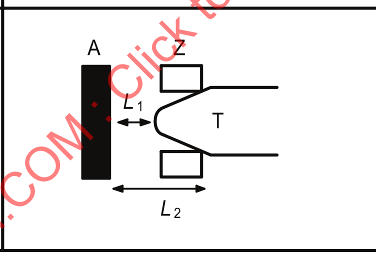
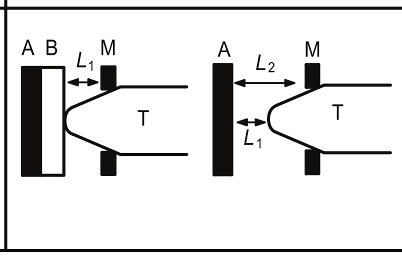
The grade of insulation – BASIC, DOUBLE or REINFORCED – depends on:

• 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 *protective bonding*	b Accessible parts not conductive	c Accessible parts conductive, but NOT connected to earth by *protective bonding*
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 *live part*	L_1 clearance for *basic insulation*	T test finger (Clause 12 of IEC 60529)
B *basic insulation* for circuit A	L_2 clearance for *reinforced insulation*	Z *supplementary insulation* for circuit A
Bc *basic insulation* for circuit C	M conductive part	Zc *supplementary insulation* for circuit C
C *adjacent circuit*	R *reinforced insulation* for circuit A	* also applies to plastic screws
D *double insulation* for circuit A	Rc *reinforced insulation* for circuit C	F *functional insulation* for circuit A
I insulation less than B	S surface of equipment	

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.

su0577a IEC 1198/07

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

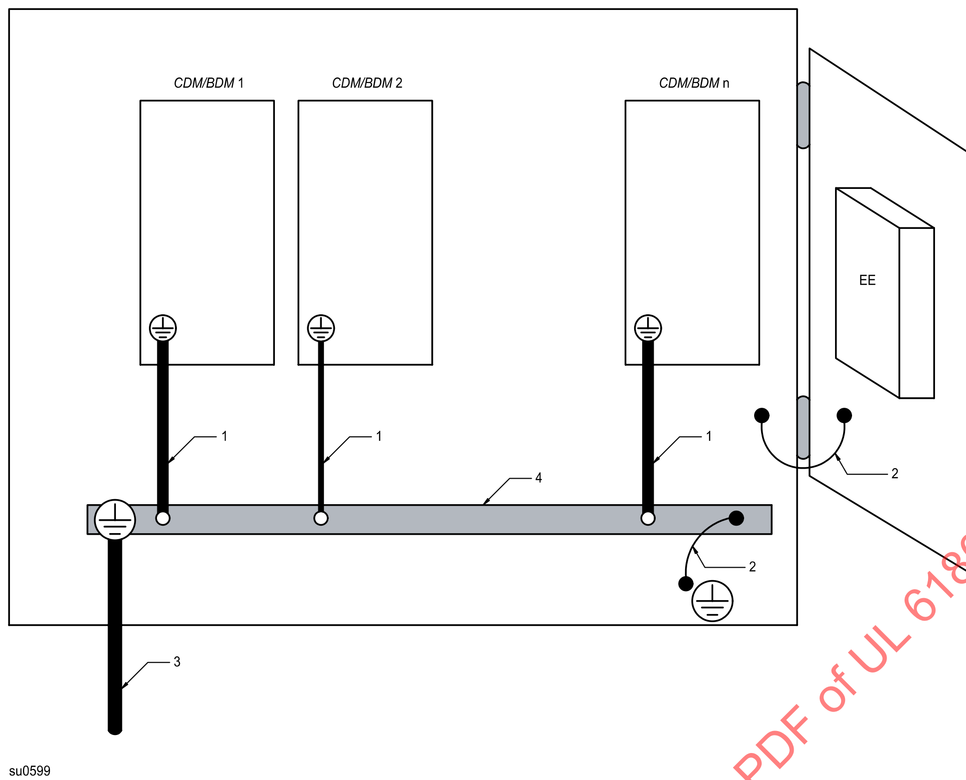
Other than in a) or b) below, PROTECTIVE BONDING shall be provided between accessible conductive parts of equipment and the means of connection for the PROTECTIVE EARTHING CONDUCTOR:

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.



1 CDM/BDMPROTECTIVE 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

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			
hp	(kW output)	V	Circuit capacity, A
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.

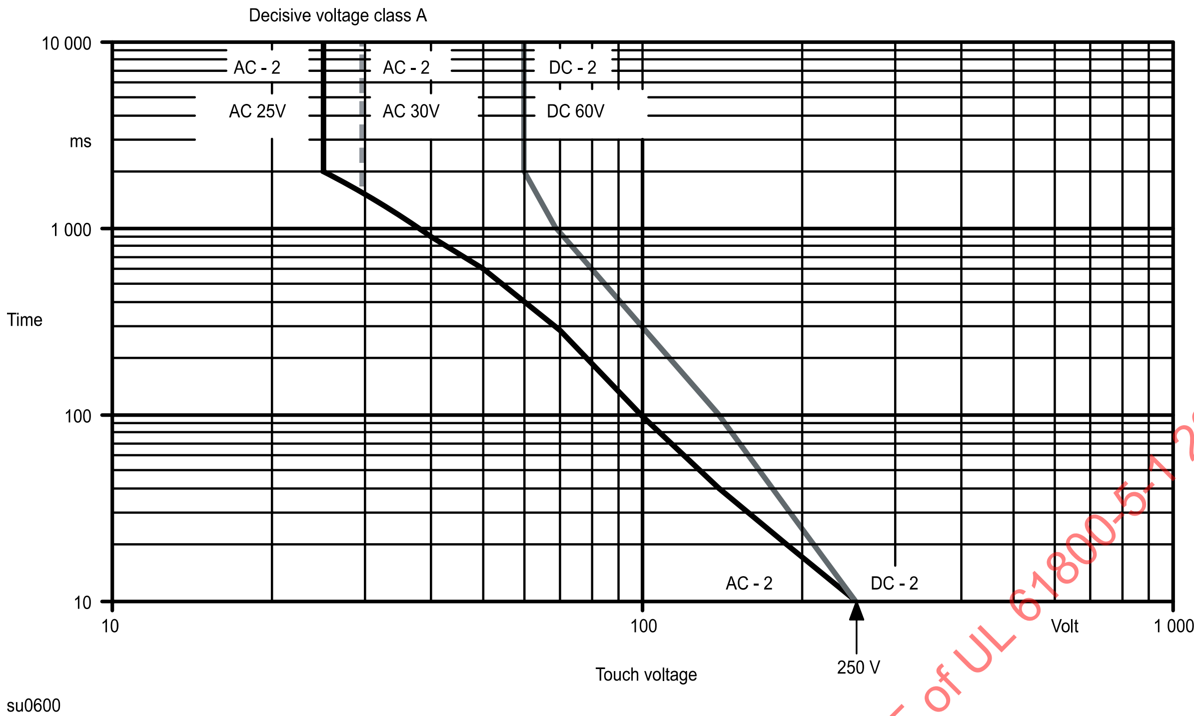
4.3.5.3.3 PROTECTIVE BONDING impedance

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.



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* (mm²)	Minimum cross-sectional area of the corresponding PROTECTIVE EARTHING CONDUCTOR S_p (mm²)
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 mm^2 if mechanical protection is provided,

or

• 4 mm^2 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 mm^2 Cu or 16 mm^2 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 mm^2 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) Overvoltage category**				**TEMPORARY OVERVOLTAGE (crest value / r.m.s.) [a] (V)**
	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) Overvoltage Category**				**TEMPORARY OVERVOLTAGE (crest value / r.m.s.) (V)**
	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 √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)

4.3.6.4DV.1.1.5 For Clamped insulating joints, clearance and creepage distances shall be measured through cracks illustrated in Figure C.1DV.1 unless the clamped joint complies with the test requirements in 5.2.13DV and complies with the additional requirements in C.1DV.

4.3.6.4DV.2 D1 *Modification to add the following:*

4.3.6.4DV.2.1 Feeder circuits

4.3.6.4DV.2.1.1 Equipment rated 600 V or less and intended for INSTALLATION in a feeder circuit, on the line side of branch circuit protective devices, shall comply with Table 4.3.6.4DV.2.

Table 4.3.6.4DV.2
Equipment Intended for INSTALLATION in a Feeder Circuit

Voltage between parts involved	Minimum clearances and creepage distances in inches (mm)							
	Between uninsulated parts of opposite polarity on line side				Between uninsulated parts on line side and any grounded dead metal			
	Creepage distance		Clearance		Creepage distance		Clearance	
0 – 125	3/4	(19,1)	1/2	(12,7)	1/2	(12,7)	1/2	(12,7)
126 – 250	1-1/4	(31,8)	3/4	(19,1)	1/2	(12,7)	1/2	(12,7)
251 – 600	2	(50,8)	1	(25,4)	1	(25,4)	1	(25,4)

4.3.6.4.1 Determination

Table 9 defines the minimum clearance distances required to provide FUNCTIONAL, BASIC, or SUPPLEMENTARY INSULATION (see Annex C for examples of clearance distances).

Clearances for use in altitudes between 2 000 m and 20 000 m shall be calculated with a correction factor according to Table A.2 of IEC 60664-1, which is reproduced as Clearances in air are a function of the atmospheric pressure according to Paschen's Law. Clearance distances provided in Table 9 are valid up to 2000 m above sea level. Clearances above 2000 m must be multiplied by the factor provided in Table D.1.

To determine clearances for REINFORCED INSULATION from Table 9:

• for LOW-VOLTAGE PDS, the value corresponding to the next higher impulse voltage, or 1,6 times the TEMPORARY OVERVOLTAGE, or 1,6 times the WORKING VOLTAGE shall be used (see IEC 60664-1:2007, 5.1.6 and IEC 62477-1: 2012, 4.4.7.4.1);

• for HIGH-VOLTAGE PDS, the value corresponding to 1,6 times the impulse voltage, TEMPORARY OVERVOLTAGE or WORKING VOLTAGE shall be used.

Clearances for REINFORCED INSULATION between circuits connected directly to the supply mains and other circuits shall not be reduced when measures to reduce transient overvoltages are provided.

The compliance of clearances shall be verified by visual inspection (see 5.2.2.1) and if necessary by performing the impulse voltage test of 5.2.3.1 and the a.c. or d.c voltage test of 5.2.3.2.

Figure E.1 and Table E.1 provide informative guidance for determination of clearances for frequencies above 30 kHz.

Table 9
Clearance distances

Column 1	2	3	4	5	6
Impulse voltage (Table 7, Table 8, 4.3.6.3)	**TEMPORARY OVERVOLTAGE (crest value) for determining insulation between surroundings and circuits or WORKING VOLTAGE (recurring peak) for determining FUNCTIONAL INSULATION**	**WORKING VOLTAGE (recurring peak) for determining insulation between surroundings and circuits**	**Minimum clearance mm**		
			Pollution degree		
(V)	**(V)**	**(V)**	**1**	**2**	**3**
N/A	≤ 110	≤ 71	0,01	0,20[a]	0,80
N/A	225	141	0,01	0,20	0,80
330	340	212	0,01	0,20	0,80
500	530	330	0,04	0,20	0,80
800	700	440	0,10	0,20	0,80
1 500	960	600	0,50	0,50	0,80
2 500	1 600	1 000	1,5		
4 000	2 600	1 600	3,0		
6 000	3 700	2 300	5,5		
8 000	4 800	3 000	8,0		
12 000	7 400	4 600	14		
20 000	12 000	7 600	25		
40 000	26 000	16 000	60		
60 000	37 000	23 000	90		
75 000	48 000	30 000	120		
95 000	61 000	38 000	160		
125 000	80 000	50 000	220		
145 000	99 000	60 000	270		

NOTE 1 Interpolation is permitted.

NOTE 2 Examples of clearance distances are given in Annex C.

NOTE 3 Clearances for TEMPORARY OVERVOLTAGE and WORKING VOLTAGE have been derived from Table A.1 of IEC 60664-1. In column 2, the voltage is approximately 80 % of the withstand voltage; in column 3, the voltage is approximately 50 % of the withstand voltage.

[a] 0,1 mm on PWB

4.3.6.4.1DV.1 DE *Modification to add the following informative note:*

Use of Table 9 for determination of required clearances from mains connected circuits to earth is as follows:

- **Determine impulse voltage from Table 7 for the circuit based on the SYSTEM VOLTAGE and appropriate overvoltage category**

• Enter Table 9 column 1 with the impulse voltage value determined above

• Verify that voltages in the circuit do not exceed the values indicated in columns 2 and 3

• If either of the values in columns 2 and 3 are exceeded then the appropriate row for the higher value shall be used for determining the minimum clearance

• If the values in columns 2 and 3 are not exceeded then the row for the impulse voltage shall be used for determining the minimum clearance based on the pollution degree in columns 4, 5 and 6

For columns 2 and 3, see the definition of WORKING VOLTAGE in 3.43.

4.3.6.4.1DV.2 D2 *Modification to add the following:*

4.3.6.4.1DV.2.1 Special coatings

4.3.6.4.1DV.2.1.1 Spacings required to be greater than 1/32 in (0,8 mm) may be reduced to 1/32 in (0,8 mm) on a printed wiring board when the printed wiring board spacings are:

a) Covered by a layer of silicone rubber at least a 1/32 in (0,8 mm) thick; or

b) Encapsulated by epoxy or potting material, without air bubbles. The silicone rubber and the potting material, when used, shall comply with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, or the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, or the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

4.3.6.4.2 Electric field homogeneity

The dimensions in Table 9 correspond to the requirements of an inhomogeneous electric field distribution across the clearance, which are the conditions normally experienced in practice. If a homogeneous electric field distribution is known to exist, and the impulse voltage is equal to or greater than 6 000 V for a circuit connected directly to the supply mains or 4 000 V within a circuit, the clearance for BASIC or SUPPLEMENTARY INSULATION may be reduced to not less than that required by Table 2 Case B of IEC 60664-1. In this case, however, the impulse voltage test of 5.2.3.1 shall be performed on the clearance.

Clearances for REINFORCED INSULATION shall not be reduced for homogeneous fields.

4.3.6.4.3 Clearance to conductive enclosures

The clearance between any non-insulated LIVE PART and the walls of a metal enclosure shall be in accordance with 4.3.6.4.1 following the deformation tests of 5.2.2.5.

If the design clearance is at least 12,7 mm and the clearance required by 4.3.6.4.1 does not exceed 8 mm, the deformation tests may be omitted.

4.3.6.4.3DV.1 D2 *Modification of 4.3.6.4.3:*

When the deformation tests of 5.2.2.5 are required, only the deflection test according to 5.2.2.5.2 is required.

4.3.6.5 Creepage distances

4.3.6.5DV.1 D1 *Modification:*

Creepage distances at field wiring terminals shall comply with Annex DVF, unless the design of the field wiring terminals precludes the possibility of reduced creepage distances due to stray strands or improper wiring INSTALLATION, in which case the requirements of the remainder of this clause are applicable.

4.3.6.5DV.2 D1 *Modification:*

Equipment rated 600 V or less and intended for INSTALLATION in a feeder circuit, on the line side of branch circuit protective devices, shall comply with Table 4.3.6.4DV.2.

4.3.6.5DV.3 D2 *Modification to add the following:*

4.3.6.5DV.3.1 Special coatings

Spacings of only 1/32 in (0,8 mm) on a printed wiring board are acceptable when the printed wiring board spacings are:

a) Covered by a layer of silicone rubber at least a 1/32 in (0,8 mm) thick; or

b) Encapsulated by epoxy or potting material, without air bubbles. The silicone rubber and the potting material, when used, shall comply with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, or the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, or the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

4.3.6.5.1 General

Creepage distances shall be large enough to prevent long-term degradation of the surface of solid insulators, according to Table 10.

For FUNCTIONAL, BASIC and SUPPLEMENTARY INSULATION, the values in Table 10 apply directly. For REINFORCED INSULATION, the distances in Table 10 shall be doubled.

When the creepage distance determined from Table 10 is less than the clearance required by 4.3.6.4.1 or the clearance determined by impulse testing (see 5.2.3.1), then it shall be increased to that clearance.

Creepage distances shall be verified by measurement or inspection (see 5.2.2.1) (see Annex C for examples of creepage distances).

Figure E.2 and Table E.2 provide informative guidance for determination of creepage distances for frequencies above 30 kHz.

4.3.6.5.1DV DE *Modification to clarify:*

The WORKING VOLTAGE in column 1 of Table 10 is the RMS value of the WORKING VOLTAGE across the creepage distance.

4.3.6.5.2 Materials

Insulating materials are classified into four groups corresponding to their comparative tracking index (CTI) when tested according to 6.2 of IEC 60112:

- Insulating material group I CTI ≥ 600;
- Insulating material group II 600 > CTI ≥ 400;
- Insulating material group IIIa 400 > CTI ≥ 175;
- Insulating material group IIIb 175 > CTI ≥ 100.

Creepage distances on printed wiring boards (PWBs) exposed to pollution degree 3 environmental conditions shall be determined based on Table 10 Pollution degree 3 under "Other insulators".

If the creepage distance is ribbed, then the creepage distance of insulating material of group I may be applied using insulating material of group II and the creepage distance of insulating material of group II may be applied using insulating material of group III. Except at pollution degree 1 the ribs shall be 2 mm high at least. The spacing of the ribs shall equal or exceed the dimension '*X*' in Table C.1.

For inorganic insulating materials, for example glass or ceramic, which do not track, the creepage distance may equal the associated clearance, as determined from Table 9

Table 10
Creepage distances (mm)

Column 1	2	3	4	5	6	7	8	9	10	11	12
WORKING VOLTAGE (r.m.s.)	PWBs[a]		Other insulators								
	Pollution degree		Pollution degree								
	1	2	1	2				3			
				Insulating material group				Insulating material group			
(V)	b	c	b	I	II	IIIa	IIIb	I	II	IIIa	IIIb
≤ 2	0,025	0,04	0,056	0,35	0,35	0,35		0,87	0,87	0,87	
5	0,025	0,04	0,065	0,37	0,37	0,37		0,92	0,92	0,92	
10	0,025	0,04	0,08	0,40	0,40	0,40		1,0	1,0	1,0	
25	0,025	0,04	0,125	0,50	0,50	0,50		1,25	1,25	1,25	
32	0,025	0,04	0,14	0,53	0,53	0,53		1,3	1,3	1,3	
40	0,025	0,04	0,16	0,56	0,80	1,1		1,4	1,6	1,8	
50	0,025	0,04	0,18	0,60	0,85	1,20		1,5	1,7	1,9	

Table 10 Continued on Next Page

Table 10 Continued

Column 1	2	3	4	5	6	7	8	9	10	11	12
WORKING VOLTAGE (r.m.s.)	PWBs[a]		Other insulators								
	Pollution degree		Pollution degree								
	1	2	1	2				3			
				Insulating material group				Insulating material group			
(V)	b	c	b	I	II	IIIa	IIIb	I	II	IIIa	IIIb
63	0,04	0,063	0,20	0,63	0,90	1,25		1,6	1,8	2,0	
80	0,063	0,10	0,22	0,67	0,95	1,3		1,7	1,9	2,1	
100	0,10	0,16	0,25	0,71	1,0	1,4		1,8	2,0	2,2	
125	0,16	0,25	0,28	0,75	1,05	1,5		1,9	2,1	2,4	
160	0,25	0,40	0,32	0,80	1,1	1,6		2,0	2,2	2,5	
200	0,40	0,63	0,42	1,0	1,4	2,0		2,5	2,8	3,2	
250	0,56	1,0	0,56	1,25	1,8	2,5		3,2	3,6	4,0	
320	0,75	1,6	0,75	1,6	2,2	3,2		4,0	4,5	5,0	
400	1,0	2,0	1,0	2,0	2,8	4,0		5,0	5,6	6,3	
500	1,3	2,5	1,3	2,5	3,6	5,0		6,3	7,1	8,0	
630	1,8	3,2	1,8	3,2	4,5	6,3		8,0	9,0	10,0	
800	2,4	4,0	2,4	4,0	5,6	8,0		10,0	11	12,5	e
1 000	3,2	5,0	3,2	5,0	7,1	10,0		12,5	14	16	
1 250	4,2	6,3	4,2	6,3	9	12,5		16	18	20	
1 600	f	f	5,6	8,0	11	16		20	22	25	
2 000			7,5	10,0	14	20		25	28	32	
2 500			10,0	12,5	18	25		32	36	40	
3 200			12,5	16	22	32		40	45	50	
4 000			16	20	28	40		50	56	63	
5 000			20	25	36	50		63	71	80	
6 300			25	32	45	63		80	90	100	
8 000			32	40	56	81		100	110	125	
10 000			40	50	71	100		125	140	160	
12 500			50	63	90	125		d	d	d	
16 000			63	80	110	150					
20 000			80	100	140	200					
25 000			100	125	180	250					
32 000			125	160	220	320					

NOTE Interpolation is permitted.

[a] These columns also apply to components and parts on PWBs, and to other creepage distances with a comparable control of tolerances.

[b] All material groups

[c] All material groups except IIIb

[d] Values for creepage distances are not determined for this range.

[e] Insulating materials of group IIIb are not normally recommended for pollution degree 3 above 630V.

[f] above 1 250 V use the values from columns 4 to 11, as appropriate.

4.3.6.6 Coating

A coating may be used to provide insulation, to protect a surface against pollution, and to allow a reduction in creepage and clearance distances (see 4.3.6.8.4.2 and 4.3.6.8.6).

4.3.6.7 PWB spacings for FUNCTIONAL INSULATION

Spacings for FUNCTIONAL INSULATION on a PWB which do not comply with 4.3.6.4 and 4.3.6.5 are permitted when all the following are satisfied:

- the PWB has a flammability rating of V-0 (see IEC 60695-11-10);
- the PWB base material has a minimum CTI of 100;
- the equipment complies with the PWB short-circuit test (see 5.2.2.2).

On PWB creepage and clearance distances for FUNCTIONAL INSULATION at working voltages less than 80 V (r.m.s.) or 110 V (recurring peak) are permitted to be evaluated according to pollution degree 1 if the tracks are covered with a suitable coating.

4.3.6.7DV D2 *Modification:*

The requirements in the second paragraph are not applicable. See 4.3.6.6.

4.3.6.8 Solid insulation

4.3.6.8DV D2 *Modification:*

For solid insulation evaluation, impulse voltage test and partial discharge test are not required.

4.3.6.8.1 General

Materials selected for solid insulation shall be able to withstand the stresses occurring. These include mechanical, electrical, thermal and climatic stresses which are to be expected in normal use. Insulation materials shall also be resistant to ageing during the EXPECTED LIFETIME of the PDS.

Tests shall be performed on components and subassemblies using solid insulation, in order to ensure that the insulation performance has not been compromised by the design or manufacturing process.

Components that comply with a relevant product standard which provides equivalent requirements to those of this standard do not require separate evaluation. Assemblies containing such components shall be tested according to the requirements of this standard.

4.3.6.8.1DV D2 *Modification:*

Compliance with the applicable test requirements of this standard satisfies the ageing requirement for insulation materials.

4.3.6.8.2 Requirements for electrical withstand capability

4.3.6.8.2.1 Basic or supplementary insulation:

• Test with impulse withstand voltage according to 5.2.3.1, column 2 or column 4 of Table 19, or Table 20, column 2 or 4, as appropriate;

and

• Test with a.c. or d.c. voltage according to 5.2.3.2, column 2 of Table 21, Table 22, or Table 23, as appropriate.

4.3.6.8.2.1DV D2 *Modification:*

For solid insulation evaluation, impulse voltage test is not required.

4.3.6.8.2.2 DOUBLE and REINFORCED INSULATION:

• Test with impulse withstand voltage according to 5.2.3.1 Table 19, column 3 or column 5, or Table 20, column 3 or 5 as appropriate;

and

• test with a.c. or d.c. voltage according to 5.2.3.2, column 3 of Table 21, Table 22, or Table 23, as appropriate;

and

• partial discharge test according to 5.2.3.3, if the recurring peak working voltage across the insulation is greater than 750 V and the voltage stress on the insulation is greater than 1 kV/mm.

NOTE The voltage stress is the recurring peak voltage divided by the distance between two parts of different potential.

The partial discharge test shall be performed as a TYPE TEST on all components, subassemblies and PWB. In addition, a SAMPLE TEST shall be performed if the insulation consists of a single layer of material.

DOUBLE INSULATION shall be designed so that failure of the BASIC INSULATION or of the SUPPLEMENTARY INSULATION will not result in reduction of the insulation capability of the remaining part of the insulation.

4.3.6.8.2.3 Functional insulation

FUNCTIONAL INSULATION shall comply with the requirements of 4.3.6.3. Testing is not required, except where the circuit analysis required by 4.2 shows that failure of the insulation could result in a hazard. In these cases, the insulation shall meet the requirements and tests for BASIC INSULATION.

4.3.6.8.3 Thin sheet or tape material

4.3.6.8.3.1 General

Subclause 4.3.6.8.3 applies to the use of thin sheet or tape materials in assemblies such as wound components and bus-bars.

4.3.6.8.3 also applies to components providing insulation. See 4.3.6.8.1 for the use of component standards.

Insulation consisting of thin (less than 0,75 mm) sheet or tape materials is permitted, provided that it is protected from damage and is not subject to mechanical stress under normal use.

Where more than one layer of insulation is used, there is no requirement for all layers to be of the same material.

NOTE 1 One layer of insulation tape wound with more than 50 % overlap is considered to constitute two layers.

NOTE 2 BASIC, SUPPLEMENTARY and DOUBLE INSULATION may be applied as a pre-assembled system of thin materials.

4.3.6.8.3.2 Material thickness not less than 0,2 mm

• BASIC or SUPPLEMENTARY INSULATION shall consist of at least one layer of material, which will meet the requirements of 4.3.6.8.1 and 4.3.6.8.2.1.

• DOUBLE INSULATION shall consist of at least two layers of material, each of which will meet the requirements of 4.3.6.8.1, 4.3.6.8.2.1, and the partial discharge requirements of 4.3.6.8.2.2, and both layers together will meet the impulse and a.c. or d.c. voltage requirements of 4.3.6.8.2.2.

• REINFORCED INSULATION shall consist of a single layer of material, which will meet the requirements of 4.3.6.8.1 and 4.3.6.8.2.2.

NOTE The requirements of this subclause indicate that DOUBLE INSULATION will be at least 0,4 mm thick, while REINFORCED INSULATION is permitted to be 0,2 mm thick.

4.3.6.8.3.3 Material thickness less than 0,2 mm

• BASIC or SUPPLEMENTARY INSULATION shall consist of at least one layer of material, which will meet the requirements of 4.3.6.8.1 and 4.3.6.8.2.1.

• DOUBLE INSULATION shall consist of at least three layers of material. Each layer shall meet the requirements of 4.3.6.8.1 and 4.3.6.8.2.1, and any two layers together shall meet the requirements of 4.3.6.8.2.2.

• REINFORCED INSULATION consisting of a single layer of material is not permitted.

4.3.6.8.3.4 Compliance

Compliance is checked by the tests described in 5.2.3.1 to 5.2.3.3.

When a component or sub-assembly makes use of thin sheet insulating materials, it is permitted to perform the tests on the component rather than on the material.

4.3.6.8.4 Printed wiring boards (PWBs)

4.3.6.8.4.1 General

Insulation between conductor layers in double-sided single-layer PWBs, multi-layer PWBs and metal core PWBs, shall meet the requirements of 4.3.6.8.1. BASIC, SUPPLEMENTARY, DOUBLE and REINFORCED INSULATION shall meet the appropriate requirements of 4.3.6.8.2.1 or 4.3.6.8.2.2. FUNCTIONAL INSULATION in PWBs shall meet the requirements of 4.3.6.8.2.3.

For the inner layers of multi-layer PWBs, the insulation between adjacent tracks on the same layer shall be treated as either:

• a creepage distance for pollution degree 1 and a clearance as in air (see Example C.14 of Annex C);

or

• solid insulation, in which case it shall meet the requirements of 4.3.6.8.1 and 4.3.6.8.2.

4.3.6.8.4.1DV.1 D2 *Modification to add the following:*

PWB shall conform with the Standard for Printed-Wiring Boards, UL 796 or the Standard for Flexible Materials Interconnect Constructions, UL 796F as appropriate, and shall be identified as suitable for direct support of LIVE PARTS with a minimum flammability rating of V2.

4.3.6.8.4.1DV.2 DE *Modification to clarify:*

It should be noted that the voltage used to evaluate the clearance and creepage distances (when not treated as solid insulation) between adjacent tracks will be the WORKING VOLTAGE, peak or rms respectively, between those tracks.

4.3.6.8.4.2 Use of coating materials

A coating material used to provide FUNCTIONAL, BASIC, SUPPLEMENTARY and REINFORCED INSULATION shall meet the requirement as specified below.

Type 1 protection (as defined in IEC 60664-3) improves the microenvironment of the parts under protection. The clearance and creepage distance of Table 9 and Table 10 for pollution degree 1 apply under the protection. Between two conductive parts, it is a requirement that one or both conductive parts, together with all the spacing between them, are covered by the protection.

Type 2 protection is considered to be similar to solid insulation. Under the protection, the requirements for solid insulation specified in 4.3.6.8 are applicable and spacings shall not be less than those specified in Table 1 of IEC 60664-3. The requirements for clearance and creepage in Table 9 and Table 10 do not apply. Between two conductive parts, it is a requirement that both conductive parts, together with the spacing between them, are covered by the protection so that no airgap exists between the protective material, the conductive parts and the printed boards.

The coating material used to provide Type 1 and Type 2 protection shall be designed to withstand the stresses anticipated to occur during the EXPECTED LIFETIME of the PDS/CDM/BDM. A TYPE TEST on representative PWBs shall be conducted according to IEC 60664-3 Clause 5. For the Cold test (5.7.1), a temperature of −25°C shall be used, and for the Rapid change of temperature test (5.7.3): −25°C to +125°C.

4.3.6.8.5 Wound components

Varnish or enamel insulation of wires shall not be used for BASIC, SUPPLEMENTARY, DOUBLE or REINFORCED INSULATION.

Wound components shall meet the requirements of 4.3.6.8.1 and 4.3.6.8.2.

The component itself shall pass the requirements given in 4.3.6.8.1 and 4.3.6.8.2. If the component has REINFORCED or DOUBLE INSULATION, the voltage test of 5.2.3.2 shall be performed as a ROUTINE TEST.

4.3.6.8.5DV DE *Modification to clarify:*

Wound components shall also meet the requirements of 4.3.6.8.3. For example, this applies to transformers, solenoids, contactor coils and the like.

4.3.6.8.6 Potting materials

A potting material may be used to provide solid insulation or to act as a coating to protect against pollution. If used as solid insulation, it shall comply with the requirements of 4.3.6.8.1 and 4.3.6.8.2. If used to protect against pollution, the requirements for Type 1 protection in 4.3.6.8.4.2 apply.

4.3.6.9 Insulation requirements above 30 kHz

Where voltages across insulation have fundamental frequencies greater than 30 kHz, further considerations apply. For low-voltage circuits, guidance is provided in IEC 60664-4.

Annex E contains flow-charts for the determination of clearance and creepage distances under these circumstances. For information, Tables 1 and 2 of IEC 60664-4 are also included in Annex E.

4.3.7 Enclosures

4.3.7DV *Modification to replace 4.3.7 with the following:*

See Annex DVD for enclosure requirements.

4.3.7.1 General

Metal enclosures shall comply with the deflection test of 5.2.2.5.2 or have a thickness as specified in 4.3.7.2 or 4.3.7.3.

Polymeric enclosures or polymeric parts, relied on to complete and maintain the integrity of an electrical enclosure, shall comply with the flammability requirements of 4.4.3 and the impact test in 5.2.2.5.3.

For INTEGRATED PDS the CDM/BDM enclosure shall comply with the above requirements. The motor enclosure shall meet the requirements of the relevant parts of IEC 60034.

Enclosures shall be suitable for use in their intended environments. The manufacturer shall specify the intended environment (see 6.3.3) and the IP rating of the enclosure (see 5.2.2.4 for test).

For INTEGRATED PDS the combination of motor and CDM/BDM shall be tested according to their intended environment. For external fans and drain holes of the motor part the requirements of IEC 60034-5 apply.

4.3.7.2 Cast metal

Die-cast metal, except at threaded holes for conduit, where a minimum of 6,4 mm is required, shall be:

- not less than 2,0 mm thick for an area larger than 155 cm^2 or having any dimension larger than 150 mm;

- not less than 1,2 mm thick for an area of 155 cm^2 or less and having no dimension larger than 150 mm.

The area under evaluation may be bounded by reinforcing ribs subdividing a larger area.

Malleable iron or permanent-mould cast aluminium, brass, bronze, or zinc, except at threaded holes for conduit, where a minimum of 6,4 mm is required, shall be:

- at least 2,4 mm thick for an area greater than 155 cm^2 or having any dimension more than 150 mm;

- at least 1,5 mm thick for an area of 155 cm^2 or less having no dimension more than 150 mm.

A sand-cast metal enclosure shall be a minimum of 3,0 mm thick except at locations for threaded holes for conduit, where a minimum of 6,4 mm is required.

4.3.7.3 Sheet metal

The thickness of a sheet-metal enclosure at points to which a wiring system is to be connected shall be not less than 0,8 mm thick for uncoated steel, 0,9 mm thick for zinc-coated steel, and 1,2 mm thick for non-ferrous metal.

Enclosure thickness at points other than where a wiring system is to be connected shall be not less than that specified in Table 11 or Table 12.

With reference to Table 11 and Table 12, a supporting frame is a structure of angle or channel or folded section of sheet metal, which is attached to and has the same outside dimensions as the enclosure surface, and which has torsional rigidity to resist the bending moments that are applied by the enclosure surface when it is deflected.

A structure which is as rigid as one built with a frame of angles or channels has equivalent reinforcing. Constructions without supporting frame include:

- a single sheet with single formed flanges – formed edges;

- a single sheet which is corrugated or ribbed;

- an enclosure surface loosely attached to a frame, for example, with spring clips; and

- an enclosure surface having an unsupported edge.

Table 11
Thickness of sheet metal for enclosures: carbon steel or stainless steel

Without supporting frame[a]		With supporting frame[a]		Minimum thickness
Maximum width mm[b]	Maximum length mm[c]	Maximum width mm[c]	Maximum length mm[c]	mm
100	Not limited	160	Not limited	0,6[d]
120	150	170	210	
150	Not limited	240	Not limited	0,75[d]
180	220	250	320	
200	Not limited	310	Not limited	0,9
230	290	330	410	

Table 11 Continued on Next Page

Table 11 Continued

Without supporting frame[a]		With supporting frame[a]		Minimum thickness
Maximum width mm[b]	Maximum length mm[c]	Maximum width mm[c]	Maximum length mm[c]	mm
320 350	Not limited 460	500 530	Not limited 640	1,2
460 510	Not limited 640	690 740	Not limited 910	1,4
560 640	Not limited 790	840 890	Not limited 1 090	1,5
640 740	Not limited 910	990 1 040	Not limited 1 300	1,8
840 970	Not limited 1 200	1 300 1 370	Not limited 1 680	2,0
1 070 1 200	Not limited 1 500	1 630 1 730	Not limited 2 130	2,5
1 320 1 520	Not limited 1 880	2 030 2 130	Not limited 2 620	2,8
1 600 1 850	Not limited 2 290	2 460 2 620	Not limited 3 230	3,0

[a] See 4.3.7.3.

[b] The width is the smaller dimension of a rectangular piece of sheet metal which is part of an enclosure. Adjacent surfaces of an enclosure are able to have supports in common and be made of a single sheet.

[c] "Not limited" applies only when the edge of the surface is flanged at least 12,7 mm or fastened to adjacent surfaces not normally removed in use.

[d] Sheet steel for an enclosure intended for outdoor use shall be not less than 0,86 mm thick.

Table 12
Thickness of sheet metal for enclosures: aluminium, copper or brass

Without supporting frame[a]		With supporting frame[a]		Minimum thickness
Maximum width mm[b]	Maximum length mm[c]	Maximum width mm[b]	Maximum length mm[c]	mm
75 90	Not limited 100	180 220	Not limited 240	0,6[d]
100 125	Not limited 150	250 270	Not limited 340	0,75
150 165	Not limited 200	360 380	Not limited 460	0,9
200 240	Not limited 300	480 530	Not limited 640	1,2
300 350	Not limited 400	710 760	Not limited 950	1,5
450 510	Not limited 640	1 100 1 150	Not limited 1 400	2,0
640	Not limited	1 500	Not limited	2,4

Table 12 Continued on Next Page

Table 12 Continued

Without supporting frame[a]		With supporting frame[a]		Minimum thickness
Maximum width mm[b]	Maximum length mm[c]	Maximum width mm[b]	Maximum length mm[c]	mm
740	1 000	1 600	2 000	
940	Not limited	2 200	Not limited	3,0
1 100	1 350	2 400	2 900	
1 300	Not limited	3 100	Not limited	3,9
1 500	1 900	3 300	4 100	

[a] See 4.3.7.3.

[b] The width is the smaller dimension of a rectangular piece of sheet metal which is part of an enclosure. Adjacent surfaces of an enclosure are able to have supports in common and be made of a single sheet.

[c] "Not limited" applies only when the edge of the surface is flanged at least 12,7 mm or fastened to adjacent surfaces not normally removed in use.

[d] Sheet aluminium, copper or brass for an enclosure intended for outdoor use shall be not less than 0,74 mm thick.

4.3.8 Wiring and connections

4.3.8.1 General

The wiring and connections between parts of the equipment and within each part shall be protected from mechanical damage during installation. The insulation, conductors and routing of all wires of the equipment shall be suitable for the electrical, mechanical, thermal and environmental conditions of use. Conductors which are able to contact each other shall be provided with insulation rated for the DVC requirements of the relevant circuits.

The compliance with 4.3.8.2 to 4.3.8.8 shall be checked by visual inspection (see 5.2.1) of the overall construction and datasheets if applicable.

NOTE Electrical reflections in a motor cable fed from a pulse width modulated (PWM) source can cause high voltages to appear on the cable, which should be taken into consideration for PDS component selection.

4.3.8.1DV.1 D2 *Modification to add the following:*

4.3.8.1DV.1.1 CONTROL CIRCUIT Wiring

4.3.8.1DV.1.1.1 Other than as noted in 4.3.8.1DV.1.1.2 – 4.3.8.1DV.1.1.5, Primary and secondary circuit internal wiring shall be provided with additional protection that complies with 4.3.8.1DV.1.1.6 when it is:

a) Connected to the load side of the branch circuit short circuit protection (see 4.3.9DV.1);

b) Located in a circuit that incorporates the coil of an internal or external motor control contactor (such as for bypass); and

c) Sized from 22 – 12 AWG (0,324 – 3,3 mm^2).

4.3.8.1DV.1.1.2 Wiring located in a Class 1 power-limited or Class 3 remote-CONTROL CIRCUIT or located in a Class 2 (see Annex DVC.1.4), Limited Voltage/Current (see Annex DVC.1.5), Limited Energy (see Annex DVC.1.6) or Limiting Impedance (see Annex DVC.1.7) secondary circuit is not required to be additionally protected.

4.3.8.1DV.1.1.3 Any wiring measuring a maximum of 12 in (305 mm) long is not required to be additionally protected.

4.3.8.1DV.1.1.4 Any wiring connected to a printed wiring board having no connections external to the drive and having no more than casual contact with insulated or un-insulated parts of opposite polarity or with grounded parts is not required to be additionally protected.

4.3.8.1DV.1.1.5 When an instantaneous trip circuit breaker is used or intended for use as the branch circuit short circuit protection (see 4.3.9DV.1) and its rating or trip setting is not more than the applicable value specified in Table 4.3.8.1DV.1, then wiring is not required to be additionally protected when the drive is marked in accordance with 6.3.7DV.2.

Table 4.3.8.1DV.1
Branch-Circuit Short-Circuit Protection

Control-circuit wire size, AWG (mm^2)		Maximum rating of branch-circuit-protective device, A	
		Conductors within enclosure	Conductors outside enclosure
22	(0,32)	12	3
20	(0,52)	20	5
18	(0,82)	25	7
16	(1,3)	40	10
14	(2,1)	100	45
12	(3,3)	120	60

4.3.8.1DV.1.1.6 Other than as noted in 4.3.8.1DV.1.1.7 and 4.3.8.1DV.1.1.8. The additional wiring protection required by 4.3.8.1DV.1.1.1 shall:

a) Be located within the drive;

b) Be rated in accordance with Table 4.3.8.1DV.2;

c) Be provided in each ungrounded conductor;

d) Be located no more than 12 in (305 mm) from the point where the wiring is connected to its source of power;

e) Either be a supplementary or a branch circuit type fuse in accordance with the UL 248 series or a branch circuit breaker in accordance with the Standard for Molded Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures, UL 489; and

f) Be provided with a marking in accordance with 6.3.7DV.4.1.2.

4.3.8.1DV.1.1.7 The additional protection noted in 4.3.8.1DV.1.1.6 is not required to be included within the drive when it is shipped from the factory and meets the following:

a) The manufacturer makes available an accessory kit that complies with 4.3.8.1DV.1.1.6;

b) This accessory kit is evaluated for field INSTALLATION; and

c) The drive is marked in accordance with 6.3.7DV.4.1.3

4.3.8.1DV.1.1.8 The additional protection noted in 4.3.8.1DV.1.1.6 is not required to be shipped with the drive when the fuseholder is included within the drive and the unit is marked in accordance with 6.3.7DV.4.1.4.

Table 4.3.8.1DV.2
Overcurrent Protection

Control-circuit wire size, AWG (mm^2)		Maximum protective device rating, A
22	(0,32)	3
20	(0,52)	5
18	(0,82)	7
16	(1,3)	10
14	(2,1)	20
12	(3,3)	25

4.3.8.1DV.1.1.9 For drives with a short circuit current rating in excess of 10 000 A, the additional wiring protection required by 4.3.8.1DV.1.1.1 shall comply with 4.3.8.1DV.1.1.6 and be rated greater than or equal to the marked short circuit current rating of the drive. When fuses are used for this protection, they shall be Class CC, CF, G, J, L, R, or T and be provided with an appropriate branch circuit type fuseholder. These fuses are not required to be factory installed.

4.3.8.1DV.2 D2 *Modification to add the following:*

4.3.8.1DV.2.1 Other than CONTROL CIRCUIT wiring

4.3.8.1DV.2.1.1 Primary overcurrent protection (not power circuit)

4.3.8.1DV.2.1.1.1 All wiring including bus bars and interconnecting cables used in the distribution of primary electric energy within and between units of equipment and all transformers and other loading devices connected to the primary circuit shall be protected against burnout and damage to insulation resulting from any overload or short-circuit condition that occurs during operation of the equipment. The protection shall be sized based on the levels identified in Table 4.3.8.1DV.1 and Table 4.3.8.1DV.2.

4.3.8.1DV.2.1.1.2 The protection referenced in 4.3.8.1DV.2.1.1.1 shall be provided by overcurrent devices included as integral parts of the control equipment or, when rated in accordance with 4.3.8.1DV.2.1.1.4, from the protection associated with the branch circuit to which the equipment is connected.

4.3.8.1DV.2.1.1.3 Overcurrent protective devices that are provided within the equipment and are types that set the requirements for branch-circuit protection in accordance with the National Electrical Code, ANSI/NFPA 70 – for example, circuit breakers or Class CC, CF, J, T, G, H, K, L, RK1, or RK5 cartridge fuses or Type S fuses – comply with the requirement in 4.3.8.1DV.2.1.1.2. Other types of overcurrent protection devices are to be investigated to determine their acceptability for the application.

4.3.8.1DV.2.1.1.4 The ratings of an overcurrent device in series with connecting wiring shall not exceed the following:

a) For motor loads alone – 300 percent of the motor full-load current observed during the maximum normal operation of the system.

b) For resistive loads, and for combination resistive and reactive loads, with or without motor loads – 250 percent of the full-load current of the circuit under evaluation.

4.3.8.1DV.2.1.1.5 A device providing overcurrent protection shall be of a type that is intended for use when supplied directly by the branch circuit to which the equipment is connected unless additional protection intended for the use is provided in the equipment.

4.3.8.1DV.2.1.1.6 An overcurrent protective device shall be connected between the ungrounded branch-circuit supply conductor and the load.

4.3.8.1DV.2.1.2 Secondary overcurrent protection

4.3.8.1DV.2.1.2.1 Cables and wiring located in Class 2 circuits do not require any additional overload or short-circuit protection.

4.3.8.1DV.2.1.2.2 All external secondary-circuit interconnecting cables and all secondary-circuit wiring between units shall be protected against burnout and damage to the insulation resulting from any overload or short-circuit condition that occurs during use of the equipment.

4.3.8.1DV.2.1.2.3 The overcurrent protection provided in the primary circuit of a transformer is considered to provide protection for the secondary circuit wiring, when it operates to protect the secondary circuit under all overload conditions including short circuit.

4.3.8.1DV.2.1.2.4 A conductor provided with overcurrent protection complying with the National Electrical Code, ANSI/NFPA 70, complies with 4.3.8.1DV.2.1.2.2.

4.3.8.1DV.2.1.2.5 Secondary circuits that are derived from power supplies or other sources are not prohibited from being used when the output wiring carries the maximum current available from the power supply without discoloration or softening of insulation, and when the power supplies or other sources:

a) Are inherently limited; or

b) Include sensing devices whose operation achieves the same result (prevention of burnout and damage to insulation resulting from overload) or de-energizes the equipment.

4.3.8.2 Routing

A hole through which insulated wires pass in a sheet metal wall within the enclosure of the equipment shall be provided with a smooth, well-rounded bushing or grommet or shall have smooth, well-rounded surfaces upon which the wires bear to reduce the risk of abrasion of the insulation.

Wires shall be routed away from sharp edges, screw threads, burrs, fins, moving parts, drawers, and similar parts, which abrade the wire insulation. The minimum bend radius specified by the wire manufacturer shall not be violated.

Clamps and guides, either metallic or non-metallic, used for routing stationary internal wiring shall be provided with smooth, well-rounded edges. The clamping action and bearing surface shall be such that abrasion or cold flow of the insulation does not occur. If a metal clamp is used for conductors having thermoplastic insulation less than 0,8 mm thick, non-conducting mechanical protection shall be provided.

4.3.8.3 Colour coding

Insulated conductors, other than those which are integral to ribbon cable or multi-cord signal cable, identified by the colour green with or without one or more yellow stripes shall not be used other than for PROTECTIVE BONDING.

NOTE The choice of green or green/yellow for the PROTECTIVE BONDING is covered by national regulations.

4.3.8.3DV D2 *Modification to add the following:*

Internal Grounding and Bonding Conductor Color Insulated grounding and bonding conductors smaller than 4 AWG shall be identified by the color green with or without one or more yellow stripes throughout the entire product. Insulated conductors sized 4 AWG or larger shall be identified in this manner, or shall be identified at each termination point by a green marking, such as green tape wrapped around the conductor. No other leads shall be so identified. This requirement does not apply to a green or green/yellow conductor provided in a wiring harness, ribbon cable, or similar prefabricated wiring assembly, which is not likely to be mistaken for a grounding conductor.

4.3.8.4 Splices and connections

All splices and connections shall be mechanically secure and shall provide electrical continuity.

Electrical connections shall be soldered, welded, crimped, or otherwise securely connected. A soldered joint, other than a component on a PWB, shall additionally be mechanically secured.

When stranded internal wiring is connected to a wire-binding screw, the construction shall be such that loose strands of wire do not contact:

• other uninsulated LIVE PARTS not always of the same potential as the wire;

• de-energized metal parts.

When screw terminal connections are used, the resulting connections may require routine maintenance (tightening). Appropriate reference shall be made in the maintenance manual (see 6.5.1).

4.3.8.4DV.1 D2 *Modification to add the following:*

When stranded internal wiring is connected to a wire-binding screw, the construction shall be such that loose strands of wire do not contact:

a) Other uninsulated LIVE PARTS not always of the same polarity as the wire; and

b) De-energized metal parts.

Means, that meet the intent of the requirement, include machine- or tool-applied pressure terminal connectors, soldering lugs, crimped eyelets, or the soldering of all strands of the wire together.

4.3.8.4DV.2 D2 *Modification to add the following:*

4.3.8.4DV.2.1 A splice shall be provided with insulation equivalent to that of the wires involved.

4.3.8.4DV.2.2 In determining when splice insulation consisting of coated-fabric, thermoplastic, or other types of tubing is usable, electrical and mechanical properties including dielectric voltage-withstand ability, heat resistance, and moisture resistance shall be evaluated. For requirements of additional insulation, 4.3.8.4DV.2.3 applies. Thermoplastic tape shall not be wrapped over a sharp edge or connection

4.3.8.4DV.2.3 Additional insulation, when used, shall be insulating sleeving, tubing, or a wrapping of not less than two layers of insulating tape. The insulation shall be made of materials rated for the temperature and voltage involved.

4.3.8.4DV.3 D2 *Modification to add the following:*

Bus bars using spring-loaded joints for connection shall be subjected to the heat cycling test of 5.2.3.8DV.3. A spring-loaded joint shall be considered to be one in which the clamping force is developed by the deflection of a spring member in the assembly of the joint or developed by the elasticity of a metal clamp or clip in the assembly of the joint. For the purpose of this requirement, a dished washer shall not be considered to exert spring loading and would not be required to be evaluated using the heat cycling test.

4.3.8.5 Accessible connections

In addition to measures given in 4.3.4.1 to 4.3.4.3 it shall be ensured that neither insertion error nor polarity reversal of connectors can lead to a voltage on an accessible connection higher than the maximum of DVC A. This applies for example to plug-in sub-assemblies or other plug-in devices which can be plugged in without the use of a tool (key) or which are accessible without the use of a tool. This does not apply to equipment intended to be installed in CLOSED ELECTRICAL OPERATING AREAS.

If relevant, non-interchangeability and protection against polarity reversal of connectors, plugs and socket outlets shall be confirmed by inspection and trial insertion.

4.3.8.6 Interconnections between parts of the PDS

In addition to complying with the requirements given in 4.3.8.1 to 4.3.8.5, the means provided for the interconnection between parts of the PDS shall comply with the following requirements or those of 4.3.8.7.

Cable assemblies and flexible cords provided for interconnection between sections of equipment or between units of a system shall be suitable for the service or use involved. Cables shall be protected from physical damage as they leave the enclosure and shall be provided with mechanical strain relief.

Misalignment of male and female connectors, insertion of a multi-pin male connector in a female connector other than the one intended to receive it, and other manipulations of parts which are accessible to the operator shall not result in mechanical damage or a risk of thermal hazards, electric shock, or injury to persons.

When external interconnecting cables terminate in a plug which mates with a receptacle on the external surface of an enclosure, no risk of electric shock shall exist at accessible contacts of either the plug or receptacle when disconnected.

NOTE An interlock circuit in the cable to de-energize the accessible contacts whenever an end of the cable is disconnected meets the intent of these requirements.

4.3.8.6DV D2 *Modification to add the following:*

4.3.8.6DV.1 Flexing

4.3.8.6DV.1.1 Wiring that is subject to flexing during servicing, such as that from a stationary part to a part mounted on a hinged door or other moveable part, shall be provided with insulation not less than 1/32 in (0,8 mm) thick. The wiring shall be flexible cord or shall comply with 4.3.8.6DV.1.2 or 4.3.8.6DV.1.3.

4.3.8.6DV.1.2 Wiring other than flexible cord may be used when provided with additional insulation at any point where it is flexed. This additional insulation shall be insulating sleeving, tubing, or a wrapping of not less than two layers of insulating tape. The insulation shall be made of materials rated for the temperature and voltage involved.

4.3.8.6DV.1.3 Wiring other than flexible cord may be used without additional insulation when damage to the wiring is not evident and the wiring withstands the A.C. or d.c. voltage test, 5.2.3.2 applied between conductors and between conductors and ground, after the wiring is mounted as intended and tested by opening the door or other moveable part as far as possible and then returning it to the original position for 500 cycles of operation (restraints such as a chain are to remain in place).

4.3.8.7 Supply connections

A PDS intended for permanent connection to the power supply shall have provision for connection to the applicable wiring system in accordance with the requirements where it is being installed. The connection points provided shall be of appropriate construction to preclude the possibility of loose strands reducing the spacing between conductors when careful attention is paid to installation.

4.3.8.7DV DR *Modification to add the following:*

4.3.8.7DV.1 The equipment shall be constructed so that the INSTALLATION can comply with requirements as specified in Article 310 and Tables 310-16 or 310-17, as appropriate, of the National Electrical Code, ANSI/NFPA 70.

4.3.8.7DV.2 Power conversion equipment intended for permanent connection to the power supply shall have provision for connection of one of the applicable wiring systems in accordance with the National Electrical Code, ANSI/NFPA 70, unless it is intended to be drilled or punched in the field to accommodate a wiring system and is provided with appropriate INSTALLATION instructions.

4.3.8.7DV.3 A tapped hole in a cast metal enclosure for the attachment of threaded rigid conduit shall be provided with:

a) An integral bushing having a smooth, rounded inlet hole with a diameter the same as the internal diameter of a standard bushing to provide protection for the

conductors equivalent to that provided by such a bushing, or shall be located so that a standard bushing is able to be attached to the end of the conduit; and

b) At least three full threads when tapped all the way through the wall of an enclosure, or with at least 3-1/2 full threads when used with an integral bushing.

4.3.8.7DV.4 It is assumed that power conversion equipment having a current rating or a horsepower rating with a full-load motor current as specified in Table DVE.1 or Table DVE.2 is intended to be connected with wire of a size determined in accordance with Table 310-16 of the National Electrical Code, ANSI/NFPA 70. Unless marked in accordance with 6.3.6.4DV.1.5 for use only with wire rated 75 °C (167 °F), the size is to be based upon wire rated for a temperature 60 °C (140 °F) for equipment rated 100 A or less; and upon wire rated for 75 °C for equipment rated greater than 100 A. The type of insulation is not specified.

4.3.8.7DV.5 Cord-connected equipment

4.3.8.7DV.5.1 Power conversion equipment intended to be cord connected to the power supply shall be provided with a length, size, and type of hard-service or junior hard-service flexible cord, such as Type S, SJ, or the equivalent, evaluated for the use conditions, that is terminated in a grounding type attachment plug and is rated for the temperature and voltage involved.

4.3.8.7DV.5.2 Equipment is able to be cord-connected to the power supply when the equipment is:

a) Portable;

b) Free standing or stationary (not permanently connected to building wiring);

c) As described in 4.3.8.7DV.5.10.

4.3.8.7DV.5.3 The cord ampacity, as specified in Table 4.3.8.7DV.1, shall not be less than the ampacity required for the equipment in 4.3.8.8.2DV.1.

Table 4.3.8.7DV.1
Ampacity of Flexible Cord

Conductor size, AWG	Number of conductors	
	2	3[a]
18	10	7
16	13	10
14	18	15
12	25	20
10	30	25
8	40	35
6	55	45
4	70	60
2	95	80

[a] Where more than three current-carrying conductors are provided, the ampacity of each of the conductors shall be: 80 percent of these values for 4 – 6 conductors; 70 percent of these values for 7 – 9 conductors; 50 percent of these values for 10 – 20 conductors; 45 percent of these values for 21 – 30 conductors; 40 percent of these values for 31 – 40 conductors; and 35 percent of these values for 41 or more conductors.

4.3.8.7DV.5.4 Cord-connected equipment provided with a standard attachment plug whose ampere rating exceeds the ampacity of the power supply cord shall be provided with an integral overcurrent protective device rated not more than the ampacity of the conductors. Cord-connected equipment provided with a multi-pin connector or without any attachment plug or connector shall be:

a) Provided with integral overcurrent protection rated not more than the ampacity of the conductors; or

b) Marked as in 6.3.7DV.4.1.1 to indicate the ratings of the overcurrent protection required to be installed in the field.

4.3.8.7DV.5.5 Strain relief shall be provided on power supply or signal multicable cords. The strain relief shall be tested in accordance with 5.2.12DV.1.

4.3.8.7DV.5.6 At the point at which the cord passes through the enclosure wall, protection shall be provided to prevent cord abrasion.

4.3.8.7DV.5.7 When a knot serves as strain relief in an attached flexible cord, any surface that the knot contacts shall be free from projections, sharp edges, burrs, fins and similar irregularities, that abrade insulation on the conductors.

4.3.8.7DV.5.8 Means shall be provided to prevent the supply cord from being pushed into the enclosure of the equipment through the cord entry hole when such displacement results in:

a) Subjecting the supply cord to mechanical damage;

b) Exposing the supply cord to a temperature higher than that for which it is rated;

c) Reducing spacings, such as to a metal strain-relief clamp, below the minimum required values; or

d) Damaging INTERNAL CONNECTIONS or components.

To determine compliance, the supply cord shall be tested in accordance with 5.2.12DV.1.2, Push-Back Relief Test.

4.3.8.7DV.5.9 A power-supply or signaling connecting cord, used on equipment having a:

a) Type 3, 3R, 3S, 4, 4X, 6, or 6P enclosure shall be evaluated for outdoor use;

b) Type 6 or 6P enclosure shall be water resistant; and

c) Type 12, 12K, or 13 enclosure shall be oil resistant (such as SO, SJO, or STO).

4.3.8.7DV.5.10 For a device that is intended to provide a signaling function, an attachment plug is not required.

4.3.8.7DV.5.11 A lead that is intended to be spliced in the field to a circuit conductor shall not be smaller than 18 AWG (0,82 mm^2) and the insulation, when of rubber or thermoplastic, shall not be less than 1/32 in (0,8 mm) thick.

4.3.8.8 Terminals

4.3.8.8.1 Construction requirements

All parts of terminals which maintain contact and carry current shall be of metal having adequate mechanical strength.

Terminal connections shall be such that the conductors can be connected by means of screws, springs or other equivalent means so as to ensure that the necessary contact pressure is maintained.

Terminals shall be so constructed that the conductors can be clamped between suitable surfaces without any significant damage either to conductors or terminals.

Terminals shall not allow the conductors to be displaced or be displaced themselves in a manner detrimental to the operation of equipment and the insulation shall not be reduced below the rated values.

The requirements of this subclause are met by using terminals complying with IEC 60947-7-1 or IEC 60947-7-2, as appropriate.

4.3.8.8.1DV D2 *Modification to add the following:*

4.3.8.8.1DV.1 Terminals shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310, the Standard for Wire Connectors, UL 486A-486B, the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E or the Standard for Terminal Blocks, UL 1059 as appropriate. Terminals that will be wired in the field shall be suitable for field wiring.

4.3.8.8.1DV.2 A pressure terminal connector, including one that is compression tool applied, for field connection to line or load is not required to be provided for equipment with field wiring larger than 10 AWG (5,3 mm^2) when the construction complies with the following conditions:

a) Component terminal connectors are available from the equipment manufacturer and one or more are specified for field INSTALLATION on the equipment.

b) A fastening device, such as a stud, nut, bolt, spring or flat washer, or similar device, that is required for INSTALLATION is:

1) Provided as part of the component terminal assembly; or

2) Mounted on or separately packaged with the equipment.

c) The INSTALLATION of the terminal assembly does not involve the loosening or disassembly of a part other than a cover or other part giving access to the terminal location. The means for securing the terminal connectors shall be accessible for tightening before and after INSTALLATION of the conductor.

d) When the pressure connector provided in a component terminal assembly requires the use of a special tool for securing the conductor, instructions referencing use of the tool shall be included with the component assembly or with the equipment.

e) INSTALLATION of a pressure terminal connector in the intended manner shall result in a product that complies with the requirements in this standard.

f) The equipment is marked in accordance with 6.3.6.4DV.1.12.

4.3.8.8.1DV.3 A terminal to which field wiring greater than 10 AWG (5,3 mm^2) is to be connected shall be a soldering lug or pressure wire connector. A terminal to which a 10 AWG (5,3 mm^2) or smaller wiring connection is to be made shall consist of a clamp or binding screw with a terminal plate having upturned lugs or the equivalent to hold the wire in position, or shall be a soldering lug or pressure wire connector.

4.3.8.8.1DV.4 A wire-binding screw to which field-wiring connections of conductors larger than 14 AWG (2,1 mm^2) are made shall be No. 8 or larger.

4.3.8.8.1DV.5 A wire-binding screw intended only for field-wiring connection of a conductor sized 14 AWG (2,1 mm^2) or smaller shall be No. 6 or larger.

4.3.8.8.1DV.6 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0,030 in (0,76 mm) thick for a 14 AWG (2,1 mm^2) or smaller wire, and not less than 0,050 in (1,27 mm) thick for a wire larger than 14 AWG (2,1 mm^2). There shall be at least two full threads in the plate unless fewer threads result in a secure connection in which the threads do not strip upon application of a 20 lb·in (2.3 N·m) tightening torque.

4.3.8.8.1DV.7 A terminal plate formed from stock having the required thickness specified in 4.3.8.8.1DV.6 is able to have the metal extruded at the tapped hole for the binding screw to provide two full threads.

4.3.8.8.1DV.8 A wire-binding screw shall thread into metal.

4.3.8.8.1DV.9 A field-wiring terminal made with an aluminum body or intended for connection of aluminum wire shall be rated AL7CU or AL9CU.

4.3.8.8.2 Connecting capacity

Terminals shall be provided which accommodate the conductors specified in the installation and maintenance manuals (see 6.3.6.4) and cables in accordance with the wiring rules applicable at the INSTALLATION. The terminals shall meet the temperature rise test of 5.2.3.8. The terminals shall also be suitable for conductors of the same type at least two sizes smaller, as given in the appropriate column of Table F.1.

Standard values of cross-section of round copper conductors are shown in Annex F, which also gives the approximate relationship between ISO metric and AWG/MCM sizes.

4.3.8.8.2DV DR ***Modification to add the following:***

4.3.8.8.2DV.1 The terminals of power conversion equipment shall each be provided with wiring terminals or leads for connection of conductors having an ampacity as follows:

a) For line terminals, not less than 125 percent of maximum rated input current and not less than 125 percent of full load motor current.

b) For motor load terminals, not less than 125 percent of the maximum marked output current and not less than 125 percent of the full-load motor current specified in Table DVE.1 or Table DVE.2 for output horsepower ratings.

c) For terminals of a DC bus circuit intended to supply one or more inverters, not less than 125 percent of the maximum marked current for those terminals.

d) For power terminals not addressed in (a), (b), (c) or (e), not less than 100 percent of the maximum marked current for those terminals.

e) Unless marked in accordance with 6.3.6.4DV.1.13, for equipment controlling a direct-current motor intended to be operated from a rectified single-phase power supply.

1) One-hundred ninety percent of full load current when a half wave rectifier is used.

2) One-hundred fifty percent of full load current when a full wave rectifier is used.

Where field wiring conductors will be larger than 10 AWG (5,3 mm^2), the wiring terminals or leads may be omitted in accordance with 4.3.8.8.1DV.2.

4.3.8.8.2DV.2 The conductor size shall be determined from the 60 °C or 75 °C column of Table 4.3.8.8.2DV.1 based on the value calculated in 4.3.8.8.2DV.1.

4.3.8.8.2DV.3 Unless marked otherwise, use the 60 °C wire for 100 A and less and 75 °C wire above 100 A.

4.3.8.8.2DV.4 For conductors in parallel, conductors shall not be smaller than 1/0 AWG.

4.3.8.8.2DV.5 When a wiring terminal is able to receive the next larger size conductor than that required in 4.3.8.8.2DV.2, the terminal shall comply with secureness and pullout requirements with that size conductor, unless the equipment is marked to restrict its use to only the smaller size conductor in accordance with 6.3.6.4DV.1.11.

Table 4.3.8.8.2DV.1
Ampacities of Insulated Conductors

Wire size AWG (mm^2)		60 °C (140 °F)		75 °C (167 °F)	
		Copper	Aluminum	Copper	Aluminum
24	(0,2)	2	–	–	–
22	(0,3)	3	–	–	–
20	(0,5)	5	–	–	–
18	(0,8)	7	–	–	–
16	(1,3)	10	–	–	–
14	(2,1)	15	–	15	–
12	(3,3)	20	15	20	15
10	(5,3)	30	25	30	25
8	(8,4)	40	30	50	40
6	(13,3)	55	40	65	50
4	(21,2)	70	55	85	65
3	(26,7)	85	65	100	75
2	(33,6)	95	75	115	90
1	(42,4)	110	85	130	100

Table 4.3.8.8.2DV.1 Continued on Next Page

Table 4.3.8.8.2DV.1 Continued

Wire size AWG (mm²)		60 °C (140 °F)		75 °C (167 °F)	
		Copper	Aluminum	Copper	Aluminum
1/0	(53,5)	–	–	150	120
2/0	(67,4)	–	–	175	135
3/0	(85,0)	–	–	200	155
4/0	(107,2)	–	–	230	180
–	–	–	–	–	–
kcmil	–	–	–	–	–
250	(127)	–	–	255	205
300	(152)	–	–	285	230
350	(177)	–	–	310	250
400	(203)	–	–	335	270
500	(253)	–	–	380	310
600	(304)	–	–	420	340
700	(355)	–	–	460	375
750	(380)	–	–	475	385
800	(405)	–	–	490	395
900	(456)	–	–	520	425
1 000	(506)	–	–	545	445
1 250	(633)	–	–	590	485
1 500	(760)	–	–	625	520
1 750	(887)	–	–	650	545
2 000	(1 013)	–	–	665	560

NOTES

1. For multiple-conductors of the same size (1/0 AWG or larger) at a terminal, the ampacity is equal to the value in Table 4.3.8.8.2DV.1 for that conductor multiplied by the number of conductors that the terminal accommodates.

2. These values of ampacity apply only when not more than three conductors are to be field-installed in the conduit. When four or more conductors, other than a neutral that carries the unbalanced current, are to be installed in a conduit (as occurs because of the number of conduit hubs provided in outdoor equipment, the number of wires required in certain polyphase systems, or other reasons), the ampacity of each of the conductors shall be 80 percent of these values when 4 – 6 conductors are involved, 70 percent of these values when 7 – 24 conductors, 60 percent of these values when 25 – 42 conductors, and 50 percent of these values when 43 or more conductors.

4.3.8.8.2DV.6 Control terminals

4.3.8.8.2DV.6.1 Terminals for control, signal, or sensor circuits shall accept 14 AWG (2,1 mm²) minimum, unless marked (on the product or INSTALLATION instructions) for the connection of 18 AWG (0,82 mm²) and 16 AWG (1,3 mm²) conductor size(s).

4.3.8.8.3 Connection

Terminals for connection to external conductors shall be readily accessible during installation.

Clamping screws and nuts shall not serve to fix any other component although they may hold the terminals in place or prevent them from turning.

4.3.8.8.4 Wire bending space for wires 10 mm^2 and greater

For LOW-VOLTAGE PDS, the distance between a terminal for connection to the main supply, or between major parts of the PDS (for example, motor, transformer, CDM/BDM), and an obstruction toward which the wire is directed upon leaving the terminal shall be at least that specified in Table 13.

Table 13
Wire bending space from terminals to enclosure

Size of wire mm^2	Minimum bending space, terminal to enclosure mm		
	Wires per terminal		
	1	2	3
10 – 16	40	–	–
25	50	–	–
35	65	–	–
50	125	125	180
70	150	150	190
95	180	180	205
120	205	205	230
150	255	255	280
185	305	305	330
240	305	305	380
300	355	405	455
350	355	405	510
400	455	485	560
450	455	485	610

For HIGH-VOLTAGE PDS, the minimum wire bending space for conductors for interconnection between parts of the PDS or to the main supply shall be:

• eight times the overall diameter for non-shielded conductors,

or

• 12 times the overall diameter for shielded or lead-covered conductors.

4.3.8.8.4DV DR *Modification to replace 4.3.8.8.4 with the following:*

4.3.8.8.4DV.1 Wire bending space for wires 8 AWG (8,4 mm^2) and greater

4.3.8.8.4DV.1.1 The space between the end of the soldering lug or pressure wire connector for the connection of field-installed wire and the wall of the enclosure toward which the wire is directed upon leaving the lug or connector shall be at least that specified in Table 4.3.8.8.4DV.1.

4.3.8.8.4DV.1.2 The space specified in 4.3.8.8.4DV.1.1 is to be the length of a straight line extending from the end of the soldering lug or pressure wire connector where the wire is connected toward and perpendicular to the enclosure wall toward which the wire is initially directed.

4.3.8.8.4DV.1.3 When a wire is restricted by barriers or other means from being bent where it leaves the connector, the distance required by 4.3.8.8.4DV.1.1 and Table 4.3.8.8.4DV.1 is to be measured from the end of the barrier. A terminal lug or connector as described in 4.11DV.1.2 is to be repositioned anywhere within the limits to obtain the shortest distance for measurement.

4.3.8.8.4DV.1.4 The wire size used to determine the wire bending space is based on 125 percent of the motor full-load current rating. See Table DVE.1 or Table DVE.2 for the full-load current rating of horsepower rated motors.

Table 4.3.8.8.4DV.1
Wire Bending Space at the Terminals of Enclosed Power Conversion Equipment

Size of wire[a] AWG or kcmil (mm^2)		Minimum bending space, Terminal to wall, in (mm)					
		Wires per terminal					
		1		2		3	
14 – 10	(2,1 – 5,3)	–	–	–	–	–	–
8 – 6	(8,4 – 13,3)	1-1/2	(38)	–	–	–	–
4 – 3	(21,2 – 26,7)	2	(51)	–	–	–	–
2	(33,6)	2-1/2	(64)	–	–	–	–
1	(42,4)	3	(76)	–	–	–	–
1/0	(53,5)	5	(127)	5	(127)	7	(178)
2/0	(67,4)	6	(152)	6	(152)	7-1/2	(191)
3/0	(85,0)	7	(178)	7	(178)	8	(203)
4/0	(107,2)	7	(178)	7	(178)	8-1/2	(216)
250	(127)	8	(203)	8	(203)	9	(229)
300	(152)	10	(254)	10	(254)	11	(279)
350	(177)	12	(305)	12	(305)	13	(330)
400	(203)	12	(305)	12	(305)	14	(356)
500	(253)	12	(305)	12	(305)	15	(381)
600	(304)	14	(356)	16	(406)	18	(457)
700	(355)	14	(356)	16	(406)	20	(508)
750 – 800	(380 – 405)	18	(457)	19	(483)	22	(559)
900	(456)	18	(457)	19	(483)	24	(610)

NOTE – Where provision for more than three conductors per terminals is provided, the bending space shall be in accordance with the appropriate tables for cabinets and boxes in Article 312 of the National Electrical Code, ANSI/NFPA 70.

[a] The wire size is to be based on 4.3.8.8.2DV.1.

4.3.9 Output short-circuit requirements

The PDS shall not present a thermal hazard, electric shock or energy hazard under short-circuit conditions at any output that is capable of providing power. In some cases, short-circuit protection may be provided by external measures, the characteristics of which shall be specified by the manufacturer.

The short-circuit evaluation of each power output of the CDM/BDM shall include short-circuits of both

- phase to phase, and

• each phase to earth.

If the CDM/BDM provides galvanic isolation between all power ports and a power output, then evaluation of phase to earth short-circuits for that specific power output, and any additional power outputs with galvanic isolation, is not necessary.

Compliance with the requirement of IEC 60364-4-41:2005/AMD1:– Clause 411[3], and Annex D is shown by

• testing according to 5.2.3.6.5, or

• supplementary protective equipotential bonding in accordance with IEC 60364-4-41:2005/AMD1:–, 415.2.

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

The ELECTRONIC POWER SHORT-CIRCUIT PROTECTION CIRCUITRY relied on to demonstrate compliance with the short-circuit test in 5.2.3.6.3 shall also comply with the requirement of 5.2.9.

NOTE IEC 60364-4-41:2005/AMD1:–, 411.3.2, provides more information about protection against indirect contact in case of a short-circuit between hazardous LIVE PARTS and protective earth.

Consideration shall be given to compliance with different type of system earthing (e.g. TN, TT, IT or corner-earthed) as the short-circuit current to protective earth depends on the type of system earthing.

NOTE Especially, the short-circuit fault current to earth is expected to be lower or equal to the rated output current of the power output depending on system earthing.

For information requirements, see 6.3.7.

For co-ordination with upstream protection devices, the manufacturer shall specify a maximum PROSPECTIVE SHORT-CIRCUIT CURRENT rating corresponding to each power output of the CDM/BDM. If protection devices with particular characteristics are necessary, these shall also be specified.

NOTE The maximum PROSPECTIVE SHORT-CIRCUIT CURRENT rating refers to the capability of the power source which supplies the PDS.

Short-circuit evaluation shall be performed according to 5.2.3.6 on all power outputs.

4.3.9DV.1 D2 *Modification:*

4.3.9DV.1.1 The number, arrangement, and ratings or settings of protective devices intended to provide motor branch-circuit short-circuit and ground-fault protection shall be as required by Part IV, Article 430 of the National Electrical Code, ANSI/NFPA 70.

4.3.9DV.1.2 The first sentence of the eighth paragraph is replaced by: For co-ordination with upstream protection devices, the manufacturer shall specify a maximum PROSPECTIVE SHORT-CIRCUIT CURRENT rating. The short-circuit current rating shall be no less than the current specified in Table 4.3.9DV.1 based on the horsepower rating of the drive. For a drive rated only in current and not in horsepower, the equivalent horsepower rating shall be as specified in Table DVE.1 and Table DVE.2.

4.3.9DV.1.3 Testing shall be done in accordance with 5.2.3.6.5, the use of supplementary protective equipotential bonding in accordance with IEC 60364-4-41:2005/AMD1:–, 415.2 is not applicable in the United States.

Note IEC 60364-4-41:2005/AMD1:–, 411.3.2 is not applicable in the United States.

4.3.9DV.2 D2 *Modification to add the following:*

4.3.9DV.2.1 Other than as noted in 4.3.9DV.2.2, a drive series shall comply with the Short Circuit Test – High Fault Currents, 5.2.3.6.2.1DV.5, and the Short Circuit Test – Standard Fault Currents, 5.2.3.6.1DV, when it is intended to be rated with:

a) A standard fault current value in accordance with Table 4.3.9DV.1; and

b) A high fault current value in excess of the standard fault current value.

4.3.9DV.2.2 A drive series is in compliance with the Short Circuit Test – High Fault Currents, 5.2.3.6.2.1DV.5, without additional testing when:

a) The drive series uses SOLID STATE SHORT CIRCUIT PROTECTION circuitry for compliance with the standard fault current short circuit test; and

b) The SOLID STATE SHORT CIRCUIT PROTECTION circuitry is used in accordance with 4.3.9DV.2.3.

Table 4.3.9DV.1
Short Circuit Test Current Values for Devices Rated 600 V or Less

Ratings		Test current
hp	(kW)	A
0 – 50	(0 – 37,3)	5 000
51 – 200	(39 – 149)	10 000
201 – 400	(150 – 298)	18 000
401 – 600	(299 – 447)	30 000
601 – 900	(448 – 671)	42 000
901 – 1 600	(672 – 1 193)	85 000
1 601 or more	(1 194 or more)	100 000
		125 000
		150 000 or 200 000

4.3.9DV.2.3 Any model is able to serve as the representative model from a series that uses SOLID STATE SHORT CIRCUIT PROTECTION circuitry for compliance with this test. As an example, for a drive series with models rated from 25 hp – 700 hp (18,64 – 521,99 kW), the testing of the 25 hp model at 5 000 A represents the testing of any models at 10 000 A, 18 000 A, 30 000 A, or 42 000 A. In addition, short circuit testing may be conducted at 5 000 A to represent higher short circuit test values when all of the following requirements are met:

a) The same solid state protection circuitry is used throughout the series;

b) Any revisions to the protection circuitry requires re-evaluation;

c) The protection circuitry turns off the output devices (Insulated Gate Bi-polar Transistor (IGBT), bi-polar, and similar devices prior to the time in which the devices are damaged by any increase in current. This is based on the manufacturer’s rating of the output devices (typically 10 μs for IGBTs, and 50 μs for bi-polars);

d) Any increase in current experienced by the output devices is the result of the DC bus capacitor bank discharging;

e) The output devices are turned off by the protection circuitry prior to any significant increase in the input current;

f) In response to a higher standard fault current (for example 42 000 A vs. 5 000 A), the protection circuitry shall react to the higher standard fault current (42 000 A) in the same or shorter time as the lower standard fault current (5 000 A). This may be verified through testing at the higher fault current value or through inspection of the SOLID STATE SHORT CIRCUIT PROTECTION hardware and software circuitry; and

g) When relying on current sensing (as opposed to output device collector voltage sensing) to actuate the protection circuitry, either the DC bus or all main motor output lines shall be monitored.

4.3.9DV.2.4 A drive that does not rely solely on solid-state short circuit protection shall also comply with the short circuit test power factor requirements in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1.

4.3.10 Residual current-operated protective (RCD) or monitoring (RCM) device compatibility

RCD and RCM are used to provide protection against insulation faults in some domestic and industrial INSTALLATIONS, additional to that provided by the installed equipment.

An insulation fault or direct contact with certain types of PDS circuits can cause current with a d.c. component to flow in the PROTECTIVE EARTHING CONDUCTOR and thus reduce the ability of an RCD or RCM of type A or AC (see IEC 60755 and IEC 62020) to provide this protection for other equipment in the INSTALLATION.

Annex G gives guidelines to assist with the selection of the RCD or RCM type.

PDS shall satisfy one of the following conditions:

a) A plug-connected single-phase PDS with rated input current less than or equal to 16 A, not using an industrial connector according to IEC 60309, shall be designed so that, under normal and fault conditions, it does not reduce the ability of RCD and RCM of type A to provide protection for other equipment in the INSTALLATION.

b) For plug-connected PDS other than a) with an industrial connector according to IEC 60309, and PDS having a fixed connection, if a d.c. current can be present in the PROTECTIVE EARTHING CONDUCTOR, a caution notice and the symbol ISO 7000-0434 (2004-01) shall be provided in the user manual, and the symbol shall be placed on the PDS (see 6.3.6.7 and Annex H.

See 6.3.6.7 for information and marking requirements.

NOTE For design and construction of electrical INSTALLATIONS, care should be taken with RCD or RCM of Type B. All the RCD or RCM upstream from an RCD or RCM of Type B up to the supply transformer should be of Type B.

4.3.10DV D2 *Deletion:*

The requirements of 4.3.10 are not applicable.

4.3.11 Capacitor discharge

Capacitors within a PDS shall be discharged to a voltage less than 60 V, or to a residual charge less than 50 µC, within 5 s after the removal of power from the PDS. If this requirement is not achievable for functional or other reasons, the information and marking requirements of 6.5.2 apply. See 5.2.3.7 for test.

NOTE This requirement also applies to capacitors used for power factor correction, filtering, etc.

In the case of plugs or similar devices that can be disconnected without the use of a tool, the withdrawal of which results in the exposure of conductors (e.g. pins), the discharge time shall not exceed 1 s. Otherwise such conductors shall be protected against direct contact to at least IPXXB. If neither a discharge time of 1 s nor a protection of at least IPXXB can be achieved, additional disconnecting devices or an appropriate warning device shall be applied.

4.3.11DV D1 *Modification:*

4.3.11DV.1 In modification of the first sentence, the discharge requirement is to achieve a voltage less than 50 V within 1 min after the removal of power from the PDS/CDM/BDM.

4.3.11DV.2 In the case of plugs or similar devices that can be disconnected without the use of a tool, the discharge voltage requirement is to achieve a voltage less than 50 V within 1 s.

4.3.12 Access conditions for HIGH-VOLTAGE PDS

The high voltage sections (transformer, converter, motor, etc.) shall be protected by an appropriate housing enclosure according to IEC 60204-11 with respect to personnel safety.

a) Operating conditions

Interlocking doors shall prevent any access inside the enclosure of the high voltage converter section when main circuit breaker(s) providing the high voltage to the circuit are on, and if LIVE PARTS have not been earthed (see b)).

b) Access for maintenance – earthing instructions

The earthing operation is performed after the normal discharge time stated by the converter manufacturer. Care shall be taken to ensure that this operation is safe even in case of failure of the discharge circuit. Care shall also be taken that on the input and output side the stray capacitance of cables, motor and/or transformer shall be discharged before possible access to LIVE PARTS. The requirements of 4.3.11 apply.

Earthing devices (earthing switches and/or earthing cables) shall be provided in sufficient quantity to facilitate work being carried out in safety on the LIVE PARTS of the HV equipment of the PDS. The earthing devices shall comply with the relevant requirements of IEC 62271-102 or IEC 61230. The earthing contacts, or an indication that the contacts of the switches are closed, shall be visible by the maintenance personnel before they access the equipment.

NOTE In particular cases, (for example, load-commutated inverters), two earthing devices (one line side, one load side) can be required.

For parts which are not directly earthed by an earthing switch the component manufacturers shall provide safe instructions to perform earthing (see 6.3.6.6).

4.3.12DV D2 *Deletion:*

This clause is not applicable because high-voltage products are outside of the scope of this document.

4.3.13DV DR *Addition:*

4.3.13DV.1 CONTROL CIRCUIT transformer grounding

4.3.13DV.1.1 Where the secondary of a CONTROL CIRCUIT transformer is intended to supply an external circuit, the secondary shall be grounded under any of the following:

a) If the transformer primary voltage exceeds 150 V to ground, and the secondary voltage is 50 V or less;

b) If the secondary voltage is 50 V to 1 000 V, and the secondary can be grounded such that the maximum voltage to ground for the ungrounded conductors does not exceed 150 V.

4.3.14DV DR *Addition:*

4.3.14DV.1 Transformers protection

4.3.14DV.1.1 CONTROL CIRCUIT transformer

4.3.14DV.1.1.1 Other than as noted in 4.3.14DV.1.1.3, a transformer whose secondary supplies a circuit incorporating the coil of an internal or external motor control contactor (such as for soft starting) shall be provided with additional protection that complies with 4.3.14DV.1.1.2.

4.3.14DV.1.1.2 The additional transformer protection required by 4.3.14DV.1.1.1 shall either be a supplementary or a branch circuit type fuse or circuit breaker in accordance with the UL 248 series or the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit Breaker Enclosures, UL 489, respectively and shall be in accordance with either (a) or (b) below:

a) For protection proveded only in the primary, the protection shall be provided in accordance with one of the following:

1) In each ungrounded conductor of the transformer primary and rated or set in accordance with Table 4.3.14DV.1; and either,

2) In the transformer primary and rated or set at a maximum of six times the rated transformer primary current when the transformer has no more than 6 percent impedance and coordinated thermal overload protection is arranged to interrupt the primary circuit; or,

3) In the transformer primary and rated or set at a maximum of four times the rated transformer primary current when the transformer has more than 6 percent and less than 10 percent impedance and coordinated thermal overload protection is arranged to interrupt the primary circuit;

b) For protection provided in both the primary and secondary, the protection shall be provided in accordance with one of the following:

1) In the transformer primary and rated or set at not more than 250 percent of the rated transformer primary current and provided in the transformer secondary and rated or set at not more than 125 percent of the rated transformer secondary current; or

2) In the transformer primary and rated or set at not more than 250 percent of the rated transformer primary current and provided in the transformer secondary and rated or set in accordance with line 2 of Table 4.3.14DV.1 when the rated transformer secondary current is 2 A or more.

4.3.14DV.1.1.3 A transformer is not required to be additionally protected when any of the following conditions exist:

a) The transformer secondary supplies a Class 1 power-limited or Class 3 remote-CONTROL CIRCUIT or supplies a Class 2 (see DVC.1.4), Limited Voltage/Current (see DVC.1.5), Limited Energy (see DVC.1.6) or Limiting Impedance (see DVC.1.7) secondary circuit;

b) The transformer secondary is rated less than 50 VA, is inherently protected and is an integral part of the drive;

c) The branch circuit protection provides the required additional protection; or,

d) The additional protection is provided by other means that comply with the applicable requirements in the National Electrical Code, NFPA 70.

Table 4.3.14DV.1
Maximum Rating of Overcurrent Device

Rating primary current, A	Maximum rating of overcurrent protective device expressed as a percent of transformer primary current rating
Less than 2	500
2 to less than 9	167
9 or more	125[a]

[a] When 125 percent of the current does not correspond to a standard fuse or nonadjustable circuit breaker rating, then the next higher standard rating shall be used. See Section 240-6 of the National Electrical Code, ANSI/NFPA 70.

4.3.14DV.1.2 CONTROL CIRCUIT wiring and transformer combination

4.3.14DV.1.2.1 For a single phase transformer with only one 2-wire secondary, compliance with the additional wiring and transformer protection requirements of 4.3.8.1DV.1.1 and 4.3.14DV.1.1.1 is obtainable by protective devices in any ungrounded primary conductor. The protective devices shall:

a) Be located in the primary of the transformer;

b) Have its maximum rating or setting limit calculated by using the appropriate protective device value from Table 4.3.8.1DV.2 based on the AWG of the secondary wiring and multiplying this value by the secondary-to-primary voltage ratio of the transformer; and

c) Have its actual rating or setting be within this maximum limit and also be in accordance with 4.3.14DV.1.1.2 (a) and (b).

4.3.14DV.1.3 Transformers

4.3.14DV.1.3.1 Other than as noted in 4.3.14DV.1.3.2, a transformer employed in PDS/CDM/BDM shall comply with the appropriate standard for transformers, unless the load is part of the equipment, in which case the transformer shall comply with the Temperature Test, 5.2.3.8, and the AC or DC Voltage Test, 5.2.3.2.

4.3.14DV.1.3.2 Pulse and current transformers constructed in a manner other than required by the applicable UL transformer Standard are in compliance with the requirement of 4.3.14DV.1.3.1 when they withstand, without breakdown, a dielectric voltage withstand potential in accordance with the AC or DC Voltage Test, 5.2.3.2, applied between the primary and secondary windings. An example of transformer constructions for which this applies are those that rely upon magnet wire coating to provide isolation instead of interwinding tape.

4.3.15DV D2 *Addition:*

4.3.15DV.1 Blower motors

4.3.15DV.1.1 Other than blower motors located in a Class 2 (see DVC.1.4), Limited Voltage/Current (see DVC.1.5) or Limiting Impedance (see DVC.1.7) secondary circuit, each blower motor shall be provided with:

a) Locked rotor protection in accordance with 4.3.15DV.1.2; and,

b) An enclosure in accordance with Enclosures, Annex DVD.

4.3.15DV.1.2 The locked rotor protection required by 4.3.15DV.1.2 shall:

a) Comply with the thermal protection requirements in the Standard for Overheating Protection for Motors, UL 2111; or,

b) Comply with the impedance protection requirements in the Standard for Overheating Protection for Motors, UL 2111; or,

c) Involve an alternative protection means that is shown by test to be equivalent to the protection specified in (a).

4.3.15DV.1.3 Regarding 4.3.15DV.1.2(c), an example of an alternative protection means is the use of fusing to limit the locked rotor temperature of the blower motor windings in accordance with the thermal protection requirements in the Standard for Overheating Protection for Motors, UL 2111. The fusing in this example shall be branch circuit or supplementary types in accordance with the UL 248 series.

4.3.16DV D2 *Addition:*

4.3.16DV.1 Fuseholders

4.3.16DV.1.1 Other than as noted in 4.3.16DV.1.2 and 4.3.16DV.1.3, power conversion equipment incorporating a disconnect switch and a fuseholder shall be so constructed that

when the switch contacts are open, the fuse may be replaced without touching any energized part.

4.3.16DV.1.2 A control-circuit fuse arrangement is not required to comply with this requirement when the fuse and control-circuit load – other than a fixed control-circuit load, such as a pilot lamp – are within the same enclosure.

4.3.16DV.1.3 This requirement is not applicable to fuses that are non-accessible and are not for renewal. Fuses are considered non-accessible when destruction or damage to the enclosure or some portion of the assembly containing the fuseholder is required to contact LIVE PARTS.

4.4 Protection against thermal hazards

4.4.1 Minimizing the risk of ignition

The risk of ignition due to high temperature shall be minimized by the appropriate selection and use of components and by suitable construction.

Electrical components shall be used in such a way that their maximum working temperature under normal load conditions is less than that necessary to cause ignition of the surrounding materials with which they are likely to come into contact. The limits in Table 15 shall not be exceeded for the surrounding material.

Where it is not practical to protect components against overheating under fault conditions, all materials in contact with such components shall be of flammability class V-1, according to IEC 60695-11-10, or better.

Compliance with 4.4.2 to 4.4.5 shall be confirmed by inspection of component and material data sheets and, where necessary, by test.

4.4.1DV D2 *Modification:*

4.4.1DV.1 There are no requirements for monitoring of temperature under fault conditions.

4.4.1DV.2 When the temperature on the back of equipment exceeds 90 °C (194 °F) per Table 16, when operated under normal conditions, the construction shall be such that only the points of support are in contact with a plane mounting surface with the remainder of the equipment spaced at least 1/4 in (6,4 mm) from the mounting surface. In addition, the mounting surface shall not attain a temperature higher than 90 °C during the temperature test.

4.4.2 Insulating materials

4.4.2.1 General

A material which is used for the direct support of an uninsulated LIVE PART shall comply with the following requirements.

NOTE A material is typically considered to be in direct support of an uninsulated LIVE PART when:

a) it is in direct physical contact with the uninsulated LIVE PART, and

b) it physically supports or maintains the relative position of the uninsulated LIVE PART.

The insulating material shall be suitable for the maximum temperature it attains as determined by the temperature rise test of 5.2.3.8. Consideration shall be given as to whether or not the insulating material additionally provides mechanical strength and whether or not the part can be subject to impact during use.

4.4.2.2 Material requirements

The insulating material shall have a CTI of 100 or greater.

No further evaluation is required when generic materials are used according to Table 14.

Table 14
Generic materials for the direct support of uninsulated LIVE PARTS

Generic material	Minimum thickness (mm)	Maximum temperature (° C)
Any cold-moulded composition	No limit	No limit
Ceramic, porcelain	No limit	No limit
Diallyl phthalate	0,7	105
Epoxy	0,7	105
Melamine	0,7	130
Melamine-phenolic	0,7	130
Phenolic	0,7	150
Unfilled nylon	0,7	105
Unfilled polycarbonate	0,7	105
Urea formaldehyde	0,7	100

In other cases, the insulating material shall comply with the glow-wire test described in 5.2.5.2 at a test temperature of 850 °C. The alternative hot wire ignition test of 5.2.5.3 may be used.

Where an insulating material is used in a device that incorporates switching contacts, and is within 12,7 mm of the contacts, it shall comply with the high current arcing ignition test of 5.2.5.1.

The manufacturer may provide data from the insulating material supplier to demonstrate compliance with the above requirements. In this case, no further testing is required.

4.4.2.2DV D2 *Modification to replace 4.4.2.2 with the following:*

4.4.2.2DV.1 Other than as noted in 4.4.2.2DV.2 – 4.4.2.2DV.8, a material that is used for the direct support of an uninsulated LIVE PART shall comply with the Flammability, Relative Thermal Index (RTI), Hot Wire Ignition (HWI), High-Current Arc Resistance to Ignition (HAI), and Comparative Tracking Index (CTI) values indicated in Table 4.4.2.2DV.1. A material is in direct support of an uninsulated LIVE PART when:

a) It is in direct physical contact with the uninsulated LIVE PART; and

b) It serves to physically support or maintain the relative position of the uninsulated LIVE PART.

4.4.2.2DV.2 Materials without HWI Performance Level Category (PLC) values or with HWI PLC values higher (worse) than those required by Table 4.4.2.2DV.1 must comply with the

end-product Abnormal Overload Test in accordance with the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C.

4.4.2.2DV.3 Materials without HAI Performance Level Category (PLC) values or with HAI PLC values higher (worse) than those required by Table 4.4.2.2DV.1 must comply with the end-product Arc Resistance Test in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

4.4.2.2DV.4 Materials used in devices that do not incorporate contacts are not required to comply with the HAI Performance Level Category PLC requirements.

4.4.2.2DV.5 Materials that are used in devices that incorporate contacts and are not used within 1/2 in (12,7 mm) of the contacts are not required to comply with the HAI Performance Level Category PLC requirements.

4.4.2.2DV.6 Materials without CTI Performance Level Category PLC values or with CTI PLC values higher (worse) than the CTI required by Table 4.4.2.2DV.1 must comply with the end-product Arc Resistance Test in accordance with the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C.

4.4.2.2DV.7 Materials without CTI Performance Level Category PLC values or with CTI PLC values higher (worse) than the CTI required by Table 4.4.2.2DV.1 comply with the intent of CTI PLC requirement when:

a) They have a High-Voltage-Arc Tracking (HVTR) PLC value of 1 or lower (better); or

b) The creepage distances between the uninsulated LIVE PARTS is 1/2 in (12,7 mm) minimum.

Table 4.4.2.2DV.1
Minimum material characteristics for the direct support of uninsulated LIVE PARTS

UL 94 Flame Class	RTI Elec	HWI[b]	HAI[b]	CTI[c, d, e]
HB	a	2	1	3
V-2	a	2	2	3
V-1	a	3	2	3
V-0	a	4	3	3

[a] The electrical RTI value of a material is to be determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B by test. This material characteristic is dependent upon the minimum thickness at which the material is being used and shall not be exceeded during the Temperature Test, 5.2.3.8.

[b] The HAI and HWI Performance Level Category (PLC) value of a material is to be determined by test in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. This material characteristic is dependent upon the minimum thickness at which the material is being used.

[c] The CTI PLC value of a material is to be determined by test in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. This material characteristic is not dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a CTI value, the material is evaluated as having the same CTI value found for the greater thickness. The CTI value applies to insulating materials used in pollution degree 3 environments for voltages of 600 V or less. For equipment where pollution degree 1 or 2 is maintained, an insulating material shall have a CTI PLC of 4 or less. For equipment rated 601 – 1500 volts, see footnote (e).

Table 4.4.2.2DV.1 Continued on Next Page

Table 4.4.2.2DV.1 Continued

UL 94 Flame Class	RTI Elec	HWI[b]	HAI[b]	CTI[c, d, e]
[d] A material without a CTI PLC value or with a CTI PLC value greater (worse) than the value required by Table 4.4.2.2DV.1 shall have a proof tracking index of 175 when used in pollution degree 3 environment or a proof tracking index of 100 when used in pollution degree 1 or 2 environment as determined by the end-product Proof Tracking Test specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. [e] For equipment having rated supply voltage 601 – 1500 volts, the insulating material shall not track beyond one inch in less than 60 minutes using the time to track method of the Inclined Plane Tracking Test specified in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. The voltage for the Inclined Plane Tracking Test shall be not less than the RATED VOLTAGE of the equipment.				

4.4.2.2DV.8 No additional evaluation is required for the direct support of uninsulated live parts when the generic materials used comply with Table 14. Each material shall be used within its minimum thickness and its RTI value shall not be exceeded during the Temperature Rise Test, 5.2.3.8.

4.4.2.2DV.9 For equipment having rated supply voltage 601 – 1 500 V, an insulating material used as direct or indirect support of an uninsulated LIVE PART shall comply with 4.4.2.2DV.1, except for the CTI requirement specified in 4.4.2.2DV.1.

4.4.2.2DV.10 For equipment having rated supply voltage 601 – 1 500 V, an insulating material used as direct or indirect support of an uninsulated LIVE PART shall comply with The Inclined-Plane Tracking Test of the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C. The test may be conducted at the application (rated) voltage.

4.4.3 Flammability of enclosure materials

Materials used for enclosures of PDS shall meet the test requirements of 5.2.5.4.

Metals, ceramic materials, and glass which is heat-resistant tempered, wired or laminated, are considered to comply without test.

Materials are considered to comply without test if, in the minimum thickness used, the material is of flammability class 5VA, according to IEC 60695-11-20.

Components which fill an opening in an enclosure, and which are intended to be mounted in this way, need not be evaluated for compliance with the flammability requirements of 5.2.5.4, provided that the components comply with the flammability aspects of the relevant IEC component standard.

NOTE Examples of these components are fuse-holders, switches, pilot lights, connectors and appliance inlets.

Compliance is checked by visual inspection and, where necessary, by test.

The manufacturer may provide data from the insulating material supplier to demonstrate compliance with the above requirements. In this case, no further testing is required.

4.4.3DV D2 *Modification:*

Compliance with flammability class 5VA shall be evaluated in accordance with Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

4.4.4 Temperature limits

4.4.4DV D2 *Modification to add the following:*

4.4.4DV.1 The environmental temperature addressed in the USA is 0 – 40 °C, (32 – 104 °F) unless otherwise stated.

4.4.4DV.2 Equipment shall be rated for service in an AMBIENT TEMPERATURE of 40 °C (104 °F) or at a higher or lower AMBIENT TEMPERATURE at an interval from 40 °C (104 °F) in a whole number multiple of ±5 °C (9 °F), such as 45, 50, 55, 60.

4.4.4DV.3 PDS/CDM/BDM tested under the conditions described in 5.2.3.8 shall not attain a temperature at any point that will adversely affect any materials employed in the equipment, and shall not exceed the values specified in Table 15DV and Table 16.

4.4.4.1 Internal parts

Equipment and its component parts shall not attain temperatures in excess of those in Table 15 when tested in accordance with the ratings of the equipment.

Table 15
Maximum measured temperatures for internal materials and components

	Materials and components	Thermometer method (° C)	Resistance method (° C)
1	Rubber- or thermoplastic-insulated conductors[a]	75	
2	USER TERMINALS[b]	c	
3	Copper bus bars and connecting straps	d	
4	Insulation systems		
	Class A (105)	105	125
	Class E (120)	120	135
	Class B (130)	125	145
	Class F (155)	135	155
	Class H (180)	155	175
	Class N (220)	195	215
5	Phenolic composition[a]	165	
6	On bare resistor material	415	
7	Capacitor	e	
8	Power switching semiconductors	f	
9	PWBs	g	
10	Liquid cooling medium	h	

[a] The limitation on phenolic composition and on rubber and thermoplastic insulation does not apply to compounds which have been investigated and found to meet the requirements for a higher temperature.

[b] The temperature on a wiring terminal or lug is measured at the point most at risk of being contacted by the insulation of a conductor installed as in actual service.

Table 15 Continued on Next Page

Table 15 Continued

Materials and components	Thermometer method (° C)	Resistance method (° C)
[c] The maximum terminal temperature shall not exceed 15 °C more than the insulation temperature rating of the conductor or cable specified by the manufacturer (see 6.3.6.4).		
[d] The maximum permitted temperature is determined by the temperature limit of support materials or insulation of connecting wires or other components. A maximum temperature of 140 °C is recommended.		
[e] For a capacitor, the maximum temperature specified by the manufacturer shall not be exceeded.		
[f] The maximum temperature on the case shall be the maximum case temperature for the applied power dissipation specified by the semiconductor manufacturer.		
[g] The maximum operating temperature of the PWB shall not be exceeded.		
[h] The maximum temperature of the cooling medium, specified by the manufacturer of the medium or determined from the known characteristics of the medium, shall not be exceeded.		

The resistance method for temperature measurement as specified in Table 15 consists of the calculation of the temperature rise of a winding using the equation:

$$\Delta t = \frac{r_2}{r_1}(k + t_1) - (k + t_2)$$

where:

- Δt is the temperature rise;
- r_2 is the resistance at the end of the test (Ω);
- r_1 is the resistance at the beginning of the test (Ω);
- t_1 is the ambient temperature at the beginning of the test (° C);
- t_2 is the ambient temperature at the end of the test (° C);
- k is 234,5 for copper, 225,0 for electrical conductor grade (EC) aluminium; values of the constant for other conductors shall be determined.

Table 15DV D2 *Modification to replace Table 15 with the following:*

Table 15DV
Maximum measured temperatures for internal materials and components

	Materials and components	Thermometer method °C	Resistance method °C
1	Rubber- or thermoplastic-insulated conductors	a	
2	USER TERMINALS[b]	c, i, j, k, l	
3	Copper bus bars and connecting straps	d	
4	Insulation systems		
	Class A (105)	105	125

Table 15DV Continued on Next Page

Table 15DV Continued

	Materials and components	Thermometer method °C	Resistance method °C
	Class E (120)	120	135
	Class B (130)	125	145
	Class F (155)	135	155
	Class H (180)	155	175
	Class N (220)	195	215
5	Phenolic composition[a]	165	
6	On bare resistor material	415	
7	Capacitor	e	
8	Power switching semiconductors	f	
9	PWBs	g	
10	Liquid cooling medium	h	

[a] The limitation on phenolic composition does not apply to compounds which have been investigated and found to meet the requirements for a higher temperature. For rubber- or thermoplastic-insulated conductors, the temperature shall not exceed the maximum operating temperature specified by the conductor manufacturer.

[b] The temperature on a wiring terminal or lug is measured at the point most at risk of being contacted by the insulation of a conductor installed as in actual service.

[c] Other than as modified by footnote k, the maximum terminal temperature shall not exceed 15 °C more than the insulation temperature rating of the conductor or cable specified by the manufacturer (see 6.3.6.4).

[d] The maximum permitted temperature is determined by the temperature limit of support materials or insulation of connecting wires or other components. A maximum temperature of 140 °C is recommended.

[e] For a capacitor, the maximum temperature specified by the manufacturer shall not be exceeded.

[f] The maximum temperature on the case shall be the maximum case temperature for the applied power dissipation specified by the semiconductor manufacturer.

[g] The maximum operating temperature of the PWB shall not be exceeded.

[h] The maximum temperature of the cooling medium, specified by the manufacturer of the medium or determined from the known characteristics of the medium, shall not be exceeded.

[i] See 6.3.6.4DV.1.5.

[j] In equipment marked for 60 °C (140 °F) supply wire, the terminal temperature shall not exceed 75 °C (167 °F).

[k] In equipment marked for 75 °C (167 °F) supply wire, the terminal temperature shall not exceed 75 °C (167 °F) for connectors marked AL7CU and for connectors marked AL9CU the terminal temperature shall not exceed 90 °C (194 °F).

[l] Equipment marked for 60/75 °C supply wires shall comply with both notes j and k of this table.

4.4.4.2 External parts of CDM

The maximum temperature for accessible exterior parts of the CDM shall be in compliance with Table 16. It is permitted that parts have temperatures exceeding these values, but they shall then be marked with a warning statement as given in 6.4.3.4. Under no circumstances shall the temperature of accessible parts exceed 150 °C.

Table 16
Maximum measured temperatures for external parts of the CDM

Part	Material	
	Metal (° C)	Thermoplastic or glass (° C)
User operated devices (knobs, handles, switches, displays, etc.).	55	65
Enclosure parts accessible to user by casual contact.	70	80
Enclosure parts where they contact building materials upon installation.	90	90

4.4.5 Specific requirements for liquid cooled PDS

NOTE Sealed heat-pipe cooling systems, used to transfer heat from a hot component to a heat sink, are not considered to be liquid cooling systems in this international standard. However, the possible failure of such components should be considered during the circuit analysis of 4.2.

4.4.5.1 Coolant

The specified coolant (see 6.2) shall be suitable for the anticipated ambient temperatures. Coolant temperature in operation shall not exceed the limit specified in Table 15.

4.4.5.1DV D2 *Modification:*

Unless the PDS/BDM/CDM is rated and marked for a different temperature range, the anticipated AMBIENT TEMPERATURE is 0 – 40 °C (32 – 104 °F).

4.4.5.2 Design requirements

4.4.5.2.1 Corrosion resistance

All cooling system components shall be suitable for use with the specified coolant. They shall be corrosion resistant and shall not corrode as a result of electrolytic action or prolonged exposure to the coolant and/or air.

4.4.5.2.2 Tubing, joints and seals

Cooling system tubing, joints and seals shall be designed to prevent leakage during excursions of pressure over the life of the equipment. The entire cooling system including tubing shall satisfy the requirements of the Hydrostatic pressure test of 5.2.7.

4.4.5.2.2DV D2 *Modification to add the following:*

Tubing used to connect refrigerant-containing components shall comply with the minimum wall thickness requirements of Table 4.4.5.2.2DV.1 and with the Hydrostatic Pressure Test requirements of 5.2.7.

Table 4.4.5.2.2DV.1
Tubing Wall Thickness

Outside diameter		Minimum wall thickness,[a] in (mm)					
		Copper				Steel	
		Protected		Unprotected			
in	(mm)						
3/16	(4,76)	0,0245	(0,62)	0,0265	(0,67)	0,025	(0,64)
1/4	(6,35)	0,0245	(0,62)	0,0265	(0,67)	0,025	(0,64)
5/16	(7,94)	0,0245	(0,62)	0,0285	(0,72)	0,025	(0,64)
3/8	(9,53)	0,0245	(0,62)	0,0285	(0,72)	0,025	(0,64)
1/2	(12,70)	0,0245	(0,62)	0,0285	(0,72)	0,025	(0,64)
5/8	(15,88)	0,0315	(0,80)	0,0315	(0,80)	0,032	(0,81)
3/4	(19,05)	0,0315	(0,80)	0.0385	(0,98)	0,032	(0,81)
7/8	(22,23)	0,0410	(1,04)	0,0410	(1,04)	0,046	(1,17)
1	(25,40)	0,0460	(1,17)	0,0460	(1,17)	0,046	(1,17)
1-1/8	(28,58)	0,0460	(1,17)	0,0460	(1,17)	0,046	(1,17)
1-1/4	(31,75)	0,0505	(1,28)	0,0505	(1,28)	0,046	(1,17)
1-3/8	(34,93)	0,0505	(1,28)	0,0505	(1,28)	0,046	(1,17)
1-1/2	(38,10)	0,0555	(1,41)	0,0555	(1,41)	0,062	(1,58)
1-5/8	(41,3)	0,0555	(1,410)	0,0555	(1,410)	–	–
2-1/8	(54,0)	0,0640	(1,626)	0,0640	(1,626)	–	–
2-5/8	(66,7)	0,0740	(1,880)	0,0740	(1,880)	–	–

[a] Nominal wall thickness of tubing will have to be greater than the thickness indicated to maintain the minimum wall thickness.

Note: "Protected" implies that the tubing is shielded by the cabinet or assembly, to the extent that unintended damage caused by objects such as tools falling on or otherwise striking the tubing during handling and after INSTALLATION of the unit is prevented. This protection may be provided in the form of baffles, channels, flanges, perforated metal, or equivalent means. If a cabinet is employed for the intended INSTALLATION of a unit, the tubing is considered shielded. Tubing not so shielded is considered to be unprotected.

4.4.5.2.3 Provision for condensation

Where internal condensation occurs during normal operation or maintenance, measures shall be taken to prevent degradation of insulation. In those areas where such condensation is expected, clearance and creepage distances shall be evaluated at least for a pollution degree 3 environment (see Table 6), and provision shall be made to prevent accumulation of water (for example by providing a drain).

4.4.5.2.4 Leakage of coolant

Measures shall be taken to prevent leakage of coolant onto LIVE PARTS as a result of normal operation, servicing, or loosening of hoses or other cooling system parts during the EXPECTED LIFETIME. If a pressure relief mechanism is provided, this shall be located so that there shall be no leakage of coolant onto live components when it is activated.

4.4.5.2.4DV D2 *Modification to add the following:*

When provided, a pressure relief mechanism shall comply with the Hydrostatic Pressure test (see 5.2.7). Coolant released as the result of operation of a pressure relief mechanism shall not be released into any electrical compartment.

4.4.5.2.5 Loss of coolant

Loss of coolant from the cooling system shall not result in thermal hazards, explosion, or shock hazard. The requirements of the Loss of coolant test of 5.2.4.5.4 shall be satisfied.

4.4.5.2.6 Conductivity of coolant

When the coolant is intentionally in contact with LIVE PARTS (for example non-earthed heatsinks), the conductivity of the coolant shall be continuously monitored and controlled, in order to avoid hazardous current flow through the coolant.

4.4.5.2.7 Insulation requirements for coolant hoses

When the coolant is intentionally in contact with LIVE PARTS (for example non-earthed heatsinks), the coolant hoses form a part of the insulation system. Depending on the location of the hoses, the requirements of 4.3.6 for FUNCTIONAL or BASIC INSULATION or PROTECTIVE SEPARATION shall be applied where relevant.

4.4.6 Motor overload and overtemperature protection

4.4.6.1 Means of protection

A motor of a PDS shall be protected against overtemperature. Depending on the application of the motor, one or more of the following means of protection for each motor driven shall be selected by the PDS manufacturer:

a) thermal or electronic overload relay that complies with the applicable requirements in IEC 60947-4-1;

b) a CDM/BDM with ELECTRONIC MOTOR OVERLOAD PROTECTION according to 4.4.6.2, which might include

  i) THERMAL MEMORY RETENTION according to 4.4.6.3, and/or

  ii) speed sensitivity according to 4.4.6.4.

c) a CDM/BDM with monitoring and automatic reduction of motor current based upon a signal from a thermal sensor mounted in or on the motor according to 4.4.6.5;

d) an embedded motor thermal protection which disconnects the motor;

e) information in accordance with 6.3.8.1.

NOTE 1 a) and d) are the only possible motor overload protections in the case that several motors in parallel are supplied from the same CDM/BDM motor power output.

For information requirements, see 6.3.8.

NOTE 2 In the United States, compliance with NFPA 70 overload protection according to NFPA 70:2014, 430.32 are achieved by a), b), c), or d); compliance with NFPA 70 overtemperature according to NFPA 70:2014, 430.126 is achieved by b) i) and ii), c), or d).

4.4.6.1DV DR *Modification:*

4.4.6.1DV.1 The number, arrangement, and ratings or settings of protective devices intended to provide motor and branch-circuit overload protection shall be as required by Part III, Article 430 of the National Electrical Code, ANSI/NFPA 70.

4.4.6.2 CDM/BDM with ELECTRONIC MOTOR OVERLOAD PROTECTION

ELECTRONIC MOTOR OVERLOAD PROTECTION shall comply with 5.2.8.1 to 5.2.8.4 and is subjected to the requirements in 5.2.9.

Adjustable ELECTRONIC MOTOR OVERLOAD PROTECTION shall not be adjustable in such a way that the limits of Table 29 are exceeded.

a) For PDS where motor and CDM/BDM are known, limits other than those in Table 29 can be specified and tested in accordance with 5.2.8.1 to 5.2.8.4.

b) For information requirements, see 6.3.8.2.

4.4.6.2DV DR *Modification*

4.4.6.2DV.1 Adjustable electronic motor overload protection may be adjustable in such a way that the limit of 1.2 times the current setting with a tripping time of 2 h of Table 29 is exceeded, however 1.25 times the current setting with a tripping time of 2 h shall not be exceeded.

4.4.6.2DV.2 Adjustable electronic motor overload protection may be adjustable such that the maximum tripping times of 8 minutes and 20 seconds in Table 29 are exceeded, provided:

a) The alternate tripping times are associated with a specific standard overload trip class as defined in 5.2.8.4DV (e.g. Class 30), and

b) The CDM/BDM complies with the testing of 5.2.8.1 to 5.2.8.4 in accordance with Table 29 when adjusted for a Class 20 trip curve, and

c) The CDM/BDM complies with the testing of 5.2.8.1 to 5.2.8.4 in accordance with 5.2.8.4DV when adjusted for a higher standard class trip curve (e.g. Class 30)

4.4.6.3 CDM/BDM with ELECTRONIC MOTOR OVERLOAD PROTECTION with THERMAL MEMORY RETENTION

ELECTRONIC MOTOR OVERLOAD PROTECTION with THERMAL MEMORY RETENTION shall comply with 5.2.8.1 to 5.2.8.6 and is subjected to the requirements in 5.2.9.

4.4.6.4 CDM/BDM with ELECTRONIC MOTOR OVERLOAD PROTECTION which is speed sensitive

ELECTRONIC MOTOR OVERLOAD PROTECTION that is speed sensitive shall comply with 5.2.8.1 to 5.2.8.7 and is subjected to the requirements in 5.2.9.

4.4.6.5 CDM/BDM providing monitoring and automatic reduction of motor current by means of thermal sensors

CDM/BDM intended to be used with motors that have thermal protection or thermal sensor in or on the motors requiring signal interface shall be provided with means to connect to that protection.

Insulation requirements for the connection of the thermal protector or thermal sensor shall be taken into account.

4.4.6.5DV DE *Modification*

Automatic reduction of motor current includes TRIP.

4.5 Protection against energy hazards

4.5.1 Electrical energy hazards

Failure of any component within the PDS shall not release sufficient energy to lead to a hazard, for example, expulsion of material into an area occupied by personnel.

Where appropriate, the possibility should be considered of energy transfer from the PDS motor to the CDM/BDM when the driven equipment over-runs the CDM/BDM control.

NOTE There are no tests in this part of IEC 61800 for this requirement.

4.5.2 Mechanical energy hazards

4.5.2.1 General

Mechanical failure due to critical speed considerations or torsional problems can create a hazard to operating personnel. These considerations are applicable to all PDS, although they are increasingly significant with increased equipment size, such as with HIGH-VOLTAGE PDS. As these subjects are application-dependent, it is not possible to include specific requirements in this standard.

4.5.2.2 Critical torsional speed

Where appropriate, communication should be established between PDS/CDM/BDM supplier, driven equipment supplier, installer, and user with respect to any anticipated critical torsional speed considerations.

4.5.2.3 Transient torque analysis

Transient torque analysis is an important design tool for PDS to check torsional stresses in the whole mechanical string. For example, the following operating conditions are areas of concern.

- start-up;
- single-phase or three-phase short-circuit at the terminals of an a.c. motor;
- impact of possible commutation failure of an a.c. CDM;
- impact of the harmonic components of an a.c. CDM;
- field supply loss in a d.c. CDM;
- short-circuit at the armature terminals of a d.c. motor.

Where appropriate, communication should be established with the driven equipment supplier and the information required by 6.3.5.4 provided.

4.5.2.3DV D2 ***Modification to add the following:***

A DC drive shall not incorporate overcurrent protection in a motor field supply circuit unless the drive incorporates a detector that senses loss of field current or voltage and prevents over-speed upon field loss.

4.5.3 Acoustic noise emission

Under consideration. Requirements for acoustic noise emission are often present in local regulations. In the absence of such regulations, it is recommended that the limits of IEC 60034-9 should be applied.

4.6 Protection against environmental stresses

The PDS/CDM/BDM shall not present any hazards as a result of specified environmental stresses. As a minimum, the PDS/CDM/BDM shall satisfy the environmental endurance tests of 5.2.6. More demanding requirements may be specified by the manufacturer, in which case less demanding tests of this standard do not need to be performed.

4.6DV D2 ***Modification:***

The environmental endurance tests of 5.2.6 are not applicable.

4.7DV D2 ***Addition:***

4.7DV.1 Plenum rated drives

4.7DV.1.1 Drives intended for use in air handling ducts and plenums shall be of the enclosed type and shall comply with all other applicable requirements of this standard.

4.7DV.1.2 Drives with enclosures that are either whole or in part non-metallic and intended to be installed in air-handling spaces shall additionally comply with the requirements in the Standard for Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces, UL 2043.

4.7DV.1.3 The requirements in 4.7DV.1.2 do not apply to the following:

a) Air filters, drive belts, wire insulation, paint applied for corrosion protection, or tubing of material equivalent to one of the types of wire insulation permitted by this Standard;

b) Gaskets forming air or water seals between metal parts;

c) Miscellaneous small parts such as refrigerant line bushings or insulating bushings, resilient or vibration mounts, wire ties, clamps, labels, or drain line fittings having a total exposed surface area not exceeding 25 square inches (161.29 cm^2);

d) An adhesive that, when tested in combination with the specific insulating material, complies with the requirement.

4.7DV.1.4 Metallic enclosure surfaces, including those which are ventilated, are suitable for use in air handling ducts and plenums without further investigation.

4.8DV DR *Addition:*

4.8DV.1 Position of operating handles

4.8DV.1.1 When a circuit breaker or switch is mounted such that movement of the operating handle, either vertically or rotationally, between the on and off positions results in one position being above the other position, the upper position shall be the on position. The requirement does not apply to a circuit breaker or switch that is operated horizontally or that is operated rotationally and the on and off positions are at the same level, nor to a switching device having two on positions, such as a transfer switch or a double throw switch.

4.8DV.1.2 All floor mounted equipment shall comply with 4.8DV.1.3 and 4.8DV.1.4. Wall mounted equipment with enclosures taller than 79 inches (2,0 m) shall be considered to be floor mounted equipment with respect to these requirements.

4.8DV.1.3 External handles and push-buttons shall be located in accordance with the following:

> **a) Every switch and circuit breaker handle shall be installed such that the handle is not more than 79 inches (2,0 m) above the floor.**
>
> **b) Operating handles requiring more than 50 lbf (222 N) to operate shall not be higher than 66 inches (1,7 m) in either the open or closed position.**

4.8DV.1.4 In determining compliance with 4.8DV.1.3, measurements shall be made to the center of the handle grip with the handle in the highest possible position. Where the handle grip is not clearly defined, it shall be considered to be at a point 3 inches (76 mm) in from the end of the handle.

4.8DV.1.5 If the mechanism of a switching device is such that automatic operation of a switch, or operation of a remote or automatic tripping devices will permit sudden movement of an operating handle, the motion of the handle shall be restricted or the handle shall be guarded to prevent injury to persons in the vicinity of the handle.

4.9DV D2 *Addition:*

4.9DV.1 Auxiliary units

4.9DV.1.1 Auxiliary units such as portable programmers intended to be used only on a temporary basis, to diagnose or program PDS/CDM/BDM shall comply with the requirements in the Standard for Information Technology Equipment Safety – Part 1: General Requirements, UL 60950-1. These units shall be evaluated as a subsystem of the PDS/CDM/BDM.

4.10DV D2 *Addition:*

4.10DV.1 Accessories

4.10DV.1.1 Equipment having provision for the use of an accessory to be attached in the field shall comply with the requirements in this standard with the accessory installed, and

the accessory shall comply with the requirements for the equipment for which it is intended. See Instructions and Marking Pertaining to Accessories, 6.3.6.8DV.

4.10DV.1.2 As part of the investigation, an accessory shall be tested and trial-installed. The accessory shall be capable of being installed, and the instructions shall be detailed and accurate. The INSTALLATION shall be capable of being accomplished using tools that are readily available unless a special tool is provided with the accessory.

4.11DV D2 *Addition:*

4.11DV.1 Securement of LIVE PARTS

4.11DV.1.1 Other than as noted in 4.11DV.1.2, an uninsulated LIVE PART, including a terminal, shall be secured to its supporting surface by a method other than friction between surfaces so that it is prevented from turning or shifting in position when such motion results in a reduction of the required spacings.

4.11DV.1.2 A pressure terminal connector is not required to be prevented from turning when no spacings less than those required result when the terminals are turned 30 degrees toward each other, or toward other uninsulated parts of opposite polarity, or toward grounded metal parts.

4.11DV.1.3 A live screwhead or nut on the underside of an insulating base shall be prevented from loosening and shall be insulated or spaced from the mounting surface. This is accomplished by:

a) Countersinking parts by at least 1/8 in (3,2 mm) and covering them with a waterproof, insulating sealing compound that does not degrade at 15 °C (27 °F) higher than its normal operating temperature and not less than 65 °C (149 °F); or

b) Securing such parts and insulating them from the mounting surface by a barrier, or the equivalent, or by clearances and creepage distances specified elsewhere in this standard.

4.12DV D2 *Addition:*

4.12DV.1 Provisions for mounting

4.12DV.1.1 Provisions shall be made for securely mounting power conversion equipment to a supporting surface. A bolt, screw, or other part used to mount a component of the equipment shall not be used for securing the equipment to the supporting surface.

4.13DV D2 *Addition:*

4.13DV.1 Phase reversal protection

4.13DV.1.1 PDS/CDM/BDM provided with phase reversal protection shall interrupt and maintain the interruption of power in all of the motor circuit.

4.14DV D2 *Addition:*

4.14DV.1 Capacitors

4.14DV.1.1 A bus capacitor shall be rated for the voltage and the temperature of the circuit involved. This rating shall be based on the continuous WORKING VOLTAGE rating and the overvoltage surge rating.

4.14DV.1.2 A capacitor bridging FUNCTIONAL INSULATION shall comply with 4.14DV.1.6 or comply with the requirements of the Standard For Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14, be used within its voltage and temperature rating, and be of any Class X or Y which has a peak impulse voltage rating greater than or equal to the required impulse voltage according to 4.3.6.1 – 4.3.6.3 for the circuit the capacitor is bridging. In the case of more than one capacitor in series bridging FUNCTIONAL INSULATION, voltage division shall be considered for both the working voltage and impulse voltage ratings.

Informational note – capacitors commonly referred to as "across the line" or "phase to phase" typically bridge FUNCTIONAL INSULATION.

4.14DV.1.3 Other than as noted in 4.14DV.1.4, a motor starting capacitor employing a liquid dielectric medium more combustible than askarel shall comply with the protected oil filled capacitor requirements, contained in the Standard for Capacitors, UL 810, including faulted overcurrent conditions based on the short circuit rating of the PDS/CDM/BDM. A motor starting capacitor and any associated solid state component shall be evaluated in accordance with the Breakdown of Components Test 5.2.3.6.4.

4.14DV.1.4 When the available fault current is limited by other components in the circuit such as a motor-start winding, the capacitor is able to be tested using a fault current less than the value specified in Table 5.2.3.6.2.1DV.1, and not less than the current established by dividing the rated circuit voltage by the impedance of the other components.

4.14DV.1.5 A non-motor starting capacitor employing a liquid dielectric medium more combustible than askarel, and any associated solid-state component, is only required to be evaluated in accordance with the Breakdown of Components Test 5.2.3.6.4.

4.14DV.1.6 A capacitor bridging FUNCTIONAL INSULATION not in compliance with 4.14DV.1.2 shall be used within its voltage and temperature rating and be subjected to the analysis, and when necessary test, described in 4.2.

4.14DV.1.7 A capacitor bridging BASIC INSULATION shall comply with the requirements of the Standard For Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14, be used within its voltage and temperature rating, and be any Class Y capacitor which has a peak impulse voltage rating greater than or equal to the required impulse voltage according to 4.3.6.1 – 4.3.6.3. Alternately, the capacitor may be a Class X capacitor, comply with the requirements of the Standard For Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14, be used within its temperature rating, and be any Class X capacitor which has a working voltage rating equal to 1.36 times the working voltage across the capacitor and peak impulse voltage rating greater than or equal to the required impulse voltage according to 4.3.6.1 – 4.3.6.3. In the case of both Y and X capacitors, if more than one capacitor is in series bridging BASIC INSULATION, voltage division shall be considered for both the working voltage and impulse voltage ratings.

Informational note – capacitors commonly referred to as "line to earth" or "phase to earth" typically bridge BASIC INSULATION.

4.14DV.1.8 Capacitors bridging functional and BASIC INSULATION in a center-connected network, see Figure 4.14DV.1.

4.14DV.1.9 Capacitors designated C1 and C2 in Figure 4.14DV.1 shall be used within their marked temperature ratings.

4.14DV.1.10 Capacitors designated C1 in Figure 4.14DV.1 shall be in compliance with one of the following with regard to the rated working voltage:

a) Any Class X capacitor with a RATED VOLTAGE greater than or equal to 1.36 times the phase to earth working voltage; or

b) Any Class Y capacitor with a RATED VOLTAGE greater than or equal to the phase to earth working voltage; or

c) Any Class X capacitor with a RATED VOLTAGE greater than or equal to phase to earth working voltage used with a C2 capacitor in compliance with 4.14DV.1.12 (a) or (b); or

d) Any Class X capacitor with a RATED VOLTAGE greater than or equal to phase to earth working voltage and subjected to the analysis of 4.2 with regard to a component failure from phase to earth; or

e) Any capacitor subjected to the analysis of 4.2 with regard to a component failure from phase to phase and used with a C2 capacitor in compliance with 4.14DV.1.12 (a) or (b); or

f) Any capacitor subjected to the analysis of 4.2 with regard to a component failure from phase to phase and phase to earth.

Class X and Class Y capacitors as referenced above are capacitors that shall be in compliance with the requirements of the Standard For Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14.

4.14DV.1.11 Capacitors designated C1 in Figure 4.14DV.1 shall be in compliance with one of the following with regard to the rated impulse voltage:

a) Any Class X or Y capacitor with a rated impulse voltage greater than or equal to the larger of: 1/2 the required phase to phase impulse voltage, or the required phase to earth impulse voltage times C2/(C1 + C2), where C1 and C2 are the capacitance of capacitors C1 and C2 respectively; or

b) Any Class X or Y capacitor with a rated impulse voltage greater than or equal to 1/2 the required phase to phase impulse voltage and used with a C2 capacitor in compliance with 4.14DV.1.13 (a) or (b); or

c) Class X or Y capacitor with a rated impulse voltage greater than or equal to 1/2 the required phase to phase impulse voltage and subjected to the analysis of 4.2 with regard to a component failure from phase to earth; or

d) Any Class X or Y capacitor with a rated impulse voltage greater than or equal to the required phase to earth impulse voltage times C2/(C1 + C2), where C1 and C2 are the capacitance of capacitors C1 and C2 respectively, and subjected to the analysis of 4.2 with regard to a component failure from phase to phase; or

e) Any capacitor subjected to the analysis of 4.2 with respect to a component failure from phase to phase and used with a C2 capacitor in compliance with 4.14DV.1.13 (a) or (b); or

f) Any capacitor subjected to the analysis of 4.2 with respect to a component failure from phase to phase and phase to earth.

Class X and Class Y capacitors as referenced above are capacitors that shall be in compliance with the requirements of the Standard For Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14; and the required phase to phase and phase to earth impulse voltage is according to 4.3.6.1 – 4.3.6.3.

4.14DV.1.12 Capacitors designated C2 in Figure 4.14DV.1 shall be in compliance with one of the following with regard to the rated working voltage:

a) Any Class Y capacitor with a RATED VOLTAGE greater than or equal to the phase to earth working voltage when used with a C1 capacitor in compliance with 4.14DV.1.10 (c) or (e); or

b) Any Class X capacitor with a RATED VOLTAGE greater than or equal to 1.36 times the phase to earth working voltage when used with a C1 capacitor in compliance with 4.14DV.1.10 (c) or (e); or

c) Any Class X or Y capacitor with any RATED VOLTAGE. when used with C1 capacitors in compliance with 4.14DV.1.10 (a), (b), (d), or (f); or

Class X and Class Y capacitors as referenced above are capacitors that shall be in compliance with the requirements of the Standard For Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14.

4.14DV.1.13 Capacitors designated C2 in Figure 4.14DV.1 shall be in compliance with one of the following with regard to the rated impulse voltage:

a) Any Class Y capacitor with a RATED VOLTAGE greater than or equal to the required phase to earth impulse voltage when used with a C1 capacitor in compliance with 4.14DV.1.11 (c) or (e); or

b) Any Class X capacitor with a RATED VOLTAGE greater than or equal to the required phase to earth impulse voltage; or

c) Any Class X or Y capacitor with a RATED VOLTAGE greater than or equal to the required phase to earth impulse voltage multiplied by 3xC1/(3C1 + C2) when used with C1 capacitors according to 4.14DV.1.11 (a), (c), (d), or (f); or

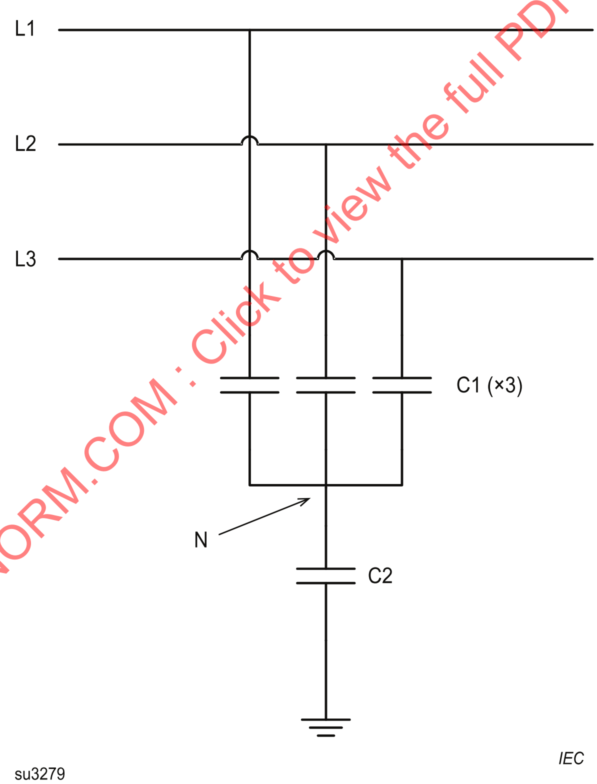
d) Any capacitor with any RATED VOLTAGE when used with C1 capacitors that are Class X or Y with a rated impulse voltage greater than or equal to the required phase to earth impulse voltage.

Class X and Class Y capacitors as referenced above are capacitors that shall be in compliance with the requirements of the Standard For Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14; and the required phase to earth impulse voltage is according to 4.3.6.1 – 4.3.6.3.

4.14DV.1.14 A capacitor bridging two adjacent circuits shall comply with the requirements of the Standard For Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14, be used within its temperature rating, and be any Class X or Y capacitor with a rated impulse voltage greater than or equal to the required impulse voltage according to 4.3.6.1 – 4.3.6.3. A Class Y capacitor shall be rated for the working voltage it bridges, a Class X capacitor shall be equal to 1.36 x the working voltage it bridges. Where two identical capacitors are connected in series, the RATED VOLTAGE shall be greater than or equal to one-half the working voltage across the capacitor series (or 1.36 times half the working voltage for X capacitors), and the rated impulse voltage shall be greater than or equal to one-half the required impulse voltage according to 4.3.6.1 – 4.3.6.3 across the capacitor series.

Figure 4.14DV.1

Capacitors in a Center-Connected Network



4.15DV D2 *Addition:*

4.15DV.1 Isolation devices

4.15DV.1.1 Optical isolators that provide isolation between primary and secondary circuits shall be constructed in accordance with the Standard for Optical Isolators, UL 1577, except

as noted in 4.15DV.1.2. The rated isolation voltage of the optical isolator shall be at least the minimum dielectric voltage withstand rating test voltage required by 5.2.3.2, A.C. or d.c. voltage test, except as noted in 4.15DV.1.3.

4.15DV.1.2 An optical isolator is not required to be subjected to the requirements in the Standard for Optical Isolators, UL 1577, when the internal insulation is of such a material and at such a thickness that it complies with 4.15DV.1.7.3.

4.15DV.1.3 An optical isolator that is constructed in accordance with the requirements in the Standard for Optical Isolators, UL 1577, and rated at a dielectric potential less than that required by the A.C. or d.c. voltage test, 5.2.3.2, complies with 4.15DV.1.1 when the internal insulation is at such thickness that it also complies with 4.15DV.1.7.3(b).

4.15DV.1.4 Power switching semiconductor devices that provide isolation to ground shall be constructed in accordance with the Standard for Electrically Isolated Semiconductor Devices, UL 1557, except as noted in 4.15DV.1.5. The dielectric voltage withstand tests required by UL 1557 shall be conducted at a dielectric potential in accordance with the A.C. or d.c. voltage test, 5.2.3.2, except as noted in 4.15DV.1.6.

4.15DV.1.5 A power switching semiconductor is not required to be subjected to the requirements in UL 1557 when the internal insulation is of such material and at such a thickness that it complies with 4.15DV.1.7.3.

4.15DV.1.6 A power switching semiconductor that is constructed in accordance with UL 1557 and rated at a dielectric potential less than that required by the A.C. or d.c. voltage test, 5.2.3.2, complies with 4.15DV.1.4 when the internal insulation is at such thickness that it also complies with 4.15DV.1.7.3(b).

4.15DV.1.7 Insulating material used as a barrier in lieu of spacings

4.15DV.1.7.1 Insulating material is not prohibited from being used as a barrier in lieu of the clearances and creepage distances required in 4.3.6.4 and 4.3.6.5, respectively.

4.15DV.1.7.2 Insulating material used as a barrier shall comply with the requirements in 4.15DV.1.7.3 when:

a) The material is in direct physical contact with an uninsulated LIVE PART;

b) The material serves to physically support, or maintain the relative position of the uninsulated LIVE PART; and

c) The material is used as a barrier in lieu of the required over surface or through air spacings.

4.15DV.1.7.3 Except as noted in 4.15DV.1.7.4 and 4.15DV.1.7.5, an insulating material used as noted in 4.15DV.1.7.1 shall:

a) Comply with 4.4.2.2DV; and

b) Be at least 0,028 in (0,71 mm) thick.

4.15DV.1.7.4 A material that complies with 4.4.2.2DV and does not comply with the thickness limit in (b) is able to alternatively be subjected to a 5 000 V ac Dielectric Voltage Withstand Test in accordance with the Internal Barrier requirements in the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C.

4.15DV.1.7.5 A material that complies with 4.4.2.2DV and is used in addition to not less than one-half the required through air spacings is able to be less than 0,028 in (0,71 mm) thick, and shall be at least 0,013 in (0,33 mm) thick. This material shall:

a) Have the required mechanical strength when exposed or otherwise subjected to mechanical damage;

b) Be held in place; and

c) Be located so that it is not adversely affected by operation of the equipment in service.

4.15DV.1.7.6 The two requirements noted in 4.15DV.1.7.3 are independent of each other. For example, even when a material complies with 4.4.2.2DV at a thickness less than the 0,028 in (0,71 mm) limit, then the material still is required to be provided at a thickness at least equal to this 0,028 in (0,71 mm) limit or at a thickness as specified by 4.15DV.1.7.4 or 4.15DV.1.7.5.

4.15DV.1.7.7 An insulating material shall also comply with the requirements in 4.15DV.1.7.3 or 4.15DV.1.7.8 when:

a) The material is in direct physical contact with an uninsulated LIVE PART;

b) The material does not serve to physically support or maintain the relative position of that uninsulated LIVE PART; and

c) The material is used as a barrier in lieu of the required over surface, or through air spacings.

4.15DV.1.7.8 The generic insulating materials in Table 4.15DV.1 meet the intent of the requirements for this application without additional evaluation.

Table 4.15DV.1
Generic Materials for Barriers

Generic material	Minimum thickness	RTI, °C
Aramid Paper	0.010 inch (0.25 mm)	105
Cambric	0.028 inch (0.71 mm)	105
Electric Grade Paper	0.028 inch (0.71 mm)	105
Epoxy	0.028 inch (0.71 mm)	105
Mica	0.006 inch (0.15 mm)	105
Mylar (PETP)	0.007 inch (0.18 mm)	105
RTV	0.028 inch (0.71 mm)	105

Table 4.15DV.1 Continued on Next Page

Table 4.15DV.1 Continued

Generic material	Minimum thickness	RTI, °C
Silicone	0.028 inch (0.71 mm)	105
Treated Cloth	0.028 inch (0.71 mm)	105
Vulcanized Fiber	0.028 inch (0.71 mm)	105
NOTE – Each material shall be used within its minimum thickness and its RTI value shall not be exceeded during the Temperature Rise Tests, 5.2.3.8.		

4.15DV.1.7.9 Except as noted in 4.15DV.1.7.10 through 4.15DV.1.7.12, an insulating material shall also comply with the requirements in 4.15DV.1.7.3 when:

a) The material is not in direct physical contact with an uninsulated LIVE PART;

b) The material does not serve to physically support, or maintain the relative position of that uninsulated LIVE PART; and

c) The material is used as a barrier in lieu of the required through air spacings.

4.15DV.1.7.10 The generic insulating materials in Table 14 meet the intent of the requirements for this application without additional evaluation.

4.15DV.1.7.11 Materials that are located at least 1/32 in (0,8 mm) from uninsulated LIVE PART are not required to comply with the Hot Wire Ignition (HWI), High – Current Arc Resistance to Ignition (HAI) or Comparative Tracking Index (CTI) Performance Level Category (PLC) requirements.

4.15DV.1.7.12 Materials that are located at least 1/2 inch (12,7 mm) from uninsulated LIVE PART are not required to comply with the Hot Wire Ignition (HWI), High – Current Arc Resistance to Ignition (HAI) or Comparative Tracking Index (CTI) Performance Level Category (PLC) requirements and also are not required to comply with the RTI requirements.

4.16DV D2 *Addition:*

4.16DV.1 BDM/CDM/PDS supplied by photovoltaic (PV) modules

4.16DV.1.1 BDM/CDM/PDS intended to receive power from photovoltaic (PV) modules and panels

4.16DV.1.1.1 Photovoltaic modules or panels used with BDM/CDM/PDS shall comply with UL 1703. If the photovoltaic modules or panels are not provided with the BDM/CDM/PDS, the installation instructions shall specify that PV modules and panels shall comply with UL 1703. See 6.3.6.8DV.2.

4.16DV.1.1.2 A power converter stage used with the BDM/CDM/PDS which receives power from PV modules or panels and converts it for use by the BDM/CDM/PDS shall comply with UL 1741.

5 Test requirements

5.1 General

5.1.1 Test objectives and classification

Testing, as defined in this Clause 5, is required to demonstrate that PDS is fully in accordance with the requirements of this part of IEC 61800. Testing may be waived if permitted by the relevant requirements subclause of Clause 4.

The subclauses in this Clause 5 describe the procedures to be adopted for the testing of PDS. The tests are classified as:

• *type tests*;

• *routine tests;*

• *sample tests*.

The manufacturer and/or test house shall ensure that the specified maximum and/or minimum environment (or test) values are imposed, taking tolerances and measurement uncertainties fully into account.

Warning ! These tests can result in hazardous situations. Suitable precautions shall be taken to avoid injury.

5.1.2 Selection of test samples

When testing a range or series of similar products, it may not be necessary to test all models in the range. Each test should be performed on a model or models having mechanical and electrical characteristics that adequately represent the entire range for that particular test.

5.1.3 Sequence of tests

In general, there is no requirement for tests to be performed in a set sequence, nor is it required that they are all performed on the same sample of equipment. However, the pass criteria for some of the tests require that they are followed by one or more further tests.

5.1.4 Earthing conditions

The manufacturer shall state the acceptable earthing systems (see 4.3.6.1.4) for the PDS. Test requirements shall be determined using the worst-case (most stressful) earthing system allowed by the manufacturer. Earthing systems may include:

• neutral to earth;

• line to earth;

• neutral to earth through high impedance;

• isolated (not earthed).

The unacceptable systems shall be indicated as

• forbidden;

• with modification of values and/or safety levels which shall be quantified through TYPE TEST.

5.1.4DV D2 *Modification to replace 5.1.4 with the following:*

The manufacturer shall rate the PDS/CDM/BDM for its acceptable earthing systems according to 4.3.6.1.4DV.2 and 4.3.6.1.4DV.3. Where the earthing system may be a factor in test results, the individual test requirements will address the worst-case (most stressful) earthing system to be used for the test.

5.1.5 Compliance

Compliance with this part of IEC 61800 shall be verified by carrying out the appropriate tests specified in this Clause 5.

Compliance may only be claimed if all relevant tests have been passed.

Compliance with construction requirements and information to be provided by the manufacturer shall be verified by suitable examination, visual inspection, and/or measurement.

Whenever design or component changes have potential impact upon compliance, new TYPE TESTING shall be performed to confirm compliance. It is desirable that the modified product should be identified, for example by using a suitable date code or serial number as described in 6.2.

5.1.5DV.1 D1 *Modification to add the following:*

Devices or systems that result in termination of a test shall be additionally evaluated to determine their suitability for the application.

5.1.5DV.2 DC *Modification to add the following:*

5.1.5DV.2.1 A thermistor in compliance with UL 873, UL 60730-1 and/or the applicable part 2 standard, or UL 1434 is in compliance with 5.1.5DV.1. A thermistor complying with UL 1434 shall have been investigated for use in a safety circuit have a rated V_{ins} (insulation voltage) and T_{moa} (maximum operating AMBIENT TEMPERATURE) ratings for the intended conditions of use.

5.1.5DV.2.2 A semiconductor device in compliance with UL 1557 which incorporates a thermistor type device that operates to disable the drive output to complete a test that is marked "Provides UL 1434 Thermistor Type Device" is in compliance with 5.1.5DV.1. The thermistor shall have been investigated for use in a safety circuit and have a rated V_{ins} (insulation voltage) and T_{moa} (maximum operating AMBIENT TEMPERATURE) ratings for the intended conditions of use.

5.1.6 Test overview

Table 17 provides an overview of the TYPE, ROUTINE and SAMPLE TESTING of electronic components, devices and PDS/CDM/BDM.

5.1.6DV D1 *Modification:*

The tests in the Table 17DV are also required.

Table 17
Test overview

Test	Type	ROUTINE	SAMPLE	Requirement(s)	Specification
Visual inspection	X	X	X		5.2.1
Mechanical tests					5.2.2
Clearance and creepage distances	X			4.3.6.1, 4.3.6.4, 4.3.6.5	5.2.2.1
PWB short-circuit	X			4.3.6.7	5.2.2.2
Non-accessibility	X			4.3.3.3	5.2.2.3
Enclosure integrity	X			4.3.7.1	5.2.2.4
Deformation tests				4.3.6.4.3	5.2.2.5
Deflection	X			4.3.7.1	5.2.2.5.2
Impact	X			4.3.7.1	5.2.2.5.3
Electrical tests				4.3.4.1, 4.3.6.8.2	5.2.3
Impulse voltage	X		X	4.3.3.2, 4.3.4.3, 4.3.6.1, 4.3.6.8.2.1, 4.3.6.8.2.2, 4.3.6.8.3	5.2.3.1
a.c. or d.c. voltage	X	X		4.3.3.2, 4.3.4.3, 4.3.6.1, 4.3.6.8.2.1, 4.3.6.8.2.2, 4.3.6.8.4.2	5.2.3.2
Partial discharge	X		X	4.3.6.1, 4.3.6.8.2.2, 4.3.6.8.3	5.2.3.3
PROTECTIVE IMPEDANCE	X	X		4.3.4.3	5.2.3.4
TOUCH CURRENT measurement	X			4.3.5.5.2	5.2.3.5
Short-circuit tests	X			4.3.9	5.2.3.6.3
Break down of components	X			4.2	5.2.3.6.4
Capacitor discharge	X			4.3.11	5.2.3.7
Temperature rise	X			4.3.8.8.2, 4.4.2.1	5.2.3.8
PROTECTIVE BONDING	X	X		4.3.5.3	5.2.3.9

Table 17 Continued on Next Page

Table 17 Continued

Test	Type	ROUTINE	SAMPLE	Requirement(s)	Specification
Abnormal operation tests				4.2	5.2.4
ELECTRONIC MOTOR OVERLOAD PROTECTION test	X			5.2.8	4.4.6.2, 4.4.6.3, 4.4.6.4
Circuit functionality evaluation		X	X	5.2.9	4.3.9, 4.4.6.2
Loss of phase	X			4.2	5.2.4.4
Inoperative blower	X			4.2	5.2.4.5.2
Clogged filter	X			4.2	5.2.4.5.3
Loss of coolant	X			4.4.5.2.5	5.2.4.5.4
Material tests					5.2.5
High current arcing ignition	X			4.4.2.2	5.2.5.1
Glow-wire	X			4.4.2.2	5.2.5.2
Hot wire ignition	X			4.4.2.2	5.2.5.3
Flammability	X			4.4.3	5.2.5.4
Environmental tests				4.6	5.2.6
Dry heat	X			4.6	5.2.6.3.1
Damp heat	X			4.6	5.2.6.3.2
Vibration test	X			4.6	5.2.6.4
Hydrostatic pressure	X	X		4.4.5.2.2	5.2.7

Table 17DV D1 ***Modification to add the following:***

Table 17DV
Modification by adding the following:

Test	Type	Rou tine	Sam ple	Requirement(s)	Specification
Contactor overload	**X**			**4.2DV.2**	**5.2.4.5.5DV**
Current limiting control	**X**			**4.2DV.3**	**5.2.4.5.6DV**
Clamped joint test	**X**			**C.1DV**	**5.2.13DV**
Secondary circuits test				**DVC.1.1.2**	**DVC.2**
Limited voltage/current secondary test				**DVC.1.5**	**DVC.2.2**
Limited energy secondary test				**DVC.1.6**	**DVC.2.3**
Limiting impedance test				**DVC.1.7**	**DVC.2.4**
Limited voltage secondary test				**DVC.1.8**	**DVC.2.5**
Isolated power supply capacity test				**DVC.1.9**	**DVC.2.6**

5.2 Test specifications

5.2DV D2 *Addition:*

5.2DV.1 Tests are to be conducted at rated frequency and a test potential not less than 120, 208, 240, 277, 480, or 600 V as appropriate for the voltage ratings. See Table 5.2DV.1. The Temperature Test shall be conducted at a potential between 90 – 110 percent of the potential specified when the load current is adjusted to produce the maximum normal heating.

Table 5.2DV.1
Values of Voltage for Tests

Voltage rating of equipment[a]					
110 – 120	220 – 240	254 – 277	380 – 415	440 – 480	560 – 600
120	240	277	415	480	600

[a] If the rating of the equipment does not fall within any of the indicated voltage ranges, it is to be tested at its RATED VOLTAGE.

5.2DV.2 Unless indicated otherwise, the tests are to be conducted at any AMBIENT TEMPERATURE within the range of 10 – 40 °C (50 – 104 °F). The AMBIENT TEMPERATURE is to be determined using either thermometers or thermocouples placed adjacent to the equipment being tested.

5.2DV.3 An OPEN TYPE device shall be mounted in an enclosure representative of the intended use. The maximum enclosure dimensions are to be determined by one of the following methods:

a) An enclosure that is 150 percent of the dimensions of the device (i.e., length, width, and height);

b) An enclosure dimensioned to meet the wire-bending space specified in 4.3.8.8.4DV;

c) The intended enclosure, such as a standard outlet box; or

d) The intended enclosure, larger than indicated in (a) – (c) when the dimensions are specified in the manufacturer's INSTALLATION instructions.

5.2DV.4 OPEN TYPE power conversion equipment is not required to be tested in an enclosure when marked with a SURROUNDING AIR TEMPERATURE RATING. See 6.3.3DV.1.

5.2DV.5 During the tests, equipment shall be mounted and wired so as to represent the intended use. All field wiring terminal blocks or wire connectors shall be tightened to the value of torque marked on the product.

5.2DV.6 Power conversion equipment intended to control a variable speed motor load is to be tested controlling:

a) A load equivalent to that of a motor with voltage, frequency, and current ratings corresponding to the marked rating;

b) A test motor capable of being loaded to the values specified; or

c) A simulation of the test motor by a passive load consisting of resistive or inductive loads.

5.2.1 Visual inspections (TYPE TEST, SAMPLE TEST and ROUTINE TEST)

Visual inspections shall be made:

• as ROUTINE TESTS, to check features such as adequacy of labelling, warnings and other safety aspects.

• as acceptance criteria of individual TYPE TESTS, SAMPLE TESTS or ROUTINE TESTS, to verify that the requirements of this standard have been met;

Routine inspections may be part of the production or assembly process.

Before TYPE TESTING, a check shall be made that the PDS delivered for the test is as expected with respect to supply voltage, input and output ranges, etc.

5.2.2 Mechanical tests

5.2.2.1 Clearances and creepage distances (TYPE TEST)

It shall be verified by measurement or visual inspection that the clearance and creepage distances comply with Table 9 and Table 10. See Annex C for measurement examples. Where this verification is impossible to perform, an impulse voltage test (see 5.2.3.1) shall be performed between the considered circuits.

5.2.2.1DV D2 *Modification to add the following:*

5.2.2.1DV.1 The test voltage between phases, as required by 5.2DV.1, shall be the maximum of (a) and (b):

a) The largest RATED VOLTAGE for equipment rated in accordance with 6.2DV.2.1.5(a); and

b) The largest higher RATED VOLTAGE for equipment rated in accordance with 6.2DV.2.1.5(b).

5.2.2.1DV.2 The source used for test shall an earthing system according to the following:

a) For BDM/DCM/PDS intended for connection to systems according to 4.3.6.1.4DV.2, the source shall have a measured r.m.s working voltage from phase to earth equal to or greater than the STRAIGHT VOLTAGE RATING, or the measured working voltage from phase to earth may be lower than the STRAIGHT VOLTAGE RATING when all measured working voltages, both rms and peak, from circuits isolated from earth to earth or a circuit referenced to earth (i.e. PELV) are multiplied by the following factor:

(STRAIGHT VOLTAGE RATING) / (Phase to earth measured r.m.s working voltage)

b) For BDCM/CDM/PDS intended for connection only to systems according to 4.3.6.1.4DV.3, the source shall have a measured r.m.s. working voltage from phase to earth equal to or greater than the rated phase to earth voltage.

5.2.2.2 PWB short-circuit test (TYPE TEST)

On PWBs, FUNCTIONAL INSULATION provided by spacings which are less than those specified in Table 9 and Table 10 (see 4.3.6.7) shall be TYPE TESTED as described below.

A sample of the equipment containing the PWB assembly shall be connected as intended to an electrical supply circuit sized and protected to simulate end-use conditions. In the case of a PDS/CDM/BDM supplied without an enclosure, a wire mesh cage which is 1,5 times the individual linear dimensions of the part under study may be used to simulate the intended enclosure.

Surgical cotton shall be placed at all openings, handles, flanges, joints and similar locations on the outside of the enclosure, and the wire mesh cage (if used), in a manner which will not significantly affect the cooling.

The decreased spacings shall be short-circuited one at a time, on representative samples, and the short-circuit shall be maintained until no further damage occurs.

As a result of the PWB short-circuit test, the PDS/CDM/BDM shall comply with the following:

• there shall be no emission of flame or molten metal;

• the surgical cotton indicator shall not have ignited;

• the earth connection shall not have opened;

• the door or cover shall not have blown open;

• during and after the test, accessible SELV and PELV CIRCUITS shall not exhibit voltages greater than the time dependent voltages of Figure 7;

• during and after the test, LIVE PARTS at voltages greater than DECISIVE VOLTAGE CLASS A shall not become accessible.

The PDS/CDM/BDM is not required to be operational after testing and it is possible that the enclosure can become deformed. Overcurrent protection integral to the PDS/CDM/BDM, or required to be used with the PDS/CDM/BDM, is allowed to open.

5.2.2.2DV D2 *Modification to add the following:*

5.2.2.2DV.1 The PDS/CDM/BDM, and the wire mesh cage (if used), shall be connected to earth. The conductor shall have a maximum length of 4 ft (1,2 m) and be sized in accordance with 4.3.5.4DV.1. For conductors sized 6 AWG (13,3 mm^2) or smaller shall be solid wire.

5.2.2.2DV.2 The source used for test shall have an earthing system according to the following:

a) For PDS/CDM/BDM intended for connection to systems according to 4.3.6.1.4DV.2, the source shall have a measured r.m.s working voltage from phase to earth equal to or greater than the STRAIGHT VOLTAGE RATING, or the measured working voltage from phase to earth may be lower than the STRAIGHT VOLTAGE RATING if the earth connection of the PDS/CDM/BDM, and the wire mesh cage (if used), are connected to the supply circuit pole least at risk of arcing to ground.

b) For BDCM/CDM/PDS intended for connection only to systems according to 4.3.6.1.4DV.3, the source shall have a measured r.m.s. working voltage from phase to earth equal to or greater than the rated phase to earth voltage.

5.2.2.3 Non-accessibility test (TYPE TEST)

This test is intended to show that LIVE PARTS, protected by means of enclosures and barriers in compliance with 4.3.3.3, are not accessible.

This test shall be performed as a TYPE TEST of the enclosure of a PDS as specified in IEC 60529 for the enclosure classification for protection against access to hazardous parts. Exception:

• the test probe for IP3X shall not penetrate the top surface of the enclosure when probed from the vertical direction ± 5° only.

5.2.2.3DV D2 *Modification to replace 5.2.2.3 with the following:*

5.2.2.3DV.1 To reduce the risk of unintentional contact that may involve a risk of electric shock or injury, the probe referenced in DVD.2.4.2.1 shall not contact an uninsulated LIVE PART or wire, electrical energy – high current levels, or moving parts when inserted through any opening in an enclosure.

5.2.2.3DV.2 The probe specified in 5.2.2.3DV.1 shall be applied in any possible configuration; and, if necessary, the configuration shall be changed after insertion through the opening.

5.2.2.3DV.3 The probe specified in 5.2.2.3DV.1 is to be applied with a force not to exceed 2,2 lbf (10 N). The probe is to be used to determine the accessibility provided by an opening, and not as an instrument to determine the strength of a material.

5.2.2.3DV.4 The probe specified in 5.2.2.3DV.1 is to be inserted as described in 5.2.2.3DV.2 into all openings, including those in the bottom of the unit. For a floor-standing unit, the probe is to be inserted into all openings in the bottom that are accessible without tipping, turning over, or otherwise moving the unit from its intended installed position. For units other than floor standing units, the unit is to be moved in whatever way necessary to make the entire bottom accessible for insertion of the probe.

5.2.2.4 Enclosure integrity test (TYPE TEST)

The claimed IP rating of the enclosure shall be verified. This test shall be performed as a TYPE TEST of the enclosure of a PDS as specified in IEC 60529 for the enclosure classification.

5.2.2.4DV D2 *Modification to replace 5.2.2.4 with the following:*

See Annex DVD for enclosure requirements.

5.2.2.5 Deformation tests

5.2.2.5DV D2 *Modification:*

Other than in 4.3.6.4.3DV.1, see Annex DVD is applicable for enclosure requirements.

5.2.2.5.1 General

The Deflection and Impact tests apply to PDS, and to enclosed CDM/BDM where they are intended for operation without a further enclosure to which access is restricted to trained maintenance staff. After completion of the Deflection test (see 5.2.2.5.2) for metallic enclosures and the Impact test (see 5.2.2.5.3) for polymeric enclosures, the PDS/CDM/BDM shall pass the tests of 5.2.3.1 and 5.2.3.2 and shall be inspected to check that:

• LIVE PARTS have not become accessible (see 4.3.3.3);

• enclosures show no cracks or openings which could cause a hazard;

• clearances are not less than their minimum permitted values and other insulation is undamaged;

• barriers have not been damaged or loosened;

• no moving parts which could cause a hazard are exposed.

The Deflection and Impact tests shall be performed at the worst case point on representative accessible face(s) of the enclosure.

The PDS/CDM/BDM is not required to be operational after testing and the enclosure may be deformed to such an extent that its original IP classification is not maintained.

5.2.2.5.2 Deflection test (TYPE TEST)

The enclosure shall be held firmly against a rigid support and subjected to a steady force of 250 N applied for 5 s through the end of a rod having a 12,7 mm by 12,7 mm square, flat steel face.

Damage to the finish, small dents and small chips which do not adversely affect the protection against electric shock or moisture, may be ignored.

5.2.2.5.3 Impact test (TYPE TEST)

A sample consisting of the enclosure or a portion thereof representing the largest non-reinforced area shall be supported in its normal position. A solid smooth steel sphere, approximately 50 mm in diameter and with a mass of 500 g ± 25 g, shall be permitted to fall freely from rest through a vertical distance of 1 300 mm onto the sample. (Vertical surfaces are exempt from this test.)

In addition, the steel sphere shall be suspended by a cord and swung as a pendulum in order to apply a horizontal impact, dropping through a vertical distance of 1 300 mm. (Horizontal surfaces are exempt from this test.)

If the pendulum test is inconvenient, it is permitted to simulate horizontal impacts on vertical or sloping surfaces by mounting the sample at 90° to its normal position and applying the vertical impact test instead of the pendulum test.

5.2.3 Electrical tests

5.2.3.1 Impulse voltage test (TYPE TEST and SAMPLE TEST)

The impulse voltage test is performed with a voltage having a 1,2/50 µs waveform (see Figure 6 of IEC 60060-1) and is intended to simulate overvoltages of atmospheric origin. It also covers overvoltages due to switching of equipment. See Table 18 for conditions of the impulse voltage test.

Tests on clearances smaller than required by Table 9 and on solid insulation are performed as TYPE TESTS using appropriate voltages from Table 19 or Table 20.

Tests on components and devices for PROTECTIVE SEPARATION are performed as a TYPE TEST and a SAMPLE TEST before they are assembled into the PDS, using the impulse withstand voltages listed in column 3 or column 5 of Table 19 or Table 20, as appropriate.

To ensure that limiting devices (see 4.3.6.2.2, 4.3.6.2.3, 4.3.6.3) are able to reduce the overvoltage, the values of column 2 or column 4 in Table 19 or Table 20, as appropriate, are applied to the PDS as a TYPE TEST, and reduced values corresponding to the next lower voltage of the same column of that Table are verified.

If it is necessary to test a clearance that has been designed for altitudes between 2 000 m and 20 000 m (using Table A.2 of IEC 60664-1), the appropriate test voltage may be determined from the clearance distance, using Table 9 in reverse.

Table 18
Impulse voltage test

Subject	Test conditions	
Test reference	Clause 19, 20.1.1 and Figure 6 of IEC 60060-1; 4.1.1.2.1 of IEC 60664-1	
Requirement reference	According to 4.3.3.2, 4.3.4.3 and 4.3.6	
Preconditioning	LIVE PARTS belonging to the same circuit shall be connected together. PROTECTIVE IMPEDANCES shall be disconnected unless required to be tested. Impulse voltage to be applied: 1) between circuit under test and the surroundings; and 2) between circuits to be tested. Power is not applied to circuits under test.	
Initial measurement	According to specification of PDS, component, or device	
Test equipment	Impulse generator 1,2/50 µs with an effective internal impedance not higher than: 2 Ω for testing clearances and limiting devices; and 500 Ω for testing solid insulation and components.	
Measurement and verification	a) Clearances smaller than required by Table 9 Clearances reduced by overvoltage limiting means or by circuit characteristics Solid BASIC or SUPPLEMENTARY INSULATION	b) Solid REINFORCED INSULATION Clearances, components and devices for PROTECTIVE SEPARATION
	Three pulses 1,2/50 µs of each polarity in ≥ 1 s interval, peak voltage (± 5 %) according to::	
Test voltage	column 2 or column 4 of Table 19, column 2 or column 4 of Table 20, as appropriate	column 3 or column 5 of Table 19, column 3 or column 5 of Table 20, as appropriate

Table 18 Continued on Next Page

Table 18 Continued

Subject	Test conditions
	When the test is carried out on a clearance at an altitude less than 2 000 m, the test voltage shall be increased according to Table 5 (and 4.1.1.2.1.2) of IEC 60664-1, which is reproduced as Impulse tests performed below 2000 m altitude for the purpose of verifying air clearances must use test voltages which have been corrected for air pressure (altitude). Test voltages which have been corrected for three altitudes are provided in Table D.2. Altitude correction of test voltage is not required for impulse testing of solid insulation. The voltage values of Table D.2 apply for the verification of clearances only. Table D.2 in this international standard.

The impulse voltage test is successfully passed if no puncture, flashover, or sparkover occurs. In the case of components and devices which use solid insulation for PROTECTIVE SEPARATION, a subsequent partial discharge test (see 5.2.3.3) shall also be passed.

Alternatively for HIGH-VOLTAGE PDS the impulse test is successfully passed if

a) three consecutive impulses for each polarity have been applied and:

• no disruptive discharge occurs,

or

• one discharge occurs in the self-restoring part of insulation, and then nine additional impulses have been applied with no disruptive discharge occurring;

or

b) 15 consecutive impulses for each polarity have been applied and:

• the number of disruptive discharges on self-restoring insulation does not exceed two for each series,

and

• no disruptive discharge on non-self-restoring insulation occurs.

Table 19
Impulse test voltage for LOW-VOLTAGE PDS

Column 1	2	3	4	5
SYSTEM VOLTAGE (see 4.3.6.2.1)	Impulse withstand voltage for insulation between circuits not connected directly to the supply mains and their surroundings according to overvoltage category II		Impulse withstand voltage for insulation between circuits connected directly to the supply mains and their surroundings according to overvoltage category III	
(V)	BASIC or SUPPLEMENTARY (V)	REINFORCED (V)	BASIC or SUPPLEMENTARY (V)	REINFORCED (V)
≤ 50	500	800	800	1 500
100	800	1 500	1 500	2 500
150	1 500	2 500	2 500	4 000

Table 19 Continued on Next Page

Table 19 Continued

Column 1	2	3	4	5
SYSTEM VOLTAGE (see 4.3.6.2.1)	Impulse withstand voltage for insulation between circuits not connected directly to the supply mains and their surroundings according to overvoltage category II		Impulse withstand voltage for insulation between circuits connected directly to the supply mains and their surroundings according to overvoltage category III	
(V)	BASIC or SUPPLEMENTARY (V)	REINFORCED (V)	BASIC or SUPPLEMENTARY (V)	REINFORCED (V)
300	2 500	4 000	4 000	6 000
600	4 000	6 000	6 000	8 000
1 000	6 000	8 000	8 000	12 000
–	Interpolation is permitted		Interpolation is not permitted	
	NOTE Test voltages for overvoltage categories I and III can be derived in a similar way from Table 7.		NOTE Test voltages for overvoltage categories II and IV can be derived in a similar way from Table 7.	

Table 20
Impulse test voltage for HIGH-VOLTAGE PDS

Column 1	2	3	4	5
SYSTEM VOLTAGE (see 4.3.6.2.1)	Impulse withstand voltage for insulation between circuits and their surroundings according to overvoltage category III		Impulse withstand voltage for insulation between circuits and their surroundings according to overvoltage category IV	
(V)	BASIC or SUPPLEMENTARY (V)	REINFORCED (V)	BASIC or SUPPLEMENTARY (V)	REINFORCED (V)
>1 000	8 000	12 800	12 000	19 200
3 600	20 000	32 000	40 000	64 000
7 200	40 000	64 000	60 000	96 000
12 000	60 000	96 000	75 000	120 000
17 500	75 000	120 000	95 000	152 000
24 000	95 000	152 000	125 000	200 000
36 000	125 000	200 000	145 000	232 000
Interpolation is permitted NOTE Test voltages for overvoltage categories I and II can be derived in a similar way from Table 8.				

5.2.3.2 A.C. or d.c. voltage test (TYPE TEST and ROUTINE TEST)

5.2.3.2DV D2 *Modification:*

ROUTINE TESTS are not required.

5.2.3.2.1 Purpose of test

The test is used to verify that the clearances and solid insulation of components and of assembled PDS/CDM/BDM has adequate dielectric strength to resist overvoltage conditions.

5.2.3.2.2 Value and type of test voltage

The values of the test voltage are determined from column 2 or 3 of Table 21, Table 22, or Table 23, depending upon whether the circuit under test is connected to low voltage mains, high voltage mains, or not mains connected.

The test voltage from column 2 is used for testing circuits with BASIC INSULATION.

Between circuits with PROTECTIVE SEPARATION (DOUBLE or REINFORCED INSULATION), the test voltage of column 3 shall be applied for TYPE TESTS. For ROUTINE TESTS between circuits with PROTECTIVE SEPARATION the values from column 2 shall be applied to prevent damage to the solid insulation by partial discharge.

The values of column 3 shall apply to PDS with protection against direct contact according to 4.3.3. The test is performed between circuits and accessible surfaces of PDS, which are non-conductive or conductive but not connected to the PROTECTIVE EARTHING CONDUCTOR.

The voltage test shall be performed with a sinusoidal voltage at 50 Hz or 60 Hz. If the circuit contains capacitors the test may be performed with a d.c. voltage of a value equal to the peak value of the specified a.c. voltage.

ROUTINE TESTS are performed to verify that clearances have not been reduced during the manufacturing operations. Protective devices designed to reduce impulse voltages on the circuits under test (see 4.3.6.2.2 and 4.3.6.2.3), and circuits belonging to monitoring or protection circuits, not designed to sustain the test overvoltage for the duration of the test, shall be disconnected in order to avoid damage and to ensure that the test voltage can be applied without a false indication of failure.

5.2.3.2.2DV D1 *Modification:*

The values of test voltage are determined from Table 5.2.3.2.2DV.1. If the test voltage is applied to evaluate PROTECTIVE SEPARATION then the value of the test voltage shall be in accordance with column 3 of Table 21 or Table 23 as appropriate.

Table 5.2.3.2.2DV.1
Dielectric Voltage Withstand Test Voltages

Voltage rating, V (rms) or DC	Test voltage (rms)[a]
0 – 600 [b,c]	1 000 V + (2 X nominal voltage rating) [b,c]
601 – 1 500	2 000 V + (2,25 X nominal voltage ratings)

[a] Alternating-current, or 1,414 times the values for direct-current.

[b] For equipment rated not more than 250 V and intended for use in a pollution degree 2 location, the test voltage may be reduced to 1 000 V. This reduced test voltage does not apply to any internal circuits, other than the DC bus, that operate at more than 250 V.

[c] For isolated secondary circuits rated not more than 250 V and intended for use in a pollution degree 2 location, the test voltage may be reduced to 1 000 V.

Table 21
A.C. or d.c. test voltage for circuits connected directly to low voltage mains

Column 1 SYSTEM VOLTAGE (see 4.3.6.2.1)	2 Voltage for TYPE TESTING circuits with BASIC INSULATION, and for all ROUTINE TESTING		3 [b] Voltage for TYPE TESTING circuits with PROTECTIVE SEPARATION, and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, PROTECTIVE CLASS II according to 4.3.5.6)	
(V)	a.c. r.m.s. [a] (V)	d.c. (V)	a.c. r.m.s. (V)	d.c. (V)
≤ 50	1 250	1 770	2 500	3 540
100	1 300	1 840	2 600	3 680
150	1 350	1 910	2 700	3 820
300	1 500	2 120	3 000	4 240
600	1 800	2 550	3 600	5 090
1 000	2 200	3 110	4 400	6 220

NOTE Interpolation is permitted.

[a] Corresponding to 1 200 V + SYSTEM VOLTAGE.

[b] A voltage source with a short-circuit current of at least 0,1 A according to 5.2.2.2 of IEC 61180-1 is used for this test.

Table 22
A.C. or d.c. test voltage for circuits connected directly to high voltage mains

Column 1 Line to line SYSTEM VOLTAGE (see 4.3.6.2.1)	2 [b] Voltage for TYPE TESTING circuits with BASIC INSULATION, and for all ROUTINE TESTING		3 [b] Voltage for TYPE TESTING circuits with PROTECTIVE SEPARATION, and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, PROTECTIVE CLASS II according to 4.3.5.6)	
(V)	a.c. r.m.s. [a] (V)	d.c. (V)	a.c. r.m.s. (V)	d.c. (V)
>1 000	3 000	4 250	4 800	6 800
3 600	10 000	14 150	16 000	22 650
7 200	20 000	28 300	32 000	45 300
12 000	28 000	39 600	44 800	63 350
17 500	38 000	53 700	60 800	85 900
24 000	50 000	70 700	80 000	113 100
36 000	70 000	99 000	112 000	158 400

NOTE Interpolation is permitted.

[a] Values from Table 2 of IEC 60071-1

[b] A voltage source with a short-circuit current of at least 0,1 A according to 5.2.2.2 of IEC 61180-1 is used for this test.

Table 23
A.C. or d.c. test voltage for circuits not connected directly to the mains

Column 1 WORKING VOLTAGE (recurring peak) (see 4.3.6.2.1) (V)	2 a) Voltage for TYPE TESTING circuits with BASIC INSULATION, and for all ROUTINE TESTING a.c. r.m.s. (V)	d.c (V)	3 a) Voltage for TYPE TESTING circuits with PROTECTIVE SEPARATION, and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, PROTECTIVE CLASS II according to 4.3.5.6) a.c. r.m.s. (V)	d.c. (V)
≤71	80	110	160	220
141	160	225	320	450
212	240	340	480	680
330	380	530	760	1 100
440	500	700	1 000	1 400
600	680	960	1 400	1 900
1 000	1 100	1 600	2 200	3 200
1 600	1 800	2 600	2 900	4 200
2 300	2 600	3 700	4 200	5 900
3 000	3 400	4 800	5 400	7 700
4 600	5 200	7 400	8 300	11 800
7 600	8 500	12 000	14 000	19 000
16 000	18 000	26 000	29 000	42 000
23 000	26 000	37 000	42 000	59 000
30 000	34 000	48 000	54 000	77 000
38 000	43 000	61 000	69 000	98 000
50 000	57 000	80 000	91 000	130 000
60 000	70 000	99 000	109 000	154 000

NOTE 1 Interpolation is permitted.

NOTE 2 Test voltages in this table are based upon 80 % of the withstand voltage for the corresponding clearance of Table 9 as provided by Table A.1 of IEC 60664-1.

a) A voltage source with a short-circuit current of at least 0,1 A according to 5.2.2.2 of IEC 61180-1 is used for this test.

5.2.3.2.3 Performing the voltage test

The test shall be applied as follows, according to Figure 8.

a) Test (1) between accessible conductive part (connected to earth) and each circuit sequentially (except DVC A circuits). Test voltage according to, Table 22, or Table 23, column 2, corresponding to voltage of considered circuit under test.

b) Test (2) between accessible surface (non conductive or conductive but not connected to earth) and each circuit sequentially (except DVC A circuits). Test voltage according to Table 21, Table 22, or Table 23, column 3 (for type test) or column 2 (for routine test), corresponding to voltage of considered circuit under test.

c) Test between each considered circuit sequentially and the other ADJACENT CIRCUITS connected together. Test voltage according to Table 21, Table 22, or Table 23, column 2, corresponding to voltage of considered circuit under test.

d) Test between DVC A circuit and each ADJACENT CIRCUIT sequentially. Test voltage according to Table 21, Table 22, or Table 23, column 3 (for TYPE TEST) or column 2 (for ROUTINE TEST), corresponding to the circuit with the higher voltage. Either the ADJACENT CIRCUIT or the DVC A circuit may be earthed for this test. It is necessary to test BASIC INSULATION between PELV and SELV CIRCUITS, but it is not necessary to test FUNCTIONAL INSULATION between ADJACENT PELV or ADJACENT SELV CIRCUITS.

Because PELV / SELV CIRCUITS and circuits of DVC C and D are typically separated from chassis (earth) by BASIC INSULATION, it is typically impossible to test DOUBLE or REINFORCED INSULATION separating low-voltage circuits from high-voltage circuits in a fully-assembled PDS without overstressing the BASIC INSULATION. Because of this, it may be necessary to disassemble the PDS, or it may not be possible to perform TYPE TESTS of protective insulation at voltages according to column 3 of Table 21 to Table 23. In these cases the TYPE TEST of insulation used for PROTECTIVE SEPARATION shall be performed at voltages according to column 2 of the appropriate table.

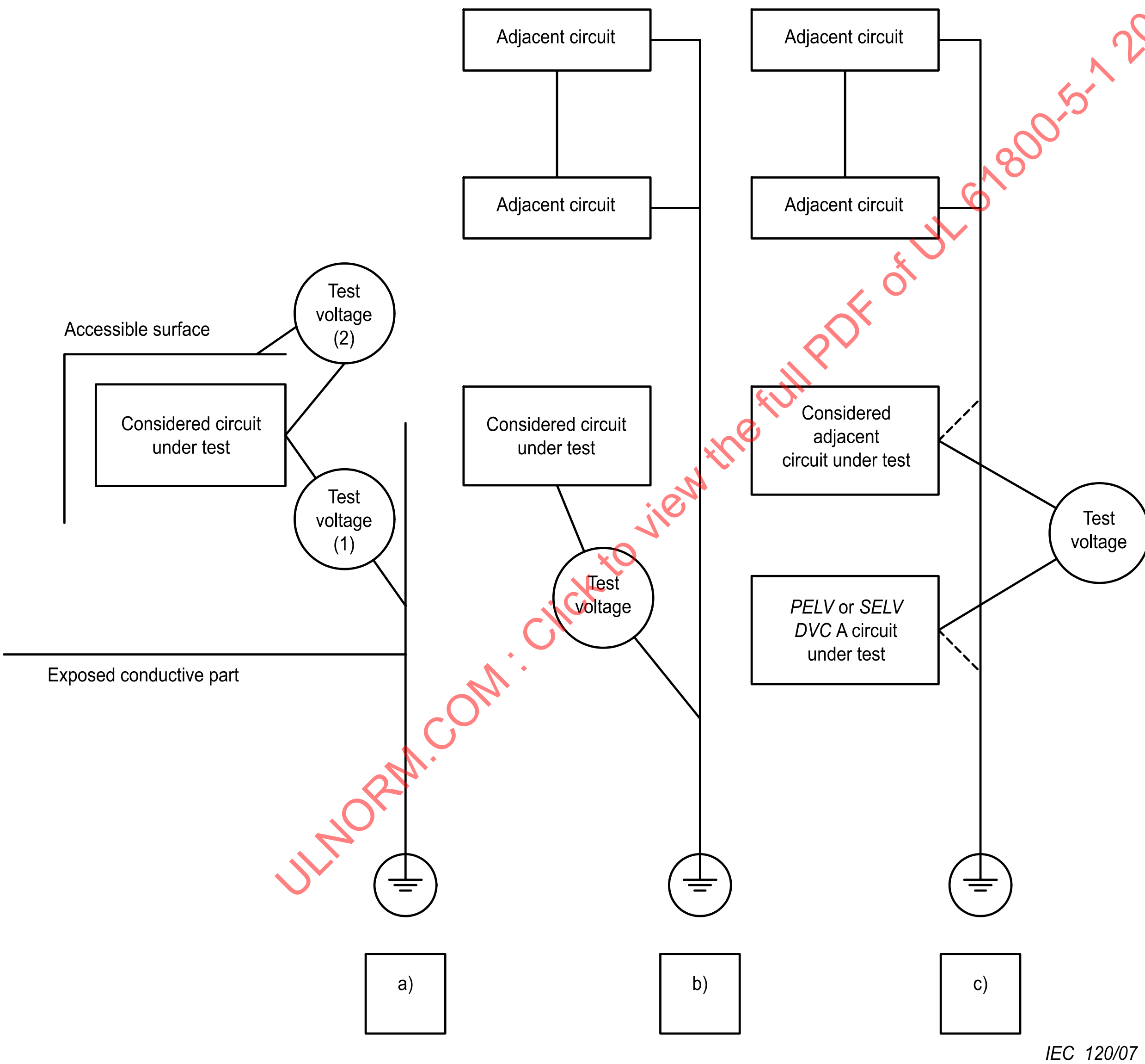


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Figure 8

Voltage test procedures

The tests shall be performed with the doors of the enclosure closed.

When the circuit is electrically connected to accessible conductive parts, the voltage test is not relevant, and may be omitted.

To create a continuous circuit for the voltage test on the PDS, terminals, open contacts on switches and semiconductor switching devices, etc. shall be bridged where necessary. Before testing, semiconductors and other vulnerable components within a circuit may be disconnected and/or their terminals bridged to avoid damage occurring to them during the test.

Wherever practicable, individual components forming part of the insulation under test, for example interference suppression capacitors, should not be disconnected or bridged before the test. In this case, it is recommended to use the d.c. test voltage according to 5.2.3.2.2.

Where the PDS is covered totally or partly by a non-conductive accessible surface, a conductive foil to which the test voltage is applied shall be wrapped around this surface for testing. In this case, the insulation test between a circuit and non-conductive accessible surface may be performed as a SAMPLE TEST instead of a ROUTINE TEST.

ROUTINE TESTING of the assembled PDS is not required if:

• ROUTINE TESTING of all subassemblies related to the insulation system of the PDS is performed;

and

• it can be demonstrated that final assembly will not compromise the insulation system;

and

• TYPE TESTING of the fully-assembled PDS was performed successfully.

PROTECTIVE IMPEDANCES according to 4.3.4.3 shall either be included in the testing or the connection to the protectively separated part of the circuit shall be opened before testing. In the latter case, the connection shall be carefully restored after the voltage test in order to avoid any damage to the insulation. Protective screens according to 4.3.2 shall remain connected to accessible conductive parts during the voltage test.

In the case of HIGH-VOLTAGE PDS, the voltage shall be applied using a ramp of up to 5 s in duration. Also, for HIGH-VOLTAGE PDS, if the test is required or requested to be repeated, the voltage shall be de-rated to 80 % of the original test voltage.

5.2.3.2.3DV.1 DE *Modification to correct:*

The test voltage in item (a) shall be according to Table 21, Table 22, or Table 23, column 2, corresponding to voltage of considered circuit under test.

5.2.3.2.3DV.2 D2 *Modification:*

5.2.3.2.3DV.2.1 Since it is not possible to conduct a ROUTINE TEST on an enclosed device with the door closed, the test may be conducted with the door open.

5.2.3.2.3DV.2.2 The test method in item (b) does not apply to circuits that are DVC A circuits.

5.2.3.2.3DV.2.3 Other than as noted in 5.2.3.2.3DV.2.4, the equipment used to conduct this test shall employ a 500 VA or larger capacity transformer, the output voltage of which is sinusoidal and is able to be varied. The applied potential is to be increased from zero to the required value at a substantially uniform rate and as rapidly as is consistent with its value being correctly indicated by a voltmeter.

5.2.3.2.3DV.2.4 A 500 VA or larger capacity transformer is not required to be used when the transformer is provided with a voltmeter that directly measures the applied output potential.

5.2.3.2.4 Duration of the a.c. or d.c. voltage test

The duration of the test shall be at least 5 s for the TYPE TEST and 1 s for the ROUTINE TEST. The test voltage may be applied with increasing and/or decreasing ramp voltage but the full voltage shall be maintained for 5 s and 1 s respectively for TYPE and ROUTINE TESTS.

5.2.3.2.4DV D2 *Modification:*

The test duration for a TYPE TEST shall be 60 s.

5.2.3.2.5 Verification of the a.c. or d.c. voltage test

The test is successfully passed if no ELECTRICAL BREAKDOWN occurs during the test.

5.2.3.3 Partial discharge test (TYPE TEST, SAMPLE TEST)

The partial discharge test (see Table 24) shall confirm that the solid insulation (see 4.3.6.8) used in components and subassemblies for PROTECTIVE SEPARATION of electrical circuits remains partial-discharge-free within the specified voltage range (see Table 24).

This test shall be performed as a TYPE TEST and a SAMPLE TEST. It may be deleted for insulating materials which are not degraded by partial discharge, for example ceramics.

The partial discharge inception and extinction voltage are influenced by climatic factors (e.g. temperature and moisture), equipment self heating, and manufacturing tolerance. These influencing variables can be significant under certain conditions and shall therefore be taken into account during TYPE TESTING.

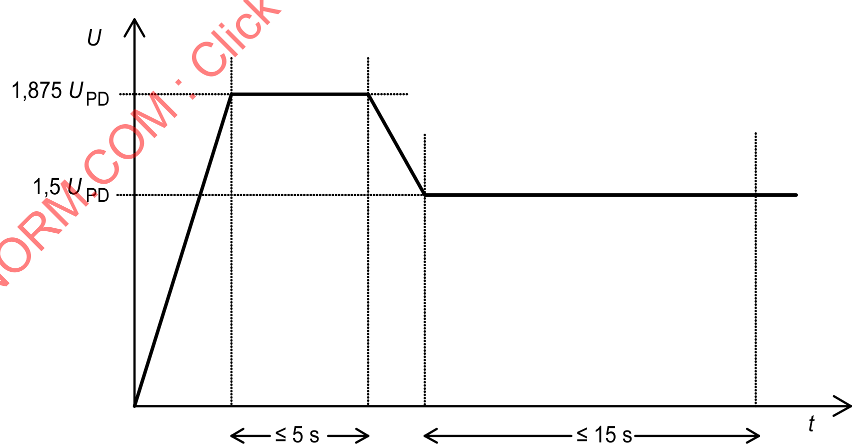
5.2.3.3DV D2 *Modification to replace 5.2.3.3 with the following:*

Partial Discharge testing is not required.

Table 24

Partial discharge test

Subject	Test conditions
Test reference	4.1.2.4 of IEC 60664-1
Requirement reference	4.3.6.8
Preconditioning	Samples shall be pre-conditioned according to method b) of 4.1.2.1. of IEC 60664-1 *Live parts* belonging to the same circuit shall be connected together It is recommended that the partial discharge test is performed after the impulse voltage test (see 5.2.3.1) in order that any damage caused by the impulse voltage test may be apparent It is advisable that the partial discharge test is performed before inserting the components or devices into the equipment because partial discharge testing is not normally possible when the equipment is assembled
Initial measurement	According to specification of component or device
Test equipment	Calibrated charge measuring device or radio interference meter without weighting filters
Test circuit	Clause C.1 of IEC 60664-1
Test voltage	The peak value of a.c. 50 Hz or 60 Hz
Test method	4.1.2.4 of IEC 60664-1: F_1 = 1,2; F_2 ,F_3 = 1,25. Test procedure 4.1.2.4.2 of IEC 60664-1
Calibration of test equipment	Clause C.4 of IEC 60664-1
Measurement	Starting from a value below the rated discharge voltage U_{PD}[a], the voltage shall be linearly increased to 1,875 times U_{PD} and held for a maximum of 5 s The voltage shall then be linearly decreased to 1,5 times U_{PD} (± 5 %) and held for a maximum time of 15 s, during which the partial discharge is measured
Verification	The test shall be considered to have been successfully passed if the partial discharge is less than 10 pC during the measurement period



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a The rated discharge voltage is the sum of the recurring peak voltages in each of the circuits separated by the insulation.

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5.2.3.4 Protective impedance (type test and routine test)

A TYPE TEST shall be performed to verify that the current through a PROTECTIVE IMPEDANCE under normal operating conditions does not exceed the values given in 4.3.4.3. The test shall be performed using the circuit of IEC 60990, Figure 4.

NOTE IEC 60990 states that the use of a single network for the measurement of a.c. combined with d.c. has not been investigated, but no suggestion is made for measurement in such cases.

The value of the PROTECTIVE IMPEDANCE shall be verified as a ROUTINE TEST.

5.2.3.4DV D2 *Modification:*

5.2.3.4DV.1 As an alternative test method for the TYPE TEST, the circuit of IEC 60990 may be replaced by a direct short to earth and measurement of the current through the short.

5.2.3.4DV.2 The value of the PROTECTIVE IMPEDANCE need not be verified as a ROUTINE TEST.

5.2.3.5 TOUCH CURRENT measurement (TYPE TEST)

The touch current shall be measured to determine if the measures of protection need not be taken (see 4.3.5.5.2). The test may be used for a BDM, but in that case the BDM shall be connected to a motor. The motor may be unloaded, but the length and the type of the motor cable indicated by the manufacturer shall be used.

The PDS shall be set up in an insulated state without any connection to the earth and shall be operated at rated voltage. Under these conditions, the touch current shall be measured between the means of connection for the PROTECTIVE EARTHING CONDUCTOR and the PROTECTIVE EARTHING CONDUCTOR itself with the measuring network of Figure 4 of IEC 60990.

• For a PDS to be connected to an earthed neutral system, the neutral of the mains of the test site shall be directly connected to the PROTECTIVE EARTHING CONDUCTOR.

• For a PDS to be connected to an isolated system or impedance system, the neutral shall be connected through a resistance of 1 kΩ to the PROTECTIVE EARTHING CONDUCTOR which shall be connected to each input phase in turn. The highest value will be taken as the definitive result.

• For a PDS to be connected to a corner earthed system, the PROTECTIVE EARTHING CONDUCTOR shall be connected to each input phase in turn. The highest value will be taken as the definitive result.

• For a PDS with a particular earthing system, this system shall operate as intended during the test.

• If a PDS is intended to be connected to more than one system network, each of these different system networks (or the worst-case, if that can be determined) shall be used to make the TOUCH CURRENT measurement.

This is performed as a TYPE TEST.

5.2.3.5DV D2 *Modification:*

5.2.3.5DV.1 In accordance with 4.3.5.5.2DV, the following test method shall be used to determine the LEAKAGE CURRENT.

5.2.3.5DV.2 All exposed conductive surfaces are to be tested for LEAKAGE CURRENTS. LEAKAGE CURRENTS from these surfaces are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible, and from one surface to another if simultaneously accessible. Parts are considered to be exposed surfaces unless they are guarded by an enclosure considered acceptable for protection against the risk of electric shock. Surfaces are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to terminals operating at voltages that are not considered to involve a risk of electric shock. If all accessible surfaces are bonded together and connected to the grounding conductor of the power-supply cord, the LEAKAGE CURRENT can be measured between the grounding conductor and the grounded supply conductor. If exposed dead metal parts of the equipment are connected to the neutral supply conductor, this connection is to be open during the test.

5.2.3.5DV.3 If a conductive surface other than metal is used for the enclosure or part of the enclosure, the LEAKAGE CURRENT is to be measured using a metal foil with an area of 4 by 8 inches (10 by 20 cm) in contact with the surface. If the surface is less than 4 by 8 inches (10 by 20 cm), the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the equipment.

5.2.3.5DV.4 The measurement circuit for LEAKAGE CURRENT for single phase equipment is to be as illustrated in Figure 5.2.3.5DV.1. For 3-phase equipment, the LEAKAGE CURRENT shall be the sum of measurements from each phase to neutral. The measurement instrument is defined in (a) – (c). The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument; it need not have all the attributes of the defined instrument.

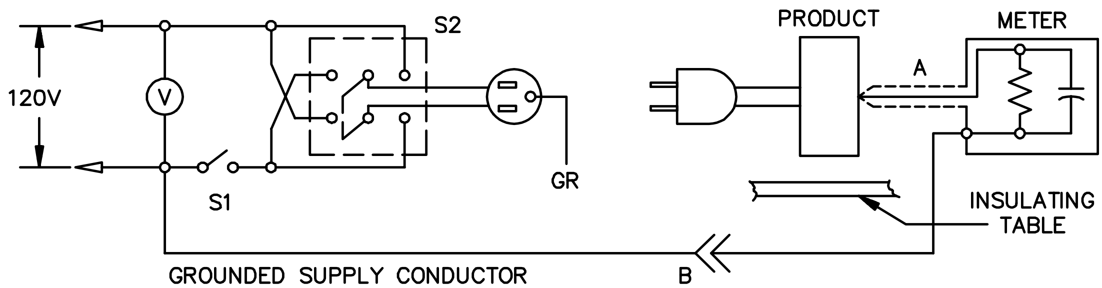
a) The meter is to have an input impedance of 1 500 Ω resistive shunted by a capacitance of 0,15 μF.

b) The meter is to indicate 1,11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor.

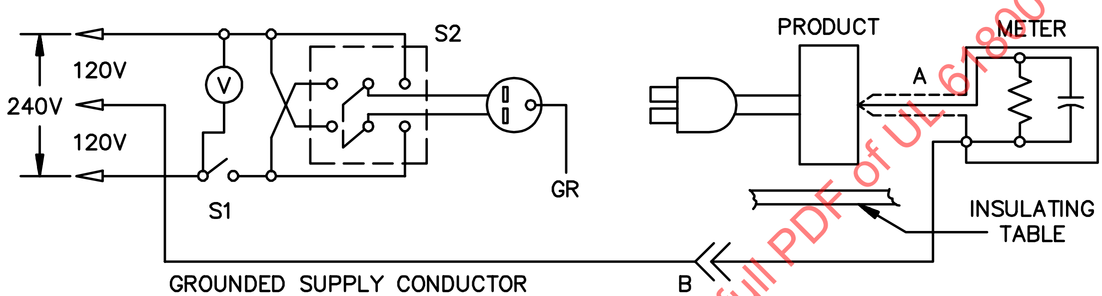
c) Over a frequency range of 0 – 100 kHz, the measurement circuitry is to have a frequency response – ratio of indicated to actual value of current – that is equal to the ratio of the impedance of a 1 500-Ω resistor shunted by a 0,15-μF capacitor to 1 500 Ω. At an indication of 3,5 mA, the measurement is to have an error of not more than 5 percent at 60 Hz.

Figure 5.2.3.5DV.1

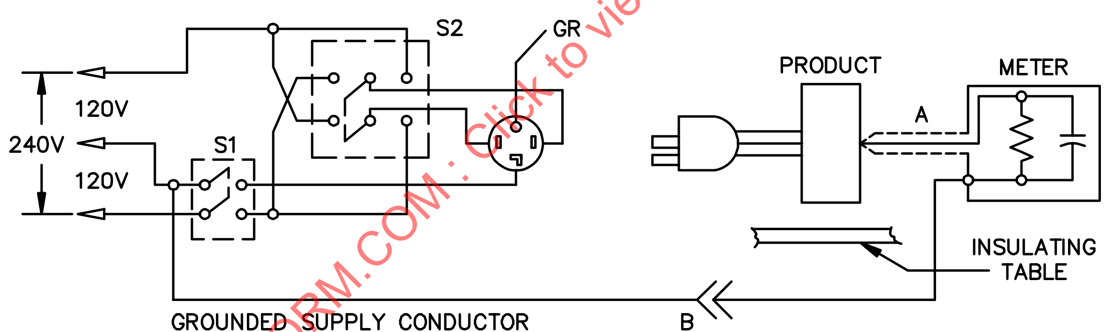
Leakage-Current Measurement Circuits



Equipment intended for connection to a 120 V power supply, as illustrated above.



Equipment intended for connection to a 3–wire, grounded neutral power supply, as illustrated above.



Equipment intended for connection to a 3–wire, grounded neutral power supply, as in the 240 V example illustrated above.

A – Probe with shielded lead.

B – Separated and used as clip when measuring currents from one part of equipment to another.

LC100K

5.2.3.5DV.5 Unless the meter is being used to measure leakage from one part of the equipment to another, the meter is to be connected between the accessible parts and the grounded supply conductor.

5.2.3.5DV.6 A sample of the equipment is to be tested for LEAKAGE CURRENT starting with the as-received condition – as-received being without prior energization except as may occur as part of the production-line testing. The grounding conductor, if any, is to be open at the attachment plug. The supply voltage is to be in accordance with Table 5.2DV.1. The test sequence, with reference to the measuring circuit, Figure 5.2.3.5DV.1, is to be as follows:

a) With switch S1 open, the equipment is to be connected to the measuring circuit. LEAKAGE CURRENT is to be measured using both positions of switch S2, and with the equipment switching devices in all their normal operating positions.

b) Switch S1 is then to be closed energizing the appliance and within 5 s the LEAKAGE CURRENT is to be measured using both positions of switch S2, and with the equipment switching devices in all their normal operating positions.

c) The LEAKAGE CURRENT is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is considered to be obtained by operation as in the normal temperature test.

5.2.3.5DV.7 Normally a sample will be carried through the complete leakage-current-test programs described in 5.2.3.5DV.6, without interruption for other tests. With the concurrence of those concerned, the Leakage Current Tests may be interrupted for the purpose of conducting other nondestructive tests.

5.2.3.6 Short-circuit test and Breakdown of components test (TYPE TESTS)

5.2.3.6DV D2 *Modification to add the following:*

5.2.3.6DV.1 GROUP INSTALLATION (Optional)

5.2.3.6DV.1.1 General

5.2.3.6DV.1.1.1 A drive that is intended to be marked as suitable for GROUP INSTALLATION per 6.3.7DV.3.2 shall be tested in accordance with 5.2.3.6DV.1.2, 5.2.3.6DV.1.3 and 5.2.3.6DV.1.5, Breakdown of Components Test – GROUP INSTALLATION for Standard Fault Currents. Drives intended for GROUP INSTALLATION at high fault currents shall be tested in accordance with 5.2.3.6DV.1.2 – 5.2.3.6DV.1.6, Breakdown of Components Test – GROUP INSTALLATION for High Fault Currents. Wiring terminals of drives intended for GROUP INSTALLATION shall comply with 5.2.3.6DV.1.1.5. Drives intended for GROUP INSTALLATION according to 5.2.3.6DV.1.1.2 shall be marked in accordance with 6.3.7DV.3.2, Branch circuit short circuit protection for GROUP INSTALLATION, and 6.3.6.4DV.1.14.

5.2.3.6DV.1.1.2 The requirements in this section cover drives:

a) For use on circuits having available short circuit currents at standard fault levels or at high fault levels; and

b) Protected by an inverse-time circuit breaker or non-semiconductor fuse(s) intended to provide branch-circuit protection for two or more motors, or one or more motors and other loads. The protective device(s) shall be selected in accordance with 5.2.3.6DV.1.1.3; and

c) Connected to branch-circuit conductors that have an ampacity not limited to 125 percent of rated full-load input controller current or 125 percent of rated fullload output motor current. The main input and output power conductors shall be sized according to 5.2.3.6DV.1.1.4; and

d) That incorporates solid state overload protection that is subjected to the requirements in 5.2.9DV and that complies with the ELECTRONIC MOTOR OVERLOAD PROTECTION test (TYPE TEST), 5.2.8.

5.2.3.6DV.1.1.3 The branch-circuit protective devices shall be selected in accordance with 5.2.3.6.2DV.4.1, with the following modifications:

a) The branch-circuit protective devices shall be either inverse time circuit breakers or non-semiconductor fuses.

b) The current rating of the protective device is permitted to be greater than the values specified in 5.2.3.6.2DV.4.1.6 (a),(b) and 5.2.3.6.2DV.4.1.8 (a),(b). The maximum size of the branch circuit protective device shall not exceed the ampere rating calculated from the following formula:

$$Amperes = [9{,}6 \cdot (maximum\ \ wire\ \ size)] - [2{,}2 \cdot (minimum\ \ motor\ \ FLA)]$$

in which:

Maximum wire size is the ampacity from Table 4.3.8.1DV.1 of the largest conductor size for which the device terminals have been evaluated; and

Minimum motor FLA is the smallest rated FLA (or equivalent FLA from horsepower rating per Table DVE.1) marked on the device.

5.2.3.6DV.1.1.4 The input and output wiring shall be in accordance with 5.2.3.6.2DV.5.1.2, with the following modifications:

a) The main input power conductors are permitted to be larger than those specified in 5.2.3.6.2DV.5.1.2(a).

b) The main output power conductors are permitted to be larger than those specified in 5.2.3.6.2DV.5.1.2(c).

5.2.3.6DV.1.1.5 A wiring terminal shall comply with secureness and pullout requirements with the maximum size conductor permitted by the marking specified in 6.3.6.4DV.1.14.

5.2.3.6DV.1.2 Sample selection

5.2.3.6DV.1.2.1 A sample drive that complies in all other respects with requirements in this standard shall be subjected to the tests specified in 5.2.3.6DV.1.1.1. The drive is to be connected in series with:

a) A non-semiconductor fuse(s) or an inverse-time circuit breaker of the maximum standard rating with which the drive is intended to be used; and

b) The maximum size of main input and output power conductors with which the equipment is intended to be used.

5.2.3.6DV.1.3 Short circuit test – GROUP INSTALLATION for standard fault currents

5.2.3.6DV.1.3.1 A drive having short circuit ratings at levels specified in Table 4.3.9DV.1 shall comply with the requirements of 5.2.3.6.1DV, Short Circuit Test – Standard Fault Currents, with the following modifications:

a) In 5.2.3.6.2.1DV.2.1, a drive controller that does not rely solely on solid-state short circuit protection shall be tested on a circuit that complies with the power factor specified in Table 5.2.3.6DV.1.3.1.1. The circuit shall be calibrated as described in the Calibration of Test Circuits, 5.2.3.6.2.1DV.3.

b) In 5.2.3.6.2DV.5.1.2, the input and output wiring shall be according to 5.2.3.6DV.1.1.4.

c) In 5.2.3.6.2DV.4.1.1 – 5.2.3.6.2DV.4.1.9, the current rating and type of branch-circuit protective device(s) shall be selected according to 5.2.3.6DV.1.1.3.

d) In 5.2.3.6.2DV.4.1.10 and 6.3.7DV.1.1, the branch-circuit short-circuit protection shall be marked in accordance with 6.3.7DV.3.2, Branch circuit short circuit protection for GROUP INSTALLATION

Table 5.2.3.6DV.1.3.1.1
Power Factor of Test Circuits for Devices Rated 600 V or Less

Test current, amperes[a]	Power factor[b]
10 000 amperes or less	0,70 – 0,80
10 001 – 20 000	0,25 – 0,30
Greater than 20 000	0,15 – 0,20

[a] Symmetrical rms amperes

[b] Lower power factor circuits than specified may be used.

5.2.3.6DV.1.4 Short circuit test – GROUP INSTALLATION for high fault currents

5.2.3.6DV.1.4.1 A drive having short circuit ratings in excess of the levels specified in Table 4.3.9DV.1 shall comply with the requirements of 5.2.3.6.2.1DV.5, Short Circuit Test – High Fault Currents, with the following modifications:

a) The 5.2.3.6.2 reference in 5.2.3.6.2.1DV.5.5 is amended by 5.2.3.6DV.1.3; and

b) The maximum current rating of the branch-circuit protective device(s) shall be selected according to 5.2.3.6DV.1.1.3. The type of the branch-circuit protective device(s) shall comply with 5.2.3.6DV.1.1.3.

5.2.3.6DV.1.5 Breakdown of components test – GROUP INSTALLATION for standard fault currents

5.2.3.6DV.1.5.1 A drive having short circuit ratings at the standard available levels specified in Table 4.3.9DV.1 shall be tested in accordance with 5.2.3.6.4, Breakdown of Components Test, with the following additional requirements:

b) The drive shall be connected in series with branch-circuit protective devices selected according to 5.2.3.6DV.1.1.3.

c) The drive shall be tested with 4 feet (1,2 m) of wire, or less, attached to each input terminal and output terminal (if required). For enclosed drives, the input wiring and output wiring (if required) is then to be routed through 10 – 12 inch (250 – 305 mm)

lengths of conduit installed on the enclosure with the ends of the conduit plugged with surgical cotton. For an open type drive controller, a wire mesh cage that is 1,5 times the size of the controller is usable to simulate the intended enclosure. The wire mesh cage must be grounded per (a).

d) The input and output wiring shall be according to 5.2.3.6DV.1.1.4.

e) The drive shall be tested on a circuit that is calibrated as described in 5.2.3.6.2.1DV.3, Calibration of Test Circuits. The available short circuit current of the test circuit shall be the standard fault current value according to Table 4.3.9DV.1.

5.2.3.6DV.1.6 Breakdown of components test – GROUP INSTALLATION for high fault currents

5.2.3.6DV.1.6.1 drive having short circuit ratings in excess of the levels specified in Table 4.3.9DV.1 shall comply with 5.2.3.6DV.1.5, Breakdown of Components Test – GROUP INSTALLATION for Standard Fault Currents.

5.2.3.6DV.1.6.2 A drive having short circuit ratings in excess of the levels specified in Table 4.3.9DV.1 shall additionally be tested in accordance with 5.2.3.6.4, Breakdown of Components Test, with the following modifications:

a) The requirements of 5.2.3.6.4 are amended by (a) – (d) of 5.2.3.6DV.1.5.1.

b) The branch-circuit protective device(s) shall also comply with 5.2.3.6.2.1DV.5.5 (a) – (g).

c) The drive shall be tested on a circuit that is calibrated as described in 5.2.3.6.2.1DV.3, Calibration of Test Circuits. The available short circuit current of the test circuit shall be the maximum value for which the drive is rated. The high fault current values for which a drive is able to be tested are not required to be one of the same values detailed in Table 4.3.9DV.1.

5.2.3.6.1 General

Protection against risk of thermal, electric shock and energy hazards in case of short circuit or breakdown of a component for a CDM/BDM or for a PDS in combination with its INSTALLATION shall be evaluated by:

a) tests defined in 5.2.3.6.3 and 5.2.3.6.4,

or

b) calculation or simulation based on tests as defined in 5.2.3.6.3 and 5.2.3.6.4 on a representative model of PDS/CDM/BDM, where no damage other than opening of fuses or tripping of circuit breakers has occurred to the test sample,

NOTE A representative model means a PDS/CDM/BDM with similar power elements (for example, power semiconductors, fuses, circuit breakers, capacitors, short circuit detection and output inductances) and circuit topologies as the PDS/CDM/BDM under consideration.

or

c) for HIGH-VOLTAGE PDS: calculation or simulation based on tests of elements that adequately represent those used in the PDS. The elements, tests and test conditions shall be selected so that there is sufficient confidence in the test results for them to be transferred (for example, by scaling from lower to higher power) to the PDS/CDM/BDM under consideration,

or

d) for custom PDS: risk and hazard analysis of the intended application, and analysis of the construction characteristics. See 6.3.9 for commissioning information requirements.

NOTE Custom PDS rely on the construction characteristics of the installation to provide protection.

5.2.3.6.1DV D2 *Modification:*

5.2.3.6.1DV.1 The normative text of items b), c) and d) does not apply. The informative note in item b) may be useful.

5.2.3.6.1DV.2 For the method in item a) with respect to only the short circuit test in 5.2.3.6.3, any model is able to serve as the representative model from a series that uses SOLID STATE SHORT CIRCUIT PROTECTION circuitry for compliance with this test. As an example, for a drive series with models rated from 25 hp to 700 hp (18,64 – 521,99 kW), the testing of the 25 hp model at 5 000 A represents the testing of any models at 10 000 A, 18 000 A, 30 000 A, or 42 000 A. In addition, short circuit testing may be conducted at 5 000 A to represent higher short circuit test values when all of the following requirements are met

a) The same solid state protection circuitry is used throughout the series;

b) Any revisions to the protection circuitry require re-evaluation;

c) The protection circuitry turns off the output devices (Insulated Gate Bi-polar Transistor (IGBT), bi-polar, and similar devices prior to the time in which the devices are damaged by any increase in current. This is based on the manufacturer's rating of the output devices (typically 10 µs for IGBTs, and 50 µs for bi-polars);

d) Any increase in current experienced by the output devices is the result of the DC bus capacitor bank discharging;

e) The output devices are turned off by the protection circuitry prior to any significant increase in the input current;

f) In response to a higher standard fault current (for example 42 000 A vs. 5 000 A), the protection circuitry shall react to the higher standard fault current (42 000 A) in the same or shorter time as the lower standard fault current (5 000 A). This may be verified through testing at the higher fault current value or through inspection of the SOLID STATE SHORT CIRCUIT PROTECTION hardware and software circuitry; and

g) When relying on current sensing (as opposed to output device collector voltage sensing) to actuate the protection circuitry, either the DC bus or all main motor output lines shall be monitored.

5.2.3.6.1DV.3 The criteria for samples to test for a drive series that uses fuses or circuit breakers for compliance with this test is based on comparing the fuse or circuit breaker ratings to the Silicon Controlled Rectifier (SCR) or transistor output device ratings for each model within the series (specific ratings to evaluate are the I^2t and I_p values).

5.2.3.6.2 Test configuration

In the case of a PDS/CDM/BDM supplied without an enclosure, a wire mesh cage which is 1,5 times the individual linear dimensions of the PDS/CDM/BDM part under study shall be used to simulate the intended enclosure.

The PDS/CDM/BDM, and the wire mesh cage (if used), shall be earthed according to the requirements of 4.3.5.3.2.

Surgical cotton shall be placed at all openings, handles, flanges, joints, and similar locations on the outside of the enclosure or around the wire mesh cage (if used).

Where the PDS under test is specified in its installation manual to require external means of protection against faults, these specific means shall be provided for the test.

The voltages of accessible SELV and PELV CIRCUITS of DVC A shall be monitored.

5.2.3.6.2DV.1 D2 *Modification to add the following:*

5.2.3.6.2DV.1.1 Enclosures

5.2.3.6.2DV.1.1.1 Enclosed type drives shall be tested within the intended enclosure.

5.2.3.6.2DV.1.1.2 OPEN TYPE drives shall be tested within one of the following:

a) An unventilated solid outer enclosure 1-1/2 times the size of the drive;

b) A wire mesh outer enclosure 1-1/2 times the size of the drive; or

c) An outer enclosure of such size and with such ventilation as described in the INSTALLATION instructions provided with the drive.

5.2.3.6.2DV.2 D2 *Modification to add the following:*

5.2.3.6.2DV.2.1 Earthing

5.2.3.6.2DV.2.1.1 The PDS/CDM/BDM, and the wire mesh cage (if used), shall be connected to earth. The conductor shall have a maximum length of 4 ft (1,2 m) and be sized in accordance with 4.3.5.4DV.1. For conductors sized 6 AWG (13,3 mm^2) or smaller shall be solid wire.

5.2.3.6.2DV.2.1.2 The source used for test shall have an earthing system according to the following:

a) For PDS/CDM/BDM intended for connection to systems according to 4.3.6.1.4DV.2, the source shall have a measured r.m.s working voltage from phase to earth equal to or greater than the STRAIGHT VOLTAGE RATING, or the measured working voltage from phase to earth may be lower than the STRAIGHT VOLTAGE RATING if the earth connection of the PDS/CDM/BDM, and the wire mesh cage (if used), are connected to the supply circuit pole least at risk of arcing to ground.

b) For BDCM/CDM/PDS intended for connection only to systems according to 4.3.6.1.4DV.3, the source shall have a measured r.m.s. working voltage from phase

to earth equal to or greater than the rated phase to earth voltage. If the source is a three phase, four wire, center earthed system (TN), the test circuit shall also be able to deliver not less than 90 % of the rated high fault current into a single-phase short circuit between each phase and “S”. The single-phase power factor shall comply with 5.2.3.6.2DV.3.

5.2.3.6.2DV.3 D2 *Modification to add the following:*

5.2.3.6.2DV.3.1 Mounting

5.2.3.6.2DV.3.1.1 Each drive shall be mounted as described in the manufacturer’s INSTALLATION instructions.

5.2.3.6.2DV.4 D2 *Modification to add the following:*

5.2.3.6.2DV.4.1 Branch circuit short circuit protection

5.2.3.6.2DV.4.1.1 Drives shall always be tested with fuses, circuit breakers, and Type E combination motor controllers unless the drive is marked to identify that branch circuit short circuit protection shall be provided in compliance with one of the following:

a) Branch circuit short circuit protection shall be provided by fuses only (either semiconductor or non-semiconductor types), then testing with circuit breakers and Type E combination motor controllers is not required.

b) Branch circuit short circuit protection shall be provided by fuses (either semiconductor or non-semiconductor types) or circuit breakers only, then testing with Type E combination motor controllers is not required.

c) Branch circuit short circuit protection shall be provided by fuses (either semiconductor or non-semiconductor types) or Type E combination motor controllers only, then testing with circuit breakers is not required.

d) Branch circuit short circuit protection shall be provided by circuit breakers only, then testing with fuses and Type E combination motor controllers is not required.

5.2.3.6.2DV.4.1.2 The overcurrent protective device used for this test shall be suitable for branch circuit protection in accordance with the National Electrical Code, NFPA 70 (fuses shall comply with the series of UL 248 standards, circuit breakers shall comply with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489, and Type E combination motor controllers shall comply with the Standard for Industrial Control Equipment, UL 508) and shall be in accordance with the marking of the drive specified in 6.3.7DV.1.1. When the drive is marked with a high fault current rating, the overcurrent protective device shall also comply with 5.2.3.6.2.1DV.5.5 through 5.2.3.6.2.1DV.5.7.

5.2.3.6.2DV.4.1.3 Testing with non-semiconductor types fuses shall not be used in lieu of testing with circuit breakers (either inverse-time or instantaneous trip types) or Type E combination motor controllers unless it can be shown that the let-through energy (I^2t) and peak let-through current (I_p) of the required inverse-time current-limiting circuit breaker and Type E combination motor controller will be less than that of the non-semiconductor type fuses with which the drive has been tested; or if the equipment under test is provided

with solid-state short circuit protection circuitry per 5.2.3.6.1DV and it can be shown by test that this circuitry operates prior to the branch circuit protection operating.

5.2.3.6.2DV.4.1.4 Testing with semiconductor type fuses shall not be used in lieu of testing with circuit breakers (either inverse-time or instantaneous trip types) or Type E combination motor controllers.

5.2.3.6.2DV.4.1.5 Even though the operation of SOLID STATE SHORT CIRCUIT PROTECTION circuitry may serve as the ultimate result to discontinue the short circuit test (see 5.2.3.6.5), the presence of this circuitry shall not replace the requirement for the fuses, breakers or Type E combination motor controllers.

5.2.3.6.2DV.4.1.6 Non-semiconductor fuse types are able to be rated any Class that is evaluated for branch circuit protection and shall have a voltage rating at least equal to the input voltage rating of the drive. These fuses shall have a current rating that is one of the following standard values – 1, 3, 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1 000, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000, 5 000 or 6 000 A – and shall comply with one of the following:

a) For drives with rated full-load output motor currents of 600 A or less, the current rating of the fuses shall be four times the maximum full-load motor output current rating;

b) For drives with rated full-load motor output currents of more than 600 A, the current rating of the fuses shall be three times the maximum full-load motor output current rating;

c) For a drive of any full-load motor output current rating, the current rating of the fuse is able to be less than that specified in (a) or (b) above when the drive is marked in accordance with 6.3.7DV.1.1.

When the calculated value of the fuse is between two standard ratings, the nearest standard rating less than the calculated value shall apply.

5.2.3.6.2DV.4.1.7 Semiconductor fuse types shall have a voltage rating at least equal to the input voltage rating of the drive and are able to have any current rating. Drives using semiconductor fuse types shall be marked in accordance with 6.3.7DV.1.1.

5.2.3.6.2DV.4.1.8 Inverse-time circuit breakers shall have a voltage rating at least equal to the voltage rating of the drive. These breakers shall have a current rating that is one of the following standard values – 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1 000, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000, 5 000 or 6 000 A – and that complies with one of the following:

a) For drives with rated full-load motor output currents of 100 A or less, the current rating of the breaker shall be four times the maximum full-load motor output current rating; or

b) For drives with rated full-load motor output currents of more than 100 A, the current rating of the breaker shall be three times the maximum full-load motor output current rating; or

c) For drives of any full-load motor output current rating, the current rating of the breaker is not prohibited from being less than that specified in (a) or (b) above when the drive is marked in accordance with 6.3.7DV.1.1.

When the calculated value of the circuit breaker is between two standard ratings, the nearest standard rating less than the calculated value shall apply. When the calculated value of the breaker is less than 15 A, a breaker rated 15 A shall be used.

5.2.3.6.2DV.4.1.9 Instantaneous trip type circuit breakers shall have a voltage rating at least equal to the input voltage rating of the drive, and are able to have any current rating, when the drive is marked in accordance with 6.3.7DV.1.1.

5.2.3.6.2DV.4.1.10 A drive utilizing non-semiconductor type fuses or inverse-time type circuit breakers sized, in accordance with 5.2.3.6.2DV.4.1.6(a), 5.2.3.6.2DV.4.1.6(b), 5.2.3.6.2DV.4.1.8(a), or 5.2.3.6.2DV.4.1.8(b) require no marking to indicate the manufacturer, model number or rating of the fuse or breaker.

5.2.3.6.2DV.4.1.11 Type E combination motor controllers are rated in volts and horsepower. To determine the current rating of the Type E combination motor controller, refer to Table DVE.1 and read the full load current rating at the intersection of the appropriate voltage and phase columns and the applicable horsepower row. If the overload setting of the Type E combination motor controller is adjustable, the full load current rating of the Type E combination motor controller is defined as the maximum current setting to which the controller may be adjusted.

5.2.3.6.2DV.4.1.12 The full load current rating of the Type E combination motor controller shall not be less than the rated input current of the drive controller.

5.2.3.6.2DV.4.1.13 When conducting the short circuit tests with a Type E combination motor controller, the tests are to be conducted with the controller at its maximum settings.

5.2.3.6.2DV.4.1.14 The short circuit interrupting rating of the fuse, the inverse-time circuit breaker or the Type E combination motor controller shall not be less than the short circuit rating of the drive controller.

5.2.3.6.2DV.4.1.15 It is not required to monitor the voltages of accessible SELV and PELV CIRCUITS if the PDS complies with the ac or dc voltage requirements in accordance with 5.2.3.2 at the conclusion of the test.

5.2.3.6.2DV.5 D2 *Modification to add the following:*

5.2.3.6.2DV.5.1 Input/output wiring connection

5.2.3.6.2DV.5.1.1 Each drive is to be tested with 4 ft (1,2 m) of wire, or less, attached to each input and output terminal. The input/output test wiring is not prohibited from exceeding 4 ft (1,2 m) in length when the wiring is in the test circuit during its calibration.

5.2.3.6.2DV.5.1.2 The wire size of the input and output wiring shall be in accordance with Table 4.3.8.8.2DV.1 with the required ampacity of the wiring being based on the marked wire temperature rating (either 60 °C or 75 °C) and each of the following:

> **a) The main input power wiring shall be sized for 125 percent of the rated fullload output motor current;**
>
> **b) All other input wiring shall be sized for 100 percent of the maximum intended full-load current;**

c) The main output power wiring shall be sized for 125 percent of the rated fullload current or shall be sized for 125 percent of the full-load output motor current specified in Table DVE.1 or Table DVE.2, based on the rated horsepower rating; and

d) All other output wiring shall be sized for 100 percent of the maximum intended full-load current.

5.2.3.6.2DV.5.1.3 The type of wire insulation shall be T or TW for 60 °C wiring and shall be THW or THWN for 75 °C wiring.

5.2.3.6.2DV.5.1.4 For drives rated more than 200 hp (150 kW), the main input/output power connections shall be in accordance with 5.2.3.6.2DV.5.1.1 – 5.2.3.6.2DV.5.1.3, or may be made with bus bars equivalent in cross-sectional area to the required wiring. The bus bars are to be in the test circuit during its calibration.

5.2.3.6.2DV.5.1.5 Input and output wiring may then be routed through 10 – 12 in (250 – 305 mm) lengths of conduit installed on the enclosure. If conduit is not used then the wire shall be routed through a bushing appropriate for the size of the conductors.

5.2.3.6.2DV.5.1.6 The ends of the conduit, the bushing opening, or the openings around the bus bars are to be plugged with surgical cotton.

5.2.3.6.2.1 Supply voltage and current

PDS rated for d.c. input shall be tested using a d.c. source. PDS rated for a.c input shall be tested at their rated input frequency.

The open-circuit voltage of the supply shall be 100 % – 105 % of the rated input voltage. The open-circuit voltage may exceed 105 % of the rated input voltage at the request of the manufacturer.

For the Short-circuit test, the supply shall be capable of delivering the specified PROSPECTIVE SHORT-CIRCUIT CURRENT (see 4.3.9) at the connection to the PDS, unless circuit analysis demonstrates that a lesser value may be used.

For the Breakdown of components test, the supply shall be capable of delivering a PROSPECTIVE SHORT-CIRCUIT CURRENT of between 1 kA and 5 kA, unless the analysis of 4.2 shows that a different value is required.

5.2.3.6.2.1DV.1 D2 *Modification to add the following – Test circuit voltage:*

5.2.3.6.2.1DV.1.1 Drives rated for alternating current within the range of 50-60 Hz are to be tested using a sinusoidal current source at a frequency in the range of 48-62 Hz.

5.2.3.6.2.1DV.2 D2 *Modification to add the following – prospective short-circuit current:*

5.2.3.6.2.1DV.2.1 The Breakdown of Components and Short-circuit tests shall be conducted at the Standard Fault Current test values in accordance with Table 5.2.3.6.2.1DV.1. When assigned a short-circuit rating higher than the Standard fault current test value, the drive must also comply with 5.2.3.6.2.1DV.2.2 and 5.2.3.6.2.1DV.2.4. The circuit capability for all of the tests shall be verified in accordance with the Calibration of Short Circuit Test Circuit, 5.2.3.6.2.1DV.3.

Table 5.2.3.6.2.1DV.1
Standard Fault Current Test Values for Devices Rated 600 V or Less

Ratings		Test current
hp[a]	(kW)[a]	A
0 – 50	(0 – 37,3)	5 000
51 – 200	(39 – 149)	10 000
201 – 400	(150 – 298)	18 000
401 – 600	(299 – 447)	30 000
601 – 900	(448 – 671)	42 000
901 – 1 600	(672 – 1 193)	85 000
1 601 or more	(1 194 or more)	100 000

[a] For drives rated only in current and not in horsepower or kilowatts, the equivalent horsepower rating shall be determined from Table DVE.1 or Table DVE.2 as appropriate.

5.2.3.6.2.1DV.2.2 Other than as noted in 5.2.3.6.2.1DV.2.3, a drive series with an assigned short circuit rating higher than the standard fault current test value shown in Table 5.2.3.6.2.1DV.1 shall comply with the short-circuit test requirements of this clause for the Standard Fault Currents and the Short Circuit Test – High Fault Currents, 5.2.3.6.2.1DV.5.

5.2.3.6.2.1DV.2.3 A drive series is in compliance with the Short Circuit Test – High Fault Currents, 5.2.3.6.2.1DV.5, without additional testing when:

a) The drive series uses SOLID STATE SHORT CIRCUIT PROTECTION circuitry for compliance with the standard fault current short circuit test; and

b) The SOLID STATE SHORT CIRCUIT PROTECTION circuitry is used in accordance with 5.2.3.6.1DV.1.

5.2.3.6.2.1DV.2.4 A drive series with an assigned short circuit rating higher than the standard fault current test value shown in Table 5.2.3.6.2.1DV.1 shall comply with the breakdown of components test requirements of this clause at the Standard Fault Current and the Breakdown of Components Test – High Fault Currents, 5.2.3.6.2.1DV.5.

5.2.3.6.2.1DV.2.5 Where circuit analysis demonstrates that the available short-circuit energy (based on the marked short-circuit rating) has no greater impact on the results of the breakdown of components testing than a lower available short-circuit energy, the breakdown of components test may be conducted at the lower energy level. The circuit analysis shall consider:

- Bursting I^2t of conductors and components;
- Identification of fault current path in the equipment;
- Possibility and extent of cascading failures;
- Nature of failure with respect to physical location (e.g. proximity to other critical components, barriers, clearances, creepage distances, vent openings);
- Identification of all energy sources (mains, capacitors, batteries, motor, etc.) in the circuit;
- For main supply, consider power circuit configuration and grounding (wye, delta, IT, etc.);

- Enclosure (size, material, structure, openings, etc.);
- Types and ratings of OCPD specified to be used with the PDS/CDM/BDM;
- Specified linearity of current limiting components (external & internal) with respect to available fault current;
- Effect of multiple ratings of the PDS (relationship of power rating and voltage);
- Variation in components within family of drives;
- Maximum variation of mains impedance, frequency, voltage with respect to specified/published product applications (use of transformer, etc.);
- Testing may be necessary to validate portions of the circuit analysis.

5.2.3.6.2.1DV.2.6 BDM/CDM/PDS supplied by photovoltaic (PV) modules

5.2.3.6.2.1DV.2.6.1 A BDM/CDM/PDS which receives power from PV modules or panels shall be tested by connecting the equipment to a power source that is representative of a PV power system with regard to maximum power voltage and current levels.

5.2.3.6.2.1DV.2.6.2 Tests involving an input for connection to a PV source shall use a source which complies with one of the following:

a) When the BDM/CDM/PDS requires the use of a source having specific V/I characteristics (such as PV modules provided with integrated electronics), the test shall be conducted with the source intended for use with the input, or with a source with V/I characteristics as close as practicable to the intended source.

b) If the BDM/CDM/PDS is required to be used with PV modules which are provided with the product, or is marked only for use with specific models of PV modules where the V/I characteristic curves are known, the test source shall be a PV simulator which can provide:

1) A minimum open circuit voltage greater than or equal to the PV module rated operating voltage multiplied by 1.5.

2) A minimum available short circuit current greater than or equal to the PV module nameplate short circuit current (I_{sc}) multiplied by 1.5.

c) If the BDM/CDM/PDS is rated for general use with PV modules which comply with NEC cl. 690.8 and 690.9, the test source shall be a PV input source (PV array or PV simulator) which can provide:

1) A minimum open circuit voltage greater than or equal to the products' rated input operating voltage multiplied by 1.25.

2) A minimum available short circuit current greater than or equal to the products' rated input short circuit current multiplied by 1.25.

5.2.3.6.2.1DV.2.6.3 If an input is rated for use with multiple source types, the source with the most severe characteristic shall be used to characterize the test source.

5.2.3.6.2.1DV.2.6.4 During testing using a PV simulator, V_{oc}, I_{sc}, and the other controllable quantities such as Irradiance, Vmp, Imp and FF (fill factor) shall be set at levels which cause the product to operate at a V/I input level which provides the required voltage and

current for the test being conducted, however V_{oc} and I_{sc} shall be set no higher than the products' maximum rated open circuit voltage and short circuit respectively.

5.2.3.6.2.1DV.2.6.5 During the temperature rise test, the PV source shall be set to operate at the operating point which creates the highest PV output voltage and the operating point which creates the highest DC current prior to a protective device or circuit operating. The recorded temperatures shall be the highest of those between the highest voltage and highest current operating points.

5.2.3.6.2.1DV.2.6.6 If the equipment is designed to utilize multiple types of sources which can be connected simultaneously, then all sources which may be connected simultaneously shall be utilized during the test, and a test source shall be provided in accordance with the above description if a PV type, or with 5.2.3.6.2.1DV.2.1 or 5.2.3.6.2.1DV.2.2 as appropriate.

5.2.3.6.2.1DV.2.6.7 The circuit capability for all of the tests shall be verified in accordance with the Calibration of Short Circuit Test Circuit, 5.2.3.6.2.1DV.3. The equipment shall be marked in accordance with 6.3.6.8DV.2.

5.2.3.6.2.1DV.3 D2 *Modification to add the following – Calibration of short circuit test circuits 10 000 A or less:*

5.2.3.6.2.1DV.3.1 For an AC circuit intended to deliver 10 000 A or less, the current is to be determined in accordance with one of the following:

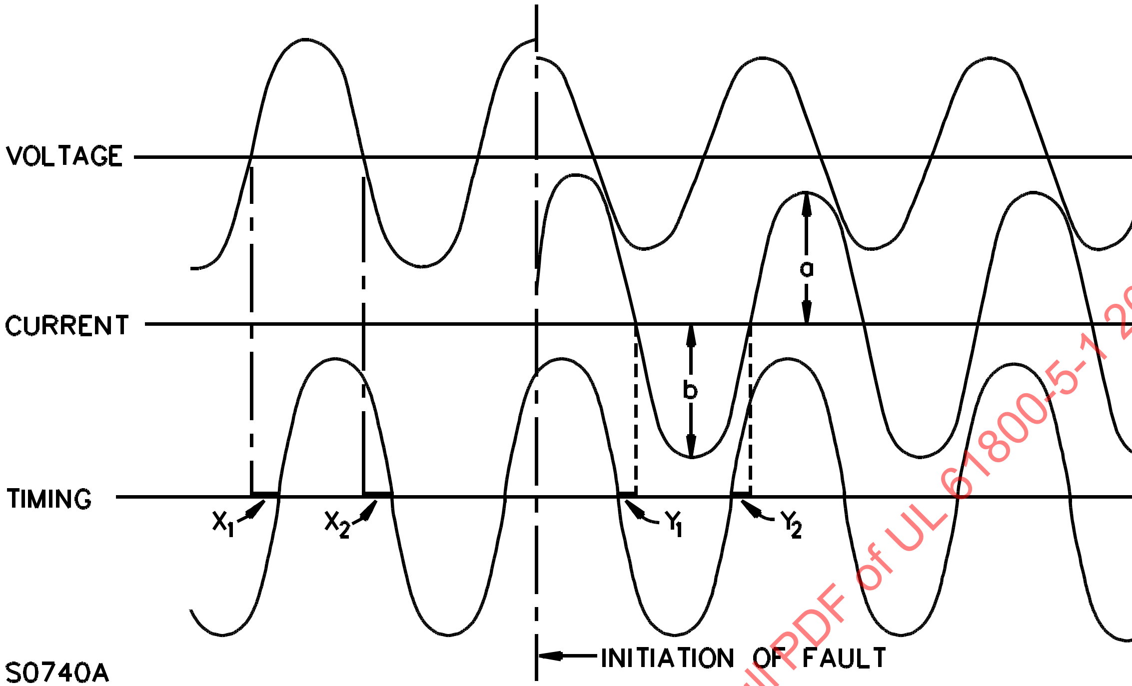
a) For a 3-phase test circuit, the current is to be determined by averaging the rms values of the first complete cycle of current in each of the three phases;

b) For a single phase test circuit, the current is to be the rms value of the first complete cycle (see Figure 5.2.3.6.2.1DV.1) when the circuit is closed to produce symmetrical current waveform. The direct current component is not to be added to the value obtained when measured as illustrated. In order to obtain the required symmetrical waveform of a single phase circuit, controlled closing is most often used although random closing methods are not prohibited from being used; or

c) For a single or 3 phase test circuit, an analytical evaluation that suitably demonstrates the available current is able to be used.

Figure 5.2.3.6.2.1DV.1

Determination of current for circuits of 10 000 A and less



5.2.3.6.2.1DV.4 D2 *Modification to add the following – Calibration of short circuit test circuits more than 10 000 A:*

5.2.3.6.2.1DV.4.1 For an AC circuit intended to deliver more than 10 000 A, the current is to be determined in accordance with one of the following:

a) In accordance with the requirements in 5.2.3.6.2.1DV.4.2 – 5.2.3.6.2.1DV.4.6. Instrumentation used to measure these test circuits of more than 10 000 A is to comply with the requirements in 5.2.3.6.2.1DV.4.7 – 5.2.3.6.2.1DV.4.17; or

b) For a single or 3 phase test circuit, an analytical evaluation that suitably demonstrates the available current is able to be used.

5.2.3.6.2.1DV.4.2 The rms symmetrical current is to be determined, with the supply terminals short-circuited by measuring the alternating-current component of the wave at an instant 1/2 cycle – on the basis of the test frequency timing wave – after the initiation of the short circuit. The current is to be calculated in accordance with Figure 7 in the Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis, ANSI/IEEE C37.09-1989.

5.2.3.6.2.1DV.4.3 For a 3-phase test circuit, the rms symmetrical current is to be the average of the currents in the three phases. The rms symmetrical current in any one phase is not to be less than 90 percent of the required test current.

5.2.3.6.2.1DV.4.4 The test circuit and its transients are to be such that:

a) 3 cycles after initiation of the short circuit, the symmetrical alternating component of current is not less than 90 percent of the symmetrical alternating component of current at the end of the first 1/2 cycle; or

b) The symmetrical alternating component of current at the time at which the overcurrent protective device interrupts the test circuit is at least 100 percent of the rating for which the controller is being tested. In 3-phase circuits, the symmetrical alternating component of current of all three phases is to be averaged.

5.2.3.6.2.1DV.4.5 The recovery voltage is to be at least equal to the RATED VOLTAGE of the controller. The peak value of the recovery voltage within the first complete half cycle after clearing and for the next five successive peaks is to be at least equal to 1,414 times the rms value of the RATED VOLTAGE of the controller. Each of the peaks is not to be displaced by more than ±10 electrical degrees from the peak values of the open-circuit recovery voltage – that is, the displacement of the peak from its normal position on a sinusoidal wave. The average of the instantaneous values of recovery voltage each of the first six, half cycles measured at the 45 degree and 135 degree points on the wave is to be not less than 85 percent of the rms value of the RATED VOLTAGE of the controller. The instantaneous value of recovery voltage measured at the 45 degree and 135 degree points of each of the first six, half cycles is in no case to be less than 75 percent of the rms value of the RATED VOLTAGE of the controller.

5.2.3.6.2.1DV.4.6 When there is no attenuation or phase displacement of the first full cycle of the recovery voltage wave when compared with the open-circuit secondary voltage wave before current flow in a circuit that employs secondary closing, the detailed measurement of recovery voltage characteristics as indicated in 5.2.3.6.2.1DV.4.5 is not required.

5.2.3.6.2.1DV.4.7 The galvanometers in a magnetic oscillograph employed for recording voltage and current during circuit calibration and while testing are to be of a type having a flat (±5 percent) frequency response from 50 – 1 200 Hz. For fast acting fuses, current limiters, or motor-short-circuit protectors, a galvanometer is often required to have a flat frequency response from 50 – 9 000 Hz or an oscilloscope is required to be used to obtain accurate values of peak current, (I_p), and energy let-through, (I^2t).

5.2.3.6.2.1DV.4.8 Galvanometers are to be calibrated as described in 5.2.3.6.2.1DV.4.9 – 5.2.3.6.2.1DV.4.12.

5.2.3.6.2.1DV.4.9 When a shunt is used to determine the circuit characteristics, a direct-current calibrating voltage is normally used. The voltage applied to the oscillograph galvanometer circuit is to result in a deflection of the galvanometer equivalent to that which is expected when the same galvanometer circuit is connected to the shunt and the nominal short-circuit current is flowing. The voltage is to be applied so as to result in the galvanometer deflecting in both directions. Additional calibrations are to be made using 50 percent and 150 percent of the voltage used to obtain the deflection indicated above, except that when the anticipated maximum deflection is less than 150 percent, such as a symmetrically closed single-phase circuit, any other usable calibration point is to be chosen. The sensitivity of the galvanometer circuit in volts per inch (or millimeter) is to be determined from the deflection measured in each case, and the results of the six trials averaged. The peak amperes per inch (or millimeter) is obtained by dividing the sensitivity by the resistance of the shunt. This multiplying factor is to be used for the determination of the rms current as described in 5.2.3.6.2.1DV.4.2.

5.2.3.6.2.1DV.4.10 A 60 Hz sine-wave potential is able to be used for calibrating the galvanometer circuit, using the same general method described in 5.2.3.6.2.1DV.4.9. The resulting factor is to be multiplied by 1,414.

5.2.3.6.2.1DV.4.11 When a current transformer is used to determine the circuit characteristics, an alternating current is to be used to calibrate the galvanometer circuit. The value of current applied to the galvanometer circuit is to result in a deflection of the galvanometer equivalent to that which is expected when the same galvanometer is connected to the secondary of the current transformer and nominal short circuit current is flowing in the primary. Additional calibrations are to be made at 50 percent and 150 percent of the current used to obtain the deflection indicated above except that when the anticipated maximum deflection is less than 150 percent, such as in a symmetrically closed single-phase circuit, any other usable calibration point is to be chosen. The sensitivity of the galvanometer circuit in rms amperes per inch (or millimeter) is to be determined in each case and the results averaged. The average sensitivity is to be multiplied by the current-transformer ratio and by 1,414 to obtain peak amperes per inch. This constant is to be used for the determination of the rms current as described in 5.2.3.6.2.1DV.4.2.

5.2.3.6.2.1DV.4.12 All the galvanometer elements employed are to line-up properly in the oscillograph, or the displacement differences are to be noted and used as required.

5.2.3.6.2.1DV.4.13 The sensitivity of the galvanometers and the recording speed are to be such that the values of voltage, current, and power factor are accurately determined. The recording speed is to be at least 60 in (1,5 m) per second.

5.2.3.6.2.1DV.4.14 With the test circuit adjusted to provide the specified values of voltage and current and with a noninductive (coaxial) shunt that has been found to provide the intended function for use as a reference connected into the circuit, the tests described in 5.2.3.6.2.1DV.4.15 and 5.2.3.6.2.1DV.4.16 are to be conducted to verify the accuracy of the manufacturer's instrumentation.

5.2.3.6.2.1DV.4.15 With the secondary open-circuited, the transformer is to be energized and the voltage at the test terminals observed to see when rectification is occurring making the circuit unusable for test purposes because the voltage and current are not sinusoidal. Six random closings are to be made to demonstrate that residual flux in the transformer core does not result in rectification. When testing is done by closing the secondary circuit, this check is able to be omitted when testing is not commenced before the transformer has been energized for 2 s, or longer and when an investigation of the test equipment shows that a longer time is required.

5.2.3.6.2.1DV.4.16 With the test terminals connected together by means of a copper bar, a single-phase circuit is to be closed as nearly as possible at the moment that produces a current wave with maximum offset. The short circuit current and voltage are to be recorded. The primary voltage is to be recorded when primary closing is used. The current measured by the reference shunt is to be within 5 percent of that measured using the manufacturer's instrumentation and there is to be no measurable variation in phase relationship between the traces of the same current. Controlled closing is not required for polyphase circuits.

5.2.3.6.2.1DV.4.17 When the verification of the accuracy of the manufacturer's instrumentation is completed, the reference coaxial shunt is to be removed from the circuit. The reference coaxial shunt is not to be used during the final calibration of the test circuit nor during the testing of controllers.

5.2.3.6.2.1DV.5 D2 *Modification to add the following – Short circuit test and breakdown of components test – high fault currents*

5.2.3.6.2.1DV.5.1 When any models within a drive series are intended to be rated with high fault current values in excess of the standard current values required by Table 5.2.3.6.2.1DV.1, then they shall comply with both (a) and (b) below, or shall comply with 5.2.3.6.2.1DV.5.2 – 5.2.3.6.2.1DV.5.10.

a) The drive series uses SOLID STATE SHORT CIRCUIT PROTECTION circuitry for compliance with the Short Circuit Test, 5.2.3.6.3; and

b) The SOLID STATE SHORT CIRCUIT PROTECTION circuitry is used in accordance with 5.2.3.6.1DV.2.

5.2.3.6.2.1DV.5.2 One representative model from those intended to be rated with high fault current values shall be used for testing. This representative model shall be subjected to only one high fault current short circuit test.

5.2.3.6.2.1DV.5.3 The criteria for samples to test for a drive series that uses fuses for compliance with this test is based on comparing the fuse ratings to the Silicon Controlled Rectifier (SCR) or transistor output device ratings for each model within the series (specific ratings to evaluate are the I^2t and I_p values).

5.2.3.6.2.1DV.5.4 The high fault current values for which a drive is able to be tested are not required to be one of the same values detailed in Table 5.2.3.6.2.1DV.1.

5.2.3.6.2.1DV.5.5 The requirements for conducting the high fault current short circuit test shall be in accordance with 5.2.3.6.2 except for the following differences:

a) For drives rated over 10 000 A, the branch circuit short circuit protection fuses shall be limited to high-interrupting capacity, current limiting types such as Class CC, CF, G, J, L, R, T, etc.

b) For drives rated 50 hp (37 kW) or less and tested at 10 000 A, the branch circuit short circuit protection fuses are able to be Class H or K.

c) A drive that is intended to be used with Class RK1 or RK5 fuses shall be tested with fuses having I^2t and I_p characteristics for Class RK5 fuses. All references to Class R fuses are intended to mean fuses with energy let-through (I^2t) characteristics of Class RK5 fuses.

d) For noncombination controllers, the circuit breaker to be used is to be from commercially available units of the molded-case type having the same characteristics with respect to opening time and without current-limiting features.

e) For circuit breakers with current limiters provided as part of the controller, the current limiter shall have a peak let-through current and a clearing I^2t not less than the maximum value established for the current limiter intended to be used with the controller being tested, when tested on a single-phase circuit.

f) A Class CC, CF, G, J, L, R, or T fuse, or motor short-circuit protector shall have a peak let-through current and clearing I^2t not less than the maximum value established for the fuse (see the UL 248 series of standards for fuses), or motor short-circuit protector rating that is intended to be used with the controller being tested, when tested on a single-phase circuit. For a fuse with I_p and I^2t limits established for several different short-circuit current levels, the test fuse is to have

at least the maximum values of the current corresponding to the marked short-circuit-withstand current of the controller.

g) A test limiter is not prohibited from being used in place of the fuses specified in (a), (b), (c), and (f) above.

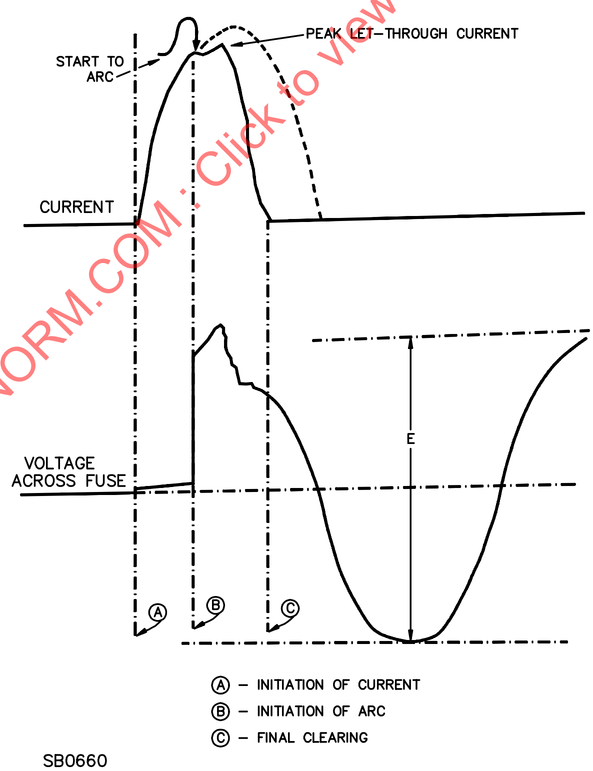
5.2.3.6.2.1DV.5.6 To obtain the required values specified in 5.2.3.6.2.1DV.5.5 (f) and (g), a fuse, current limiter, or motor short-circuit protector larger than that specified for use with the device being tested is able to be used; or a commercially available test fuse designed and calibrated to exhibit I^2t and I_p characteristics at least equal to the maximum limits for the fuse, current limiter, or motor short-circuit protector rating. The let-through characteristics are to be determined in accordance with 5.2.3.6.2.1DV.4.9 – 5.2.3.6.2.1DV.4.12.

5.2.3.6.2.1DV.5.7 Fuses, current limiters, or motor short-circuit protectors used for tests are to be from a batch from which two samples have been tested. The value of the I_p and I^2t determined for the two samples is to be equal to or greater than the required values. These determinations are to be made in accordance with 5.2.3.6.2.1DV.5.8 – 5.2.3.6.2.1DV.5.10.

5.2.3.6.2.1DV.5.8 Figure 5.2.3.6.2.1DV.2 is typical of oscillograms obtained during the test of a fuse, current limiter, or motor short-circuit protectors on an alternating-current circuit; and represents a circuit that opened before the current reached its first major peak. The peak let-through current I_p is to be determined as illustrated.

Figure 5.2.3.6.2.1DV.2

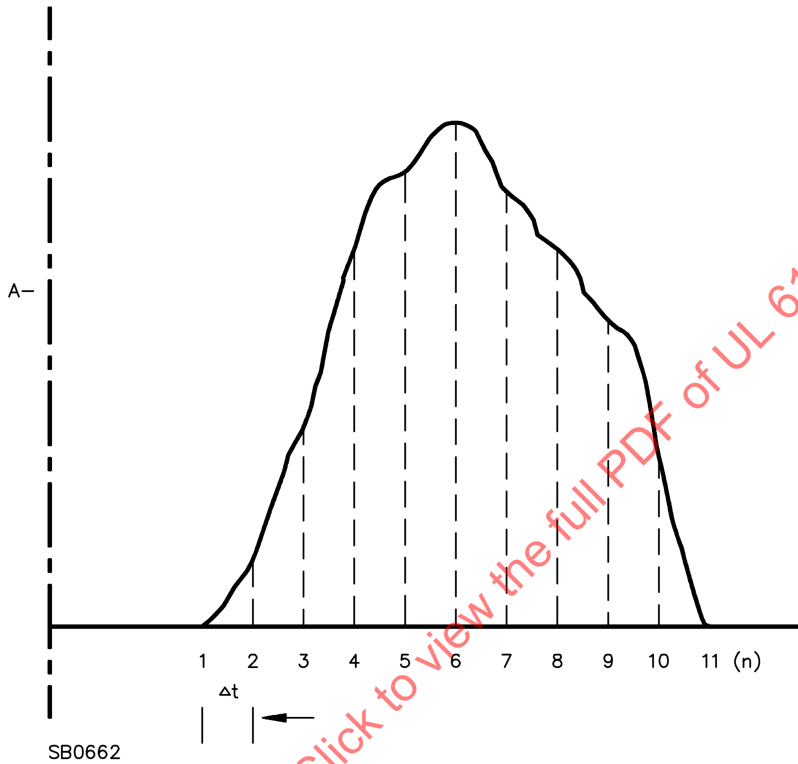
Peak Let-Through Current



5.2.3.6.2.1DV.5.9 The let-through energy (I^2t) is to be determined from an oscillogram showing a current trace during the interruption of the circuit by the fuse, current limiter, or motor short-circuit protectors. The determination is to be made by the application of Simpson's rule illustrated in Figure 5.2.3.6.2.1DV.3 or the use of an integrating planimeter.

Figure 5.2.3.6.2.1DV.3

Application of Simpson's Rule to Fuse Current Oscillogram to Obtain Let-Through I^2t



5.2.3.6.2.1DV.5.10 The time base in degrees-per-inch (degrees/cm) is to be determined by averaging the distance, between zero-line crossover points of the voltage wave or a timing wave, in which the fuse-current race is most nearly centered.

5.2.3.6.3 Short-circuit test

5.2.3.6.3.1 Load conditions

The short circuit test shall be performed with the CDM/BDM at full load or light load whichever creates the more severe condition.

5.2.3.6.3.1DV D2 *Modification to add the following:*

As an alternate to providing a full load or light load, a remote circuit may be connected to each drive such that the output devices are actuated independent of any loading.

5.2.3.6.3.2 Short-circuit between phase terminals of power outputs

Power outputs shall be provided with conductors of a cross-section and material appropriate to the rated current available at the power output. The length of the loop (forth and back) shall be approximately 2 m, unless the size of the PDS requires a greater length, in which case the length shall be as short as practical to perform the test.

All phase terminals of each power output tested shall be simultaneously connected together, using an appropriate switching device.

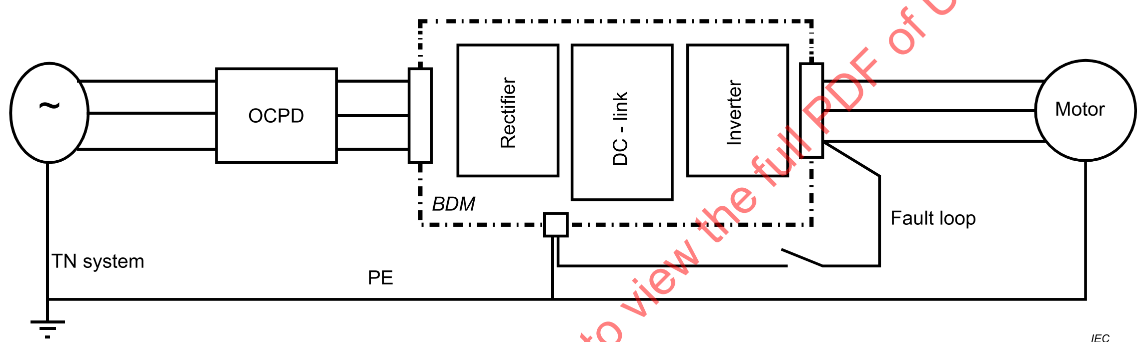
NOTE Terminals connected to the d.c. link are, for the tests of 5.2.3.6.3.2 and 5.2.3.6.3.3, treated as phases.

5.2.3.6.3.3 Short-circuit between phase terminals of power output and protective earth

The phase to protective earth fault condition shall be evaluated for each phase, one at a time, as a protective earth short-circuit.

It is permitted to operate only one test per output if a symmetry per phase can be demonstrated and if the selected phase to be tested represents the most severe case.

See Figure 11, Figure 12, and Figure 13 for examples.



su4302

Key

OCPD Over current protective device

Figure 11

Example of short-circuit test between CDM/BDM motor power output and protective earth (motor separately earthed)

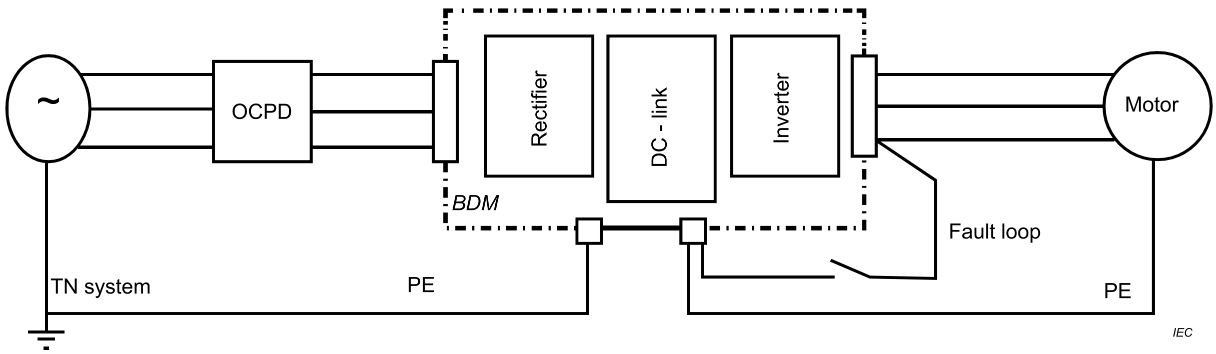


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Figure 12

Example of short-circuit test between CDM/BDM motor power output and protective earth (motor earthed through CDM/BDM)

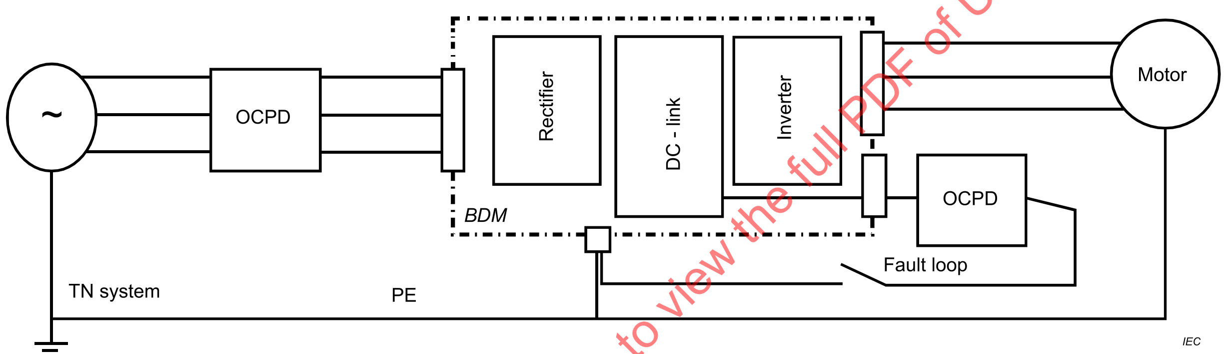

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Figure 13

Example of short-circuit test between CDM/BDM d.c. link power output and protective earth

5.2.3.6.3.3DV D2 *Modification:*

When OCPD is intended to be field installed in the BDM/CDM/PDS output (for example as in Figure 13), the OCPD shall only be included in the fault loop if the OCPD is integral to enclosed BDM/CDM/PDS or if the BDM/CDM is open type and the installation instructions shall specify that the protective device be included in the same end use enclosure as the BDM/CDM. See 6.3.7DV.1.1.

5.2.3.6.4 Breakdown of components test

5.2.3.6.4.1 Load conditions

The breakdown of a component, identified as a result of the circuit analysis of 4.2, shall be tested with the CDM/BDM at full load or light load whichever creates the more severe condition.

5.2.3.6.4.2 Application of short-circuit or open-circuit

The short circuit or open circuit shall be applied with cable of a cross-section of minimum 2,5 mm^2 and an appropriate switching device. The length of the loop shall be as short as practical to perform the test.

Each identified component shall be subjected to only one Breakdown of components test.

5.2.3.6.5 Test sequence

The PDS shall be powered, with its output(s) operating.

• For the Short-circuit test, a short-circuit shall be introduced at the output under test.

• For the Breakdown of components test, identified components shall be short-circuited or open-circuited, whichever creates the worse hazard, one at a time.

For the short-circuit test of 5.2.3.6.3.2 and breakdown of components test of 5.2.3.6.4, the PDS shall be operated until one or more of the following ultimate results are obtained:

a) the operation of ELECTRONIC POWER OUTPUT SHORT-CIRCUIT PROTECTION CIRCUITRY;

b) the opening of a short-circuit protection device, or

c) a steady state temperature is attained after a minimum of 10 min.

For the short-circuit test of 5.2.3.6.3.3, the PDS shall be operated until one or more of the following ultimate results are obtained:

i) an ELECTRONIC POWER OUTPUT SHORT-CIRCUIT PROTECTION CIRCUITRY that reduces the fault current to a value that ensures the voltage with respect to earth at the output phase under test is reduced to 50 V a.c. or 120 V d.c. or less. The voltage reduction shall be accomplished within 40 ms or in a time as given in IEC 60364-4-41:2005/AMD1:–, 411.3.2.2, 411.3.2.3 or 411.3.2.4, as applicable; or

ii) a disconnection is achieved by a short circuit protective device specified by the manufacturer within the time specified in IEC 60364-4-41:2005/AMD1:–, 411.3.2.

For pass criteria, also refer to 5.2.3.6.6.

5.2.3.6.5DV D2 *Modification:*

5.2.3.6.5DV.1 If the test is terminated by the operation of a SOLID STATE SHORT CIRCUIT PROTECTION circuitry this circuitry shall be subjected to the requirements in 5.2.9. If the SOLID STATE SHORT CIRCUIT PROTECTION circuitry is not subjected the requirements in 5.2.9, that circuitry shall be defeated prior to the test.

5.2.3.6.5DV.2 If the test is terminated by the opening of a short circuit protection device this device shall:

a) Be a fuse that complies with the UL 248 series of standards for fuses;

b) Be a circuit breaker that complies with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489; or

c) Be a self-protected combination motor controller that complies with the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1.

An open circuit failure of a semiconductor device is permitted for the termination of the test.

5.2.3.6.5DV.3 When none of the stated ultimate results occur, the drive shall not be in compliance with this section.

5.2.3.6.5DV.4 For the short-circuit test of 5.2.3.6.3.3, the PDS shall be operated until one or more of the following ultimate results are obtained:

a) The operation of electronic power output short-circuit protection circuitry;

b) The opening of a short-circuit protection device, or

c) A steady state temperature is attained after a minimum of 10 min.

5.2.3.6.6 Pass criteria

As a result of the Short-circuit test and the Breakdown of components test, the PDS/CDM/BDM shall comply with the following:

• there shall be no emission of flame or molten metal;

• the surgical cotton indicator shall not have ignited;

• the earth connection shall not have opened;

• the door or cover shall not have blown open;

• during and after the test, accessible SELV and PELV CIRCUITS shall not exhibit voltages greater than the time dependent voltages of Figure 7;

• during and after the test, LIVE PARTS at voltages greater than DECISIVE VOLTAGE CLASS A shall not become accessible.

The PDS/CDM/BDM is not required to be operational after testing and it is possible that the enclosure can become deformed.

5.2.3.6.6DV.2 D2 *Modification:*

It is not required to monitor the voltages of accessible SELV and PELV CIRCUITS if the PDS complies with the ac or dc voltage requirements in accordance with 5.2.3.2 at the conclusion of the test.

5.2.3.7 Capacitor discharge (TYPE TEST)

Verification of the capacitor discharge time as required by 4.3.11 may be done by a TYPE TEST and/or by calculation.

5.2.3.7DV D2 *Modification:*

Verification shall only be done by TYPE TEST. The drive shall be connected to a supply at the maximum RATED VOLTAGE until the capacitors under evaluation are fully charged. There shall be no load connected and the drive shall be in the stopped condition. The voltage across the capacitor shall be monitored before and after removal of the supply power. Timing shall start upon removal of the supply power. The voltage monitoring device shall have an input impedance of no less than 1 MΩ. Time to discharge to the specified voltage value shall be used to determine whether marking in accordance with 6.5.2 is required.

5.2.3.8 Temperature rise test (TYPE TEST)

The test is intended to ensure that parts and accessible surfaces of the PDS do not exceed the temperature limits specified in 4.4 and that the manufacturer's temperature limits of safety-relevant parts are not exceeded.

Where possible, the PDS shall be tested at worst-case conditions of rated power and CDM/BDM output current. For INTEGRATED PDS where the motor speed might affect the thermal condition in the CDM/BDM the test shall be conducted at worst case operating speed and load according to the manufacturer's specification.

If this is not possible, it is permitted to simulate the temperature rise, if the validity of the simulation can be demonstrated by tests at lower power levels.

The PDS shall be tested with at least 1,2 m of wire attached to each USER TERMINAL. The wire shall be of the smallest size intended to be connected to the PDS as specified by the manufacturer for installation. When there is only provision for the connection of bus bars to the PDS, they shall be of the minimum size intended to be connected to the PDS as specified by the manufacturer, and they shall be at least 1,2 m in length.

The test shall be maintained until thermal stabilization has been reached. That is, when three successive readings, taken at intervals of 10 percent of the previously elapsed duration of the test and not less than 10 minute intervals, indicate no change in temperature, defined as ± 1 °C between any of the three successive readings, with respect to the ambient temperature.

The maximum temperature of electrical insulation (other than that of windings), the failure of which could cause a hazard, is measured on the surface of the insulation at a point close to the heat source.

The maximum temperature attained shall be corrected to the rated ambient temperature of the PDS by adding the difference between the ambient temperature during the test and the maximum rated ambient temperature.

No corrected temperature shall exceed the rated temperature of the material or component measured.

During the test, thermal cutout, overload detection functions and devices shall not operate.

5.2.3.8DV.1 D2 *Modification to add the following:*

5.2.3.8DV.1.1 At the completion of the temperature test, the sample shall comply with the requirements of the a.c. or d.c. voltage test of 5.2.3.2.

5.2.3.8DV.1.2 Temperatures are to be measured with all parts operating simultaneously as under normal conditions, as the heating of one part is able to affect the heating of another part.

5.2.3.8DV.2 D2 *Modification:*

5.2.3.8DV.2.1 Open and enclosed type equipment shall be tested with an assumed minimum environmental ambient of 40 °C (104 °F) unless the equipment is marked for a higher or lower end use ambient. When the equipment is tested in an ambient other than the end use temperature rating, the maximum measured temperatures shall be linearly extrapolated for the intended end use ambient (for example, in a 25 °C ambient, 15 °C would be added to each temperature measurement where the maximum intended end use ambient is 40 °C). To determine the ambient, several temperature sensors are to be placed at different points around the equipment at a distance of 3 to 6 ft (0,9 to 1,8 m). The temperature sensors are to be located in the path of the cooling air of the equipment, and are to be protected from drafts and abnormal heat radiation. The AMBIENT TEMPERATURE is to be the mean of the readings of the temperatures taken at equal intervals of time during the final quarter of the duration of the test.

5.2.3.8DV.2.2 To determine whether power conversion equipment complies with the temperature test requirements, it is to be operated at the voltage specified in 5.2DV.1 until thermal stabilization occurs under normal conditions as follows:

a) For continuous operation, according to the continuous ratings;

b) For intermittent operation, according to the rated duty cycle; or

c) For short-time operation, for the rated operating time.

5.2.3.8DV.2.3 The rated current for equipment rated only in horsepower and not in current is to be as specified in Table DVE.1 and Table DVE.2. When the equipment is rated in current and horsepower, and the current rating is not the same as specified in Table DVE.1 and Table DVE.2 for the rated horsepower, the load current shall be the greater of the two current values. No protective devices or circuitry shall trip during the test.

5.2.3.8DV.2.4 When there is only provision for the connection of bus bars to power conversion equipment rated at 450 A or more, copper bus bars 1/4 in (6,4 mm) thick of the width specified in Table 5.2.3.8DV.1 and at least 4 ft (1,2 m) in length are to be used. The spacing between multiple bus bars is to be 1/4 in (6,4 mm) with no intentional wider spacing except as required at the individual terminals of the equipment.

Table 5.2.3.8DV.1
Width of Copper Bus Bars

Product ratings, A	Bus bars per terminal	Width of bus bars, in	(mm)
450 – 600	1	2	(51)
601 – 1 000	1	3	(76)
1 001 – 1 200	1	4	(102)
1 201 – 1 600	2	3	(76)
1 601 – 2 000	2	4	(102)
2 001 – 2 500	2	5	(127)
	4	2-1/2	(64)
2 501 – 3 000	3	5	(127)
	4	4	(102)

5.2.3.8DV.2.5 Wire size for the test shall be the smallest size having an ampacity of at least 125 % of the test current. See Table 4.3.8.8.2DV.1 for wire size ampacities.

5.2.3.8DV.2.6 The thermocouple method for temperature measurement as specified in Table 15 consists of the determination of temperature by use of a potentiometer type instrument and thermocouples that are applied to the hottest accessible parts. The thermocouples are to be made of wires not larger than 24 AWG (0,21 mm^2) and not smaller than 30 AWG (0,05 mm^2). The thermocouples and related instruments are to be accurate and calibrated in accordance with standard laboratory practice. The thermocouple wire is to conform with the requirements specified in the Initial Calibration Tolerances for Thermocouples table in Temperature Measurement Thermocouples, ANSI/ISA MC96.1.

5.2.3.8DV.2.7 The maximum junction temperature of power switching semiconductors, as specified by the semiconductor manufacturer, shall not be exceeded during the temperature test. To determine the junction temperature, reference temperatures (case, tab, heat sink, or similar parts) are to be measured and the junction temperature is to be calculated based on the semiconductor manufacturer's power dissipation and thermal resistance data.

5.2.3.8DV.3 D2 *Modification to add the following:*

5.2.3.8DV.3.1 Heat Cycling Test

5.2.3.8DV.3.1.1 Spring-loaded bus bar joints as described in 4.3.8.4DV.3 shall be subjected to a heat cycling test.

5.2.3.8DV.3.1.2 For the heat cycling test, the rated bus bar current shall vary in cycles in the manner described in 5.2.3.8DV.3.2.1 and 5.2.3.8DV.3.2.2. Results shall comply with the limitations on increase in temperature rise specified in 5.2.3.8DV.3.2.2.

5.2.3.8DV.3.1.3 The spring-loaded joints shall be conditioned by being assembled and disassembled 5 times prior to final assembly for the test.

5.2.3.8DV.3.2 Heat Cycling Test arrangement

5.2.3.8DV.3.2.1 The temperature rises on the contacts of the spring-loaded bus bar joint shall be determined while the equipment is carrying the specified current continuously. After temperatures have become constant under these conditions, the current shall be stopped and the equipment shall be allowed to cool to room temperature.

5.2.3.8DV.3.2.2 The equipment shall then be subjected to two successive sets of cycling of the current. Each set shall consist of 42 complete cycles. During each cycle the current shall be on for 2 hours and off for 2 hours; or if, during the initial heating mentioned in 5.2.3.8DV.3.2.2, average temperatures on the spring-loaded bus bar joint at the end of 2 hours are more than 5 °C lower than the average final temperatures during continuous operation, the current shall remain on for 3 hours in each cycle. Stable maximum temperatures shall be observed again after the 42nd cycle and also after the 84th cycle. The final temperatures shall not be more than 5 °C higher than those observed initially, nor shall the final temperatures be more than 5 °C higher than those observed at the conclusion of the 42nd cycle.

5.2.3.9 Protective bonding (type test and routine test)

The impedance of each PROTECTIVE BONDING circuit between the PE terminal and relevant points that are part of each PROTECTIVE BONDING circuit shall be measured with a current of at least 10 A derived from a supply source, the output of which is not earthed, having a maximum no-load voltage of 24 V.

When the PROTECTIVE BONDING has been designed using the cross-section rules of 4.3.5.4, the impedance shall not exceed 0,02 Ω.

When the PROTECTIVE BONDING has been designed using the rules of 4.3.5.3.3, the impedance shall not exceed the value required to meet the time dependent voltage limits of Figure 7.

NOTE 1 The use of a supply with an earthed output can produce misleading results.

NOTE 2 The use of larger currents increases the accuracy of the test result, especially with low resistance values, i.e. larger cross sectional areas and/or shorter conductor length.

NOTE 3 As this is a very low resistance, care should be exercised in positioning the measuring probes.

This test shall be performed as a ROUTINE TEST if the continuity of the PROTECTIVE BONDING is achieved at any point by means of a single fastener.

5.2.3.9DV D2 *Modification:*

Each PROTECTIVE BONDING circuit shall always be subjected to an impedance test and the calculated impedance based on the test current shall not exceed 0,02 Ω.

5.2.4 Abnormal operation tests

5.2.4.1 General

Before all operation tests, the test sample shall be mounted, connected, and operated as described in the temperature rise test.

In the case of a CDM/BDM supplied without an enclosure, a wire mesh cage which is 1,5 times the individual linear dimensions of the CDM/BDM part under study shall be used to simulate the intended enclosure.

The PDS, and the wire mesh cage (if used), shall be earthed according to the requirements of 4.3.5.3.2.

Surgical cotton shall be placed at all openings, handles, flanges, joints and similar locations on the outside of the enclosure, and the wire mesh cage (if used), in a manner which will not significantly affect the cooling.

5.2.4.1DV D2 *Modification to add the following:*

5.2.4.1DV.1 The PDS/CDM/BDM, and the wire mesh cage (if used), shall be connected to earth. The conductor shall have a maximum length of 4 ft (1,2 m) and be sized in accordance with 4.3.5.4DV.1. For conductors sized 6 AWG (13,3 mm^2) or smaller shall be solid wire.

5.2.4.1DV.2 The test voltage between phases, as required by 5.2DV.1, shall be the maximum of (a) and (b):

a) The largest RATED VOLTAGE for equipment rated in accordance with 6.2DV.2.1.5(a); and

b) The largest higher RATED VOLTAGE for equipment rated in accordance with 6.2DV.2.1.5(b).

5.2.4.1DV.3 The source used for test shall have an earthing system according to the following:

a) For PDS/CDM/BDM intended for connection to systems according to 4.3.6.1.4DV.2, the source shall have a measured r.m.s working voltage from phase to earth equal to or greater than the STRAIGHT VOLTAGE RATING, or the measured working voltage from phase to earth may be lower than the STRAIGHT VOLTAGE RATING if the earth connection of the PDS/CDM/BDM, and the wire mesh cage (if used), are connected to the supply circuit pole least at risk of arcing to ground.

b) For PDS/CDM/BDM intended for connection only to systems according to 4.3.6.1.4DV.3, the source shall have a measured r.m.s. working voltage from phase to earth equal to or greater than the rated phase to earth voltage.

5.2.4.2 Test duration

The individual tests shall be performed until terminated by a protective device or mechanism (internal or external), a component failure occurs, or the temperature stabilizes.

5.2.4.3 Pass criteria

As a result of the Abnormal operation tests, the PDS/CDM/BDM shall comply with the following:

- there shall be no emission of flame or molten metal;
- the surgical cotton indicator shall not have ignited;
- the earth connection shall not have opened;
- the door or cover shall not have blown open;

• during and after the test, accessible SELV and PELV CIRCUITS shall not exhibit voltages greater than the time dependent voltages of Figure 7;

• during and after the test, LIVE PARTS at voltages greater than DECISIVE VOLTAGE CLASS A shall not become accessible.

The PDS/CDM/BDM is not required to be operational after testing and it is possible that the enclosure can become deformed.

5.2.4.3DV.1 D2 *Modification to add the following:*

In addition to the pass criteria noted above, the test sample shall also comply with the requirements for the a.c. or d.c. voltage test of 5.2.3.2 for all of the abnormal operation tests except for the current limiting control test.

5.2.4.3DV.2 DE *Modification to add the following clarification:*

For the purposes of this requirement, "accessible SELV and PELV CIRCUITS" are considered to be those which are intended to be connected to devices external to the PDS/CDM/BDM or which can be contacted during normal operation. SELV and PELV CIRCUITS" are considered to be those which are intended to be connected to devices external to the PDS/CDM/BDM that do not have insulation as required elsewhere in this standard are considered to be accessible.

5.2.4.4 Loss of phase (TYPE TEST)

A multi-phase PDS shall be operated with each line (including neutral, if used) disconnected in turn at the input. The test shall be performed by disconnecting one line with the power conversion equipment operating at its maximum normal load (this particular requirement does not apply to HIGH-VOLTAGE PDS and may be simulated for LOW-VOLTAGE PDS with rated input current greater than 500 A) and shall be repeated by initially energizing the device with one lead disconnected.

5.2.4.4DV D1 *Modification:*

5.2.4.4DV.1 The second parenthetical clause does not apply, in that simulation is not permitted.

5.2.4.4DV.2 At the completion of the test, the sample shall comply with the requirements of the a.c. or d.c. voltage test of 5.2.3.2.

5.2.4.5 Cooling failure tests (TYPE TESTS)

5.2.4.5.1 General

For PDS having a combination of cooling mechanisms, all relevant tests shall be performed. It is not necessary to perform the tests simultaneously.

5.2.4.5.2 Inoperative blower motor

A PDS having forced ventilation shall be operated at rated load with blower motor or motors made inoperative, singly or in combination from a single fault, by physically preventing their rotation.

5.2.4.5.2DV D2 *Modification to add the following:*

5.2.4.5.2DV.1 Where a single electrical fault could result in the loss of operation of one or more blowers, that fault will be applied and the blower rotation will not be prevented. This is in addition to testing with physically preventing the rotation of individual blowers.

5.2.4.5.2DV.2 At the completion of the test, the sample shall comply with the requirements of the a.c. or d.c. voltage test of 5.2.3.2.

5.2.4.5.3 Clogged filter

Enclosed PDS/CDM/BDM having filtered ventilation openings shall be operated with the openings blocked to represent clogged filters. The test shall be performed initially with the ventilation openings blocked 50 %. The test shall be repeated under a full blocked condition.

5.2.4.5.3DV D1 *Modification to add the following:*

At the completion of the test, the sample shall comply with the requirements of the a.c. or d.c. voltage test of 5.2.3.2.

5.2.4.5.4 Loss of coolant

A liquid cooled PDS shall be operated at rated load. Loss of coolant shall be simulated by blocking the flow or disabling the system coolant pump. The a.c. or d.c. voltage test 5.2.3.2 shall be performed after termination of the Loss of coolant test.

5.2.4.5.4DV D1 *Modification:*

The loss of coolant test shall be started with the liquid cooled PDS in a condition representing the thermally stable state at the conclusion of the temperature test.

5.2.4.5.5DV D2 *Addition:*

5.2.4.5.5DV.1 Contactor overload

5.2.4.5.5DV.1.1 A contactor having the coil circuit interlocked or sequenced such that in normal operation the contactor does not make or break load current is to be subjected to five close-open operations, with the interlocking or sequencing defeated. The test current shall be the current the contactor carries when the PDS/CDM/BDM is delivering the maximum overload current. The maximum overload current is defined as the maximum current the PDS/CDM/BDM is capable of delivering for a time of one cycle of mains frequency. The duration of current flow when the contactor is closed shall be at least 4 cycles and the maximum time between cycles shall be 240 s. Power factor or time constant for the load shall be representative of the power factor or time constant on the contactor circuit when in operation in the PDS/CDM/BDM. The test circuit voltage to the contactor shall be equal to the highest voltage to which the contactor is subjected during operation in the PDS/CDM/BDM.

5.2.4.5.5DV.1.2 There shall be no continuity across any pole of the contactor at the end of the fifth operation.

5.2.4.5.5DV.1.3 At the completion of the test, the sample shall comply with the requirements of the a.c. or d.c. voltage test of 5.2.3.2.

5.2.4.5.6DV D2 *Addition:*

5.2.4.5.6DV.1 Current limiting control

5.2.4.5.6DV.1.1 Power conversion equipment incorporating a current limiting control is to be operated with the load increased such that the current limit mode is reached. When the current limiting control is adjustable, it is to be adjusted to result in the most severe condition. The duration of the test is not to exceed the maximum time required for operation of the overload protective device on the system supplied or specified on the marking required by 6.3.7.

5.2.5 Material tests

5.2.5DV D2 *Modification:*

Materials complying with the requirements in 4.4.2.2DV need not be subjected to the tests in 5.2.5.1 through 5.2.5.4 for direct support applications. See Annex DVD for requirements for enclosures made of polymeric material.

5.2.5.1 High current arcing ignition test (TYPE TEST)

Five samples of each insulating material (see 4.4.2) to be tested are used. The samples are 130 mm long minimum by 13 mm wide and of uniform thickness representing the thinnest section of the part. Edges shall be free from burrs, fins, etc.

Each test is made with a pair of test electrodes and a variable inductive impedance load connected in series to a source of 220 V to 240 V a.c., 50 Hz or 60 Hz (see Figure 9).

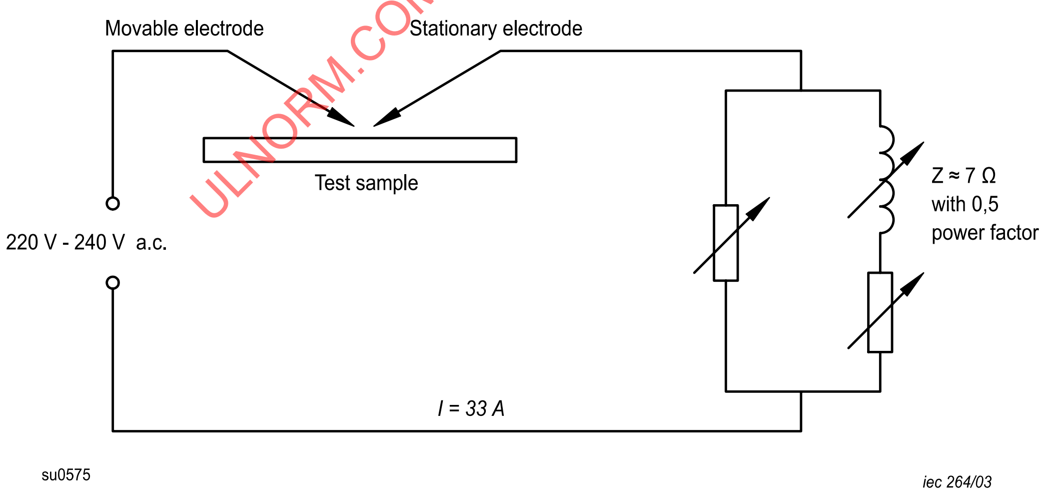


Figure 9

Circuit for high-current arcing test

It is permitted to use an equivalent circuit.

One electrode is stationary and the second movable. The stationary electrode consists of a 3,5 mm diameter solid copper conductor having a 30° chisel point. The movable electrode is a 3 mm diameter stainless steel rod with a symmetrical conical point having a total angle of 60° and is capable of being moved along its own axis. The radius of curvature for the electrode tips does not exceed 0,1 mm at the start of a given test. The electrodes are located opposing each other, in the same plane, at an angle of 45° to the horizontal. With the electrodes short-circuited, the variable inductive impedance load is adjusted until the current is 33 A at a power factor of 0,5.

The sample under test is supported horizontally in air or on a non-conductive surface so that the electrodes, when touching each other, are in contact with the surface of the sample. The movable electrode is manually or otherwise controlled so that it can be withdrawn from contact with the stationary electrode to break the circuit and lowered to remake the circuit, so as to produce a series of arcs at a rate of approximately 40 arcs/min, with a separation speed of (250 ± 25) mm/s.

The test is continued until ignition of the sample occurs, a hole is burned through the sample or a total of 200 arcs have elapsed.

The average number of arcs to ignition of the specimens tested shall be not less than 15 for V-0 class materials and not less than 30 for other materials.

5.2.5.2 Glow-wire test (TYPE TEST)

The glow-wire test shall be made under the conditions specified in 4.4.2 according to IEC 60695-2-10 and IEC 60695-2-13.

NOTE If the test has to be made at more than one place on the same sample, care should be taken to ensure that any deformation caused by previous tests does not affect the test to be made.

5.2.5.3 Hot wire ignition test (TYPE TEST – alternative to Glow-wire test)

Five samples of each insulating material (see 4.4.2) are tested. The samples are 130 mm long minimum by 13 mm wide and of a uniform thickness representing the thinnest section of the part. Edges shall be free from burrs, fins, etc.

A 250 mm ± 5 mm length of nichrome wire (nominal composition 80 % nickel, 20 % chromium, iron-free) approximately 0,5 mm diameter and having a cold resistance of approximately 5 Ω/m is used. The wire is connected in a straight length to a variable source of power which is adjusted to generate 0,25 W/mm ± 0,01 W/mm in the wire for a period of 8 s to 12 s. After cooling, the wire is wrapped around a sample to form five complete turns spaced 6 mm apart.

The wrapped sample is supported in a horizontal position (see Figure 10) and the ends of the wire connected to the variable power source, which is again adjusted to generate (0,25 ± 0,01) W/mm in the wire.

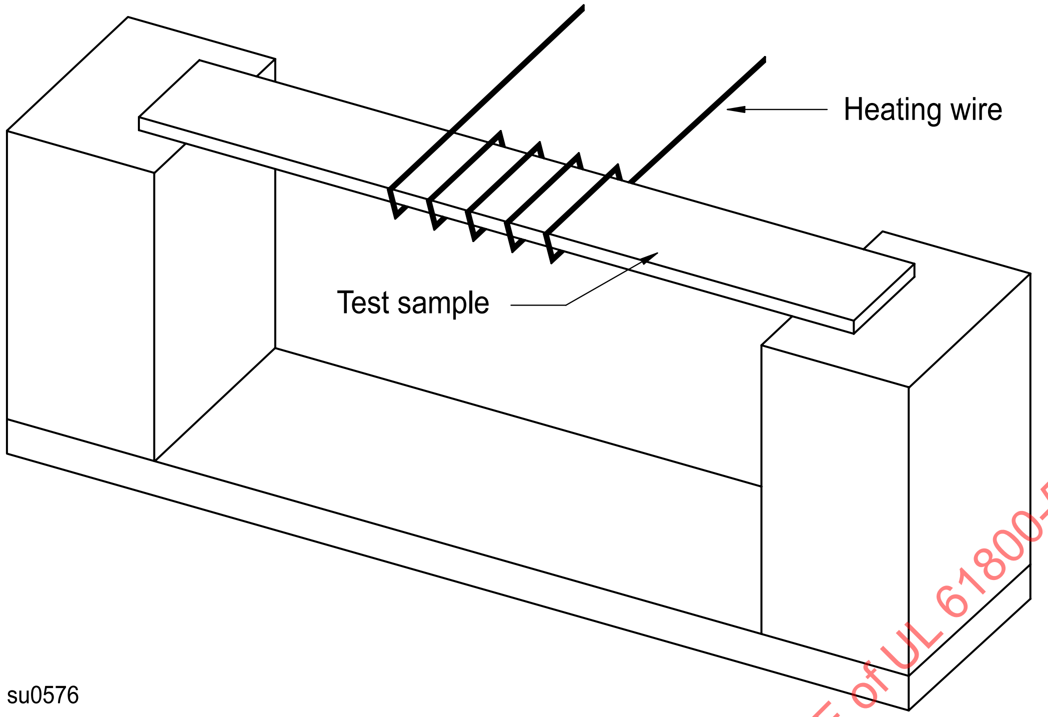


Figure 10

Test fixture for hot-wire ignition test

The test is continued until the test specimen ignites or until 120 s have passed. When ignition occurs or 120 s have passed, the test is discontinued and the test time recorded. For specimens which melt through the wire without ignition, the test is discontinued when the specimen is no longer in intimate contact with all five turns of the heater wire.

The test is repeated on the remaining samples.

The average ignition time of the specimens tested shall not be less than 15 s.

5.2.5.4 Flammability test (TYPE TEST)

Three samples of the complete equipment or three test specimens of the enclosure thereof (see 4.4.3) shall be subjected to this test. Consideration shall be given to leaving in place components and other parts that might influence the performance. The test samples shall be conditioned in a full draft circulating air oven for seven days at 10 °C greater than the maximum use temperature but not less than 70 °C in any case. Prior to testing, the samples shall be conditioned for a minimum of 4 h at 23 °C ± 2 °C and 50 % ± 5 % relative humidity. The flame shall be applied to an inside surface of the sample at a location judged to be likely to become ignited because of its proximity to a source of ignition including surfaces provided with ventilation holes. If more than one part is near a source of ignition, each sample shall be tested with the flame applied to a different location.

The three test samples shall result in the acceptable performance described below. If one sample does not comply, the test shall be repeated on a set of three new samples with the flame applied under the same conditions as for the unsuccessful sample. If all the new specimens comply with the requirements described below the material is acceptable.

The laboratory burner, adjustment and calibration shall be identical to that described in IEC 60695-11-10 and IEC 60695-11-20.

When a complete enclosure is used to conduct the flame test, the sample shall be mounted as intended in service, if it does not impair the flame testing, in a draft-free test chamber, enclosure, or laboratory hood. A layer of absorbent 100 % cotton shall be located 305 mm below the point of application of the test flame. The 127 mm flame shall be applied to any portion of the interior of the part judged as likely to be ignited (by its proximity to live or arcing parts, coils, wiring, and the like) at an angle of approximately 20° insofar as possible from the vertical so that the tip of the blue cone touches the specimen. The test flame shall be applied to three different locations on each of the three samples tested. A supply of technical-grade methane gas shall be used with a regulator and meter for uniform gas flow. Natural gas having a heat content of approximately 37 MJ/m^3 at 23 °C has been found to provide similar results and may be used.

The flame shall be applied for 5 s and removed for 5 s. The operation shall be repeated until the specimen has been subjected to five applications of the test flame.

The following conditions shall be met as a result of this test:

• the material shall not continue to burn for more than 1 min after the fifth 5 s application of the test flame, with an interval of 5 s between applications of the flame;

and

• flaming drops or flaming or glowing particles that ignite surgical cotton 305 mm below the test specimen shall not be emitted by the test sample at any time during the test;

5.2.6 Environmental tests (TYPE TESTS)

5.2.6DV D2 *Deletion:*

5.2.6 is not applicable.

5.2.6.1 General

Environmental testing is required to establish the safety of the PDS at the extremes of the environmental classification to which it will be subjected.

If size or power considerations prevent the performance of these tests on the complete PDS, it is permitted to test individual parts that are considered to be relevant to the safety of the PDS.

5.2.6.2 Acceptance criteria

The following acceptance criteria shall be satisfied:

• no degradation of any safety-relevant component of the PDSICDMIBDM;

• no potentially hazardous behaviour of the PDSICDMIBDM during the test;

• no sign of component overheating;

• no LIVE PART shall become accessible;

• no cracks in the enclosure and no damaged or loose insulators;

• pass routine a.c. or d.c. voltage test 5.2.3.2;

pass PROTECTIVE BONDING test 5.2.3.9;

• no potentially hazardous behaviour when the PDSICDMIBDM is operated following the test.

5.2.6.3 Climatic tests

5.2.6.3.1 Dry heat test (steady state)

The Dry heat (steady state) test shall be performed according to Table 25.

Table 25
Dry heat test (steady state)

Subject	Test conditions
Test reference	Test Bd of IEC 60068-2-2
Requirement reference	4.6
Preconditioning	According to 5.1.2 and 5.2.1
Operating conditions Temperature Accuracy Humidity Duration of exposure	Operating at rated conditions 40 °C or manufacturer's specified maximum temperature, whichever is higher ± 2 °C (see 37.1 of IEC 60068-2-2) According to IEC 60068-2-2, Test Bd (16 ± 1) h
Recovery procedure – time – climatic conditions – Temperature – Relative humidity – Barometric pressure – power supply	 1 h minimum 15 °C to 35 °C 25 % to 75 % 86 kPa to 106 kPa Power supply unconnected

5.2.6.3.2 Damp heat test (steady state)

To prove the resistance to humidity, the CDM shall be subjected to a Damp heat test (steady state) according to Table 26.

Table 26
Damp heat test (steady state)

Subject	Test conditions
Test reference	Test Cab of IEC 60068-2-78
Requirement reference	4.6
Preconditioning	According to 5.1.2 and 5.2.1

Table 26 Continued on Next Page

Table 26 Continued

Subject	Test conditions
Operating conditions	Power supply disconnected
Special precautions	Internal voltage sources may remain connected if the heat produced by them in the specimen is negligible
Temperature	(40 ± 2) °C (according to IEC 60068-2-78)
Humidity	$(93\ ^{+2}{}_{-3})$ % non-condensing
Duration of exposure	4 Days
Recovery procedure	
– time	1 h minimum
– climatic conditions	
– Temperature	15 °C to 35 °C
– Relative humidity	25 % to 75 %
– Barometric pressure	86 kPa to 106 kPa
– power supply	Power supply disconnected
– condensation	All external and internal condensation shall be removed by air flow prior to performing the a.c. or d.c. voltage test or re-connecting the CDM to a power supply

5.2.6.4 Vibration test (TYPE TEST)

To verify the mechanical strength, a vibration test shall be performed according to Table 27 as a TYPE TEST using a sliding frequency.

For PDS/CDM/BDM with a mass more than 100 kg, this test may be performed on sub-assemblies.

NOTE For large equipment, the possibility of using a shock test as an alternative to a vibration test is under consideration.

Table 27
Vibration test

Subject	Test conditions
Test reference	Test Fc of IEC 60068-2-6
Requirement reference	4.6
Preconditioning	According to 5.1.2 and 5.2.1
Conditions	Power supply unconnected
Motion	Sinusoidal
Vibration amplitude/acceleration	
10 Hz ≤ f ≤ 57 Hz	0,075 mm amplitude
57 Hz < f ≤ 150 Hz	1 g
Vibration duration	10 sweep cycles per axis on each of three mutually perpendicular axes
Detail of mounting	According to manufacturer's specification
Where the manufacturer specifies vibration levels that are greater than those above, the higher levels shall be used for the test. The acceptance criteria shall not be changed.	

5.2.7 Hydrostatic pressure (TYPE TEST and ROUTINE TEST)

For TYPE TESTS, the pressure inside the cooling system of a liquid cooled PDS (see 4.4.5.2.2) shall be increased at a gradual rate until a pressure relief mechanism (if provided) operates, or until a pressure of twice the operating value or 1,5 times the maximum pressure rating of the system is achieved, whichever is the greater.

For ROUTINE TESTS, the pressure shall be increased to its operating value.

The pressure shall be maintained for at least 1 min.

There shall be no thermal, shock, or other hazard resulting from the test. There shall be no significant leakage of coolant or loss of pressure during the test, other than from a pressure relief mechanism during a TYPE TEST.

5.2.7DV D2 *Modification:*

For the TYPE TEST, the pressure shall be increased at a gradual rate until a pressure relief mechanism operates or until five times the maximum working pressure rating is attained. If a pressure relief mechanism does not operate, the pressure shall be maintained at five times the maximum pressure rating for 1 min. There shall be no leakage of coolant during the test, other than from a pressure relief mechanism, during the TYPE TEST. Leakage from a pressure relief mechanism shall not occur in the electrical compartment. After the TYPE TEST, the a.c. or d.c. voltage test of 5.2.3.2 shall be performed.

5.2.8 ELECTRONIC MOTOR OVERLOAD PROTECTION test (TYPE TEST)

5.2.8.1 General requirements

This test shall demonstrate on one sample of a representative model that the ELECTRONIC MOTOR OVERLOAD PROTECTION operates within the specified limits.

PDS/CDM/BDM series that incorporate ELECTRONIC MOTOR OVERLOAD PROTECTION shall comply with test in 5.2.8.4.

PDS/CDM/BDM series that incorporate ELECTRONIC MOTOR OVERLOAD PROTECTION that has THERMAL MEMORY RETENTION shall have one sample of the representative model used complying with the tests in 5.2.8.4, 5.2.8.5 and 5.2.8.6.

PDS/CDM/BDM series that incorporate ELECTRONIC MOTOR OVERLOAD PROTECTION that is speed sensitive shall have one sample of the representative model used complying with the tests in 5.2.8.4 and 5.2.8.7.

5.2.8.2 Test set-up

Before all operation tests, the test sample shall be mounted, connected, and operated as described in the temperature rise test and then subjected to the overload condition.

The motor may be simulated by an electronic load or a reactor.

5.2.8.2DV DE *Modification:*

5.2.8.2DV.1 The motor may be simulated by an electrical load consisting of a resistance, reactance, or both such that the load draws the full required r.m.s current at the BDM/CDM motor power output.

5.2.8.2DV.2 The test sample shall be mounted, and operated as described in 5.2DV.1 – 5.2DV.6 and connected as described in either 5.2.3.8DV.2.4, 5.2.3.8DV.2.5 or 5.2.8.2DV.3 and then subjected to the overload condition.

5.2.8.2DV.3 Conductors smaller than 14 AWG are not permitted unless the following conditions are met.

a) For 16 AWG:

1) If CDM/BDM output is rated more than 5.0 A, overload shall not exceed class 10 or class 10A

2) If CDM/BDM output is rated 5.0 A or less, overload shall not exceed class 20

b) For 18 AWG:

1) If CDM/BDM output is rated more than 3.5 A, overload shall not exceed class 10 or class 10A

2) If CDM/BDM output is rated 3.5 A or less, overload shall not exceed class 20.

The overload class designation defines the maximum time for the overload protection to operate under specific overload levels. Class 10 and 10A require overload protection to operate within 10 s at 600 %; at 200 %, class 10 must operate within 4 min, while class 10A must operate within 2 min. Class 20 requires overload protection to operate within 20 s at 600 % and within 8 min at 200 %.

5.2.8.2DV.4 The main output power wire size for the test of a BASIC DRIVE MODULE/ COMPLETE DRIVE MODULE intended for use as output conductor protection shall comply with the requirements of DVI.3.1.4.

5.2.8.3 Pass criteria

The PDS/CDM/BDM is required to be operational after testing and shall comply with each requirement of the tests in 5.2.8.4, 5.2.8.5, 5.2.8.6 and 5.2.8.7.

5.2.8.4 CDM/BDM ELECTRONIC MOTOR OVERLOAD PROTECTION test (TYPE TEST)

For the verification of the functionality of the ELECTRONIC MOTOR OVERLOAD PROTECTION, the test shall be conducted at any current being able to verify the overload tripping condition according to Table 29.

CDM/BDM with fixed overload protection levels shall comply with Table 29 under those fixed settings. CDM/BDM with adjustable overload protection levels shall comply with Table 29 under the highest and lowest settings.

The ELECTRONIC MOTOR OVERLOAD PROTECTION in the representative model shall TRIP at any point below the limits from Table 29:

Table 29
Maximum tripping time for electronic motor overload protection test

Multiple of current setting	Maximum tripping time
7,2	20 s
1,5	8 min
1,2	2 h

NOTE 1 The current setting is defined as the rated current for the motor according to its nameplate, which is intended to be protected.

NOTE 2 Table 29 covers the minimum requirement for electronic overload relays of class 20 according to IEC 60947-4-1:2009, 8.2.1.5.1.1.

5.2.8.4DV DR *Modification:*

In accordance with 4.4.6.2DV part c), the maximum tripping times for Class 30 are 12 minutes at 1.5x the current setting and 30 s at 7.2x the current setting. The maximum tripping times for Class 40 are 16 minutes at 1.5x the current setting, and 40 s at 7.2x the current setting.

5.2.8.5 CDM/BDM electronic motor THERMAL MEMORY RETENTION shutdown test (TYPE TEST)

The purpose of this test is to verify that the ELECTRONIC MOTOR OVERLOAD PROTECTION functionality evaluated under 5.2.8.4 maintains the THERMAL MEMORY when the CDM/BDM is restarted after a TRIP. The test shall be conducted under the conditions specified in 5.2.8.5.

The test is conducted as follows:

a) the THERMAL MEMORY of the CDM/BDM is reset;

b) the CDM/BDM shall be operated at any multiple of current setting according to Table 29 until the overload protection TRIPS the CDM/BDM;

c) the duration between the start of the overload condition and tripping is the first elapsed time;

d) without removing the power supply, the test shall be restarted with the same overload condition, within a time shorter than the first elapsed time;

e) the CDM/BDM shall be operated until the overload protection TRIPS the CDM/BDM again;

f) the duration between the start of the second overload condition and tripping is the second elapsed time.

Compliance is shown when the second elapsed time until tripping is less than the first elapsed time.

For information requirements, see 6.3.8.

5.2.8.6 CDM/BDM electronic motor THERMAL MEMORY RETENTION loss of power test (TYPE TEST)

The purpose of this test is to verify that the ELECTRONIC MOTOR OVERLOAD PROTECTION evaluated under 5.2.8.4 maintains the THERMAL MEMORY when the CDM/BDM is restarted after a TRIP and loss of the supply voltage. The test shall be conducted under the conditions specified in 5.2.8.6.

The test is conducted as follows:

a) the THERMAL MEMORY of the CDM/BDM is reset;

b) the CDM/BDM shall be operated at any multiple of current setting according to Table 29 until the overload protection TRIPS the CDM/BDM;

c) the duration between the start of the overload condition and tripping is the first elapsed time;

d) all power supplies shall be removed from the CDM/BDM;

e) wait until all circuits for control functions cease to operate, except for circuits that are powered by an internal source, such as a battery;

f) all power supplies shall be restored to the CDM/BDM;

g) the test shall be restarted with the same overload condition within a time shorter than the first elapsed time;

h) the CDM/BDM shall be operated until the overload protection TRIPS the CDM/BDM again;

i) the duration between the start of the second overload condition and tripping is the second elapsed time.

Compliance is shown when the second elapsed time until tripping is less than the first elapsed time.

Step e) may be waived if the manufacturer demonstrates that the stored THERMAL MEMORY data is retained for a duration long enough to ensure protection of the motor.

For information requirements, see 6.3.8.

5.2.8.7 CDM/BDM electronic motor thermal speed sensitivity test (type test)

The purpose of this test is to verify that the ELECTRONIC MOTOR OVERLOAD PROTECTION functionality evaluated under 5.2.8.4 maintains the THERMAL MEMORY under reduced motor speed. The test shall be conducted under the conditions specified in 5.2.8.7.

NOTE Motors with a fan impeller mounted on the shaft have reduced cooling at low speed.

The test is conducted as follows:

a) the THERMAL MEMORY of the CDM/BDM is reset;

b) the CDM/BDM shall be operated at 40 % of the rated output frequency or voltage, while delivering any multiple of current setting according to Table 29 until the overload protection TRIPS the CDM/BDM;

c) the duration between the start of the overload condition and tripping is the first elapsed time;

d) the THERMAL MEMORY of the CDM/BDM is reset;

e) the CDM/BDM shall be restarted at 20 % of the rated output frequency or voltage, with the same overload condition;

f) the CDM/BDM shall be operated until the overload protection TRIPS the CDM/BDM again;

g) the duration between the start of the second overload condition and tripping is the second elapsed time.

Compliance is shown when the second elapsed time to operation of the overload protection is less than that recorded of the first elapsed time.

If testing CDM/BDM with the values above is not possible due to the motor characteristic, more practical values for the frequency or voltage may be selected.

For PDS where motor and CDM/BDM are known, limits of the above test settings may be selected depending of the motor characteristic.

For information requirements, see 6.3.8.

5.2.8.7DV DE *Modification:*

With respect to (b) and (e), output frequency shall apply to CDM/BDM with AC rated motor power output and output voltage shall apply to CDM/BDM with DC rated motor power output.

5.2.9 Circuit functionality evaluation (ROUTINE and/or SAMPLE TEST)

Circuit functionality evaluation is required for the verification of hardware and software when used for compliance with TYPE TESTS as required by

a) electronic short-circuit protection according to 4.3.9, and

b) ELECTRONIC MOTOR OVERLOAD PROTECTION according to 4.4.6.

Prior to being shipped from the manufacturing facility, all electronic short-circuit and motor overload protection circuitry shall be subjected to a procedure involving

c) identification of early production faults as a SAMPLE TEST or ROUTINE TEST, and

d) verification of functionality as a ROUTINE TEST.

This identification and verification procedure may include one of the following:

e) in-coming component screening; or

f) a burn-in method that varies in conditions (such as duration, temperature, and similar conditions); or

g) diagnostic test, which may be accomplished by providing signals for the software and/or hardware.

5.2.9DV D1 *Addition:*

The circuit functionality evaluation shall be done as a routine test.

5.2.10DV D1 ***Addition:***

5.2.10DV.1 Production line dielectric voltage-withstand test

5.2.10DV.1.1 Equipment provided with a power-supply cord with an attachment plug for connection to a nominal 120 V or higher voltage circuit shall withstand without ELECTRICAL BREAKDOWN, as a routine production-line test, the application of an alternating-current potential at a frequency within the range of 40 – 70 Hz or a direct-current potential between the primary wiring, including connected components, and accessible dead metal parts that are likely to become energized.

5.2.10DV.1.2 The production-line test shall be in accordance with either Condition A or B of Table 5.2.10DV.1.

Table 5.2.10DV.1
Production – Line Test Conditions

Equipment rating, V	Condition A			Condition B		
	Potential, V ac	Potential, V dc	Time, s	Potential, V ac	Potential, V dc	Time, s
250 or less	1 000	1 400	60	1 200	1 700	1
More than 250	1 000 +2V[a]	1 400 +2,8V[a]	60	1 200 +2,4V[a]	1 700 +3,4V[a]	1

[a] Maximum marked voltage.

5.2.10DV.1.3 The test potential is able to be gradually increased to the required value but the full value is to be applied for 1 s or 1 min as required.

5.2.10DV.1.4 The equipment is able to be at normal operating temperature, at room temperature, or at any intermediate temperature for the test.

5.2.10DV.1.5 The test shall be conducted when the equipment is fully assembled. It is not intended that the equipment be unwired, modified, or disassembled for the test.

a) A part, such as a snap cover or friction-fit knob, that would interfere with performance of the test need not be in place.

b) The test is able to be performed before final assembly if the test represents that for the completed equipment. Any component not included shall not affect the results with respect to determination of possible risk of electric shock resulting from miswiring, defective component, insufficient spacings, and the like.

5.2.10DV.1.6 Solid-state and similar components that might be damaged by a secondary effect of the test are able to be short-circuited by means of a temporary electrical jumper or the test is able to be conducted without the component electrically connected, providing the wiring and terminal spacings are maintained.

5.2.10DV.1.7 The test equipment shall have a means of indicating the test potential, an audible or visual indicator of ELECTRICAL BREAKDOWN, and, for automated or station-type operations, either a manually reset device to restore the equipment after ELECTRICAL BREAKDOWN or an automatic-reject feature for any unacceptable unit. When an alternating-current test potential is applied, the test equipment shall include a transformer having an essentially sinusoidal output.

5.2.10DV.1.8 When the test equipment is adjusted to produce the specified voltage, and a resistance of 120 000 Ω is connected across the output, the test equipment is to indicate an unacceptable performance within 0,5 s. A resistance of more than 120 000 Ω is able to be used to produce an indication of unacceptable performance when the manufacturer elects to use a tester having higher sensitivity.

5.2.10DV.1.9 When the rated output of the test equipment is less than 500 VA, the equipment shall include a voltmeter in the output circuit to directly indicate the applied test potential.

5.2.10DV.1.10 When the rated output of the test equipment is 500 VA or more, the test potential is able to be indicated by:

a) A voltmeter in the primary circuit or in a tertiary winding circuit;

b) By a selector switch marked to indicate the test potential; or

c) In the case of equipment having a single test-potential output, by a marking in a readily visible location to indicate the test potential.

If an indicating voltmeter is not used, the test equipment shall include a visual means, such as an indicator lamp, to indicate that the test voltage is present at the test-equipment output.

5.2.10DV.1.11 Test equipment other than that described by 5.2.10DV.1.7 – 5.2.10DV.1.10 is able to be used if found to accomplish the intended factory control.

5.2.10DV.1.12 For the test, either a sufficient number of control devices are to be closed or separate applications of the test potential made so that all parts of the primary circuit are tested.

5.2.11DV D1 *Addition:*

5.2.11DV.1 Production-line grounding-continuity test

5.2.11DV.1.1 Equipment that has an attachment plug or a power-supply cord with an attachment plug shall be tested, as a routine production-line test, to determine that grounding continuity is provided between the grounding blade or pin of the attachment plug and the accessible dead metal parts that are likely to become energized.

5.2.11DV.1.2 Only a single test need be conducted if the accessible metal selected is conductively connected to all other accessible metal.

5.2.11DV.1.3 Any indicating device (an ohmmeter, a battery and buzzer combination, or the like) is able to be used to determine compliance with the grounding continuity requirement.

5.2.12DV D2 *Addition:*

5.2.12DV.1 Cord and plug connected devices

5.2.12DV.1.1 Strain relief test

5.2.12DV.1.1.1 The device provided with a strain relief as in 4.3.8.7DV.5.5 shall withstand a direct pull of 35 lbf (156 N) applied to the cord for 1 min. There shall be no damage or displacement of the cord or conductors. Supply connections within the equipment are to be disconnected from terminals or splices during the test.

5.2.12DV.1.1.2 A field wiring lead shall withstand without damage or displacement a direct pull of:

a) 20 lbf (90 N) for 1 min applied to a lead extending from the enclosure such as through a hub or nipple; and

b) 10 lbf (44.5 N) for 1 min applied to a field wiring lead within a wiring compartment or an outlet box.

5.2.12DV.1.2 Push-back relief test

5.2.12DV.1.2.1 To determine compliance with 4.3.8.7DV.5.8, a product shall be tested in accordance with 5.2.12DV.1.2.2 without occurrence of any of the conditions specified in 4.3.8.7DV.5.8 (a) – (d).

5.2.12DV.1.2.2 The supply cord or lead is to be held 1 in (25,4 mm) from the point where the cord or lead emerges from the product and is then to be pushed back into the product. When a removable bushing which extends further than 1 in (25,4 mm) is present it is to be removed prior to the test. When the bushing is an integral part of the cord, then the test is to be carried out by holding the bushing. The cord or lead is to be pushed back into the product in 1-in (25,4-mm) increments until the cord buckles or the force to push the cord into the product exceeds 6 lbf (26,7 N). The supply cord or lead within the product is to be manipulated to determine compliance with 4.3.8.7DV.5.8.

5.2.12DV.1.3 Production-Line Polarization-Continuity Test – Cord and Plug Connected Equipment

5.2.12DV.1.3.1 Equipment provided with a grounding type attachment plug shall maintain electrical continuity between the grounding blade of the attachment plug and all accessible parts and shall be verified as a routine production-line test. The continuity shall be determined through the use of an electrical test.

5.2.13DV D2 *Addition:*

5.2.13DV.1 Clamped joint test

5.2.13DV.1.1 With respect to Annex C.1DV, a clamped joint between two insulators is to be tested using two samples.

a) The first sample is to have the clamped joint opened up to produce a space 1/8 in (3,2 mm) wide. This is accomplished by loosening the clamping means or by drilling a 1/8 in diameter hole at the joint between the insulators at a point of minimum spacing between the metal parts on the opposite sides of the joint. The drilled hole shall not decrease spacings between the opposite polarity parts as measured through the crack between the insulators. The 60 Hz dielectric breakdown voltage through this hole is then determined by applying a gradually increasing voltage (500 V/s) until breakdown occurs.

b) The second sample with the clamped joint intact is to be subjected to a gradually increasing 60 Hz voltage until 110 percent of the breakdown voltage of (a) has been reached. When the breakdown voltage of (a) is less than 4 600 V rms, the voltage applied to the second sample is to be further increased to 5 000 V rms and held for 1 s. The clamped joint meets the intent of the requirement when there is no dielectric breakdown of the second sample.

6 Information and marking requirements

6.1 General

The purpose of this Clause 6 is to define the information necessary for the safe selection, installation and commissioning, operation, and maintenance of PDS/CDM/BDM. It is presented as Table 28, showing where the information shall be provided, followed by explanatory subclauses.

The requirements of this Clause 6 apply to all PDS/CDM/BDM, unless otherwise stated.

Since any electrical equipment can be installed or operated in such a manner that hazardous conditions can occur, compliance with the design requirements of this part of IEC 61800 does not by itself assure a safe INSTALLATION. However, when equipment complying with those requirements is properly selected and correctly installed and operated, the hazards will be minimized.

All information shall be in an appropriate language, and documents shall have identification references. Drawing symbols shall conform to IEC 60417 or IEC 60617 as appropriate. Symbols not shown in IEC 60417 or IEC 60617 shall be identified where used.

NOTE Further guidance for the preparation of documentation is provided in IEC 61082, and for the preparation of instructions and manuals in IEC 62079.

6.1DV D2 *Modification:*

6.1DV.1 Table 28DV replaces Table 28 to provide a list of required markings, clause references for details and the required locations for the markings based on whether the equipment is enclosed or open.

6.1DV.2 Every product supplied, even if more than one is provided to a single customer, shall be provided with all markings required to be in locations A – G in accordance with Table 28DV. Wiring diagrams or instruction manuals in accordance with location H of Table 28DV shall be supplied with every product or available via the manufacturer's website and marked in accordance with footnote c of Table 28DV.

6.1DV.3 The use of international symbols is not required unless specifically identified.

Table 28
Information requirements

Information	Subclause reference	Location[a, b, c]					Technical subclause reference
		1	2	3	4	5	
For selection	**6.2**						
Manufacturer’s name and catalogue number	6.2	X	X	X	X	X	
Voltage rating	6.2	X		X	X	X	
Current rating	6.2	X		X		X	
Power rating	6.2	X		X		X	
Short-circuit ratings	6.2			X			4.3.9
IP rating	6.2	X		X		X	4.3.3.3, 4.3.7.1
Reference to standards	6.2			X			
Date code or serial number	6.2	X					
Reference to instructions	6.2			X	X	X	
For installation and commissioning	**6.3**						
Dimensions (SI units)	6.3.2			X		X	
Mass (SI units)	6.3.2		X	X		X	
Mounting details (SI units)	6.3.2			X		X	
Operating and storage environments	6.3.3			X		X	
Enclosure details	6.3.3			X		X	4.3.3.3, 4.3.7.1, 4.4.3
Handling requirements	6.3.4		X	X		X	
Motor requirements	6.3.5			X	X	X	
Interconnection and wiring diagrams	6.3.6.2			X		X	
Cable requirements	6.3.6.3			X		X	4.3.8
Terminal details	6.3.6.4	X		X		X	4.3.8.8.2
Protection requirements	6.3.6.5			X		X	4.3
Earthing	6.3.6.6	X		X		X	4.3.5.3, 4.3.5.3.2, 4.3.12
PROTECTIVE EARTHING CONDUCTOR CURRENT	6.3.6.7	X		X		X	4.3.5.5.2, 4.3.10
Special requirements	6.3.6.8			X		X	
Supply overload protection	6.3.7	X		X		X	
Motor overload protection	6.3.8			X		X	
Commissioning information	6.3.9			X			
For use	**6.4**						
General	6.4.1			X		X	
Adjustment	6.4.2			X	X	X	
Labels, signs, and signals	6.4.3	X		X	X	X	
For maintenance	**6.5**						
Maintenance procedures	6.5.1					X	4.3.3.3
Maintenance schedules	6.5.1				X	X	
Subassembly and component locations	6.5.1					X	
Repair and replacement procedures	6.5.1					X	

Table 28 Continued on Next Page

Table 28 Continued

Information	Subclause reference	Location[a, b, c]					Technical subclause reference
		1	2	3	4	5	
Adjustment procedures	6.5.1			X	X	X	
Special tools list	6.5.1				X	X	
Capacitor discharge	6.5.2	X		X		X	4.3.11
Auto restart/bypass	6.5.3			X	X	X	
PT/CT connection	6.5.4	X		X		X	
Other hazards	6.5.5	X				X	

[a] Location: 1. On product (see 6.4.3); 2. On packaging; 3. In installation manual; 4. In user's manual; 5. In maintenance manual.

[b] The installation, user's and maintenance manuals may be combined as appropriate and, if acceptable to the customer, may be supplied in electronic format. When more than one of any product is supplied to a single customer, it is not necessary to supply a manual with each unit, if acceptable to the customer.

[c] For INTEGRATED PDS the information required for location 1 may be combined with the motor nameplate information required by IEC 60034-1.

Table 28DV D2 *Modification to replace Table 28 with the following:*

Table 28DV
Marking Locations

Clause reference	Required marking[a]	Locations[b]	
		Enclosed	Open
GENERAL			
6.2	Manufacturers name, trademark, or identifier, electrical rating, catalog number or equivalent	B	D
6.2DV.1.1	Enclosure environmental type rating	B	–
6.2DV.1.2	Type 4X indoor use only	B	–
6.2DV.1.3	Multiple rated equipment	B	B
6.2DV.1.4	Liquid cooled operating pressure	B or H[c]	B or H[c]
6.2DV.1.5	Closing of openings in environmental enclosures	B or H[c]	B or H[c]
6.2DV.2.1.1	Electrical rating	B	D
6.2DV.2.1.2	Field supply	B	D
6.2DV.2.1.3	Range of motors	B or H[c]	B or H[c]
6.2DV.2.1.4	Duty cycle	B or H[c]	B or H[c]
6.3.7DV.4.1.2	Marking for supplementary fuse near fuse holder	B or H[c]	F or H[c]
6.3.7DV.4.1.3	Additional wiring protection from field installed accessory kit	B or H[c]	F or H[c]
6.3.7DV.4.1.4	Additional wiring protection from non-supplementary fuse	B or H[c]	F or H[c]
6.3.7DV.6.1	Overcurrent protection for cord-connected equipment	B	B
6.2DV.3.1.1	Marking for more than one factory	E	E
6.2DV.3.1.1	Class 2 power source externally accessible	B	B

Table 28DV Continued on Next Page

Table 28DV Continued

Clause reference	Required marking[a]	Locations[b]	
		Enclosed	Open
6.2DV.3.1.2	Secondary circuit supplied from a Class 2 transformer or power source in the field	B	B
6.2DV.3.1.3	Secondary circuit supplied from an external isolating source	H[c]	H[c]
6.3.1DV.1	Notice concerning operating instructions	B or G[c]	B or G[c]
6.3.2	Mechanical considerations	H[c]	H[c]
6.3.2	AMBIENT TEMPERATURE if greater than 40 °C	H	–
6.3.3	AMBIENT TEMPERATURE if less than 40 °C	B	–
6.3.3DV.1	Maximum surrounding air temperature for open drives	–	H[c]
6.3.3DV.2	Suitability for Plenum INSTALLATION	B	–
6.3.4	Handling and mounting	H[c]	H[c]
6.3.6.1	Electrical connections	H[c]	H[c]
6.3.6.2	Interconnection and wiring diagrams	H[c]	H[c]
6.3.6.2DV.1	Circuits capable of being connected to separate supplies and intended to be connected to common supply	H[c]	H[c]
6.3.6.2DV.2	Equipment with special fitting for connection	H[c]	H[c]
6.3.6.3	Conductor (cable) selection	H[c]	H[c]
6.3.6.4	Marking for proper connections	H[c]	H[c]
6.3.6.4 Paragraph 2	Identification of USER TERMINALS	See referenced clause	See referenced clause
6.3.6.4DV.1	Torque values marking for field terminals	H[c]	H[c]
6.3.6.4DV.1.5	Temperature rating of field installed conductors	H[c]	H[c]
6.3.6.4DV.1.6	Field wiring terminals with aluminum bodied connectors or intended for use with aluminum wire	B	B
6.3.6.4DV.1.7	Terminal connection of grounded supply conductor	H[c]	H[c]
6.3.6.4DV.1.9	Marking for low voltage wiring	H[c]	H[c]
6.3.6.4DV.1.10	Field wiring terminal marking for wire type (Al, Cu)	H[c]	H[c]
6.3.6.4DV.1.11	Field wiring terminal not intended to receive conductor one size larger	H[c]	H[c]
6.3.6.4DV.1.14	Maximum conductor allowed in field wiring terminal of power conversion equipment suitable for GROUP INSTALLATION	H	H
6.3.6.4DV.1.12	Marking for providing terminals separately in terminal kit	H[c]	H[c]
6.3.6.5	Protection requirements	H[c]	H[c]

Table 28DV Continued on Next Page

Table 28DV Continued

Clause reference	Required marking[a]	Locations[b]	
		Enclosed	Open
6.3.6.6	Earthing and Bonding	See referenced clause	See referenced clause
6.3.6.6DV.3	Grounding continuity between conduit on nonmetal enclosures	H[c]	H[c]
6.3.6.8	Special requirements	H[c]	H[c]
6.3.6.8DV.1.5	Overload protective device reset kit	B or H[c]	H[c]
6.3.7	Overcurrent or short-circuit protection	H[c]	H[c]
6.3.7DV.2	Required protection by fuses, circuit-breakers, or Type E combination motor controllers	B or H[c]	F or H[c]
6.3.7DV.3.1.1	Short circuit rating and overcurrent protection device rating	B or H[c]	B or H[c]
6.3.7DV.3.1.2	Integral SOLID STATE SHORT CIRCUIT PROTECTION	B or H[c]	B or H[c]
6.3.7DV.3.2.1	Power conversion equipment suitable for GROUP INSTALLATION	B or H	B or H
6.3.7DV.3.2.1	Short circuit rating and fuse type/circuit breaker and size of power conversion equipment for GROUP INSTALLATION	B or H	B or H
6.3.7DV.3.2.2	Power conversion equipment for GROUP INSTALLATION provided with solid state short circuit protection in accordance with 4.3.9DV.2.3.	B or H	B or H
6.3.7DV.4	CONTROL CIRCUIT Protection	B or H[c]	F or H[c]
6.3.7DV.4.1.1	Maximum branch circuit protective-device size corresponding to the size of control-circuit wire	B or H[c]	F or H[c]
6.3.8.1	Equipment not incorporating internal overload protection or overtemperature protection	B	F
6.3.8.2	CDM/BDM without thermal memory retention or speed sensitivity	B	B
6.3.8.2	Equipment with connections for motors with integral thermal protection. Information regarding overload protection in multiple of current setting, tripping time, and instructions for adjustment. Information regarding thermal memory retention and instructions for adjustment. Information regarding speed sensitivity and instructions for adjustment.	H[c]	H[c]
6.4.2	Adjustments	H[c]	H[c]
6.4.3	Labels, signs and signals – General requirements	–	–
6.4.3.2	Isolators	See referenced clause	See referenced clause

Table 28DV Continued on Next Page

Table 28DV Continued

Clause reference	Required marking[a]	Locations[b]	
		Enclosed	Open
6.4.3.4DV	Hot surfaces	See referenced clause	See referenced clause
6.4.3.5	Controls, indicating devices, fuses and polarity identification	See referenced clause	See referenced clause
6.5DV.1	Separate supplies provided, multiple disconnects required	See 6.5DV.2	See 6.5DV.2
6.5DV.3	Enclosures Provided with removable covers	A	–
6.5.1	Safety information	H[c]	H[c]
6.5.2	Capacitor discharge	B	B or F
6.5.3	Auto restart/bypass connection	H[c]	H[c]
6.5.4	PT/CT connection	H[c]	H[c]
6.5.5	Other hazards	See referenced clause	See referenced clause
6.5.5DV	LIVE PARTS exposed during servicing	C	C
Annex DVC.1.1.3.5 and DVC.1.1.3.6	Field wired isolated secondary circuit separation from other wiring	H[c]	H[c]
Annex DVC.1.5.6	Isolating source and protective device field installed	H[c]	H[c]
Annex DVC.1.5.7	Isolating source and protective device field installed – accessory	H[c]	H[c]
Annex DVC.1.7.6(a)	Limiting impedance circuit maximum voltage to ground	B	B
Annex DVD.3.5.3.1	Environmental rating for individual compartments	B	–
Annex DVD.2.4.4.6.4(b)	Environmental rating where blower motor	B	–
Annex DVI.5.1.1	Output motor conductor protection	B	F
CAUTIONARY MARKINGS			
6.4.3.1DV.8	Placement of cautionary markings Instructing operator or servicing instructions	See referenced clause	See referenced clause
6.3.6.4DV.1.13	Control with direct-current motor ratings	H[c]	H[c]
6.3.7DV.3.1.1	Warning for high available fault currents	B	B or F
ACCESSORIES			
6.3.6.8DV.1	Accessories available for equipment	H[c]	H[c]
6.3.6.8DV.1.2	New accessories for existing product	I	I
6.3.6.8DV.1.3	Manufacturer name, rating and catalog number of accessory	See referenced clause	See referenced clause
6.3.6.8DV.1.4	Accessories provided with instructions	G or I	G or I
6.3.6.8DV.1.5	Kit available for overload protection device	G	G
In this table, references provided to original clauses indicate that the full clause and any national deviations are applicable. Where specific different marking requirements are contained in national deviations, those national			

Table 28DV Continued on Next Page

Table 28DV Continued

Clause reference	Required marking[a]	Locations[b]	
		Enclosed	Open
deviation clauses are separately referenced in the table. Where the national deviation replaces the original clause, only the national deviation clause is referenced in the table. Those original clauses not considered to be applicable are not referenced in the table.			
[a] These are a brief summary of marking requirements. For complete details see the specific requirement reference. [b] For marking locations identified below, "A" is the highest order of location, and "H" is the lowest order of location. At the option of the manufacturer, a higher order of location category is able to be used. Location "I" is not part of the order of locations. [c] If marking is only provided in location H, then the marking of 6.3.1DV.1 is required. A. Marking shall be visible when the enclosure cover is on and the door is closed. B. Marking shall be visible 1) When the enclosure cover is removed or the door is open; 2) When other devices are mounted nearby as intended; and 3) When devices are installed side by side with intended clearances. The marking shall not be obscured by attachments such as a disconnect switch operating handle. C. Marking is on LIVE PARTS. D. Marking is visible when the device is mounted singularly. The marking is able to be on the side of the device, and need not be visible when the device is mounted next to other devices. E. Marking is able to be anywhere on the device and is not required to be visible after INSTALLATION. F. Marking is on a separable, self-adhesive permanent label that is shipped with the device. For a device that is installed in an enclosure, the marking shall be on the inside of the enclosure. G. Marking is on the device or separate sheet provided with the device. H. Marking is on wiring diagram or instructional manual shipped with the device, provided in electronic read-only digital media format, such as a USB storage devcie or other media provided with the device, or available via the manufacturer's website on the world wide web. I. Marking is shipped separately with kit.			

6.2 Information for selection

Each part of a PDS that is supplied as a separate product shall be provided with information relating to its function, electrical characteristics, and intended environment, so that its fitness for purpose and compatibility with other parts of the PDS can be determined. For CDM/BDM, this information includes, but is not limited to:

• the name or trademark of the manufacturer, supplier or importer;

• catalogue number or equivalent;

input and output voltage range, current, and power rating information, including:

– number of phases;

– frequency range;

• PROTECTIVE CLASS;

• the type of electrical supply system (e.g. TN, IT, etc.) to which the PDS/CDM/BDM may be connected;

• PROSPECTIVE SHORT-CIRCUIT CURRENT rating(s) and protective device characteristics

• field supply requirements (if any);

• coolant type and design pressure for liquid cooled product;

• IP rating;

• operating and storage environment;

• reference(s) to relevant international standard(s) for manufacture, test, or use;

• date code, or serial number from which the date of manufacture can be determined;

• reference to instructions for installation, use and maintenance.

The information shall be limited to that which is essential for correct selection to be made, and should relate to specific equipment. If information covers a number of product variants, it shall be readily possible to distinguish between them.

6.2DV.1 D2 *Modification to add the following:*

6.2DV.1.1 Power conversion equipment shall be plainly marked with the enclosure type rating for enclosed equipment. Marking of the IP rating is not required.

6.2DV.1.2 With reference to DVD.2.1.3.2, a Type 4X enclosure intended for indoor use only shall be marked "Type 4X Indoor Use Only" in letters that are legible and of the same font and height.

6.2DV.1.3 For equipment intended for use in various applications that require different wiring arrangements with corresponding different capabilities, the information in 6.2 is not prohibited from being provided in literature supplied with the equipment when the equipment is marked: "Multiple rated equipment. See instruction manual." or with an equivalent statement.

6.2DV.1.4 Liquid cooled equipment shall be marked with the nominal operating pressure and the maximum working pressure.

6.2DV.1.5 Enclosures intended for field INSTALLATION of conduit hubs, closure plates, or other equipment (such as push-button switches) shall be marked or provided with instructions that identify the equipment necessary to maintain the environmental integrity of the enclosure. This may be accomplished by identifying the necessary environmental type designation or by identifying the specific manufacturer and model number of the field installed equipment.

6.2DV.1.6 The type of electrical supply system (e.g. TN or IT) to which the PDS/CDM/BDM may be connected to is not information required to be included with the PDS/CDM/BDM.

6.2DV.2 D2 *Modification to add the following:*

6.2DV.2.1 Rating

6.2DV.2.1.1 Power conversion equipment shall be rated according to:

a) Input.

1) Voltage.

2) Maximum full load current.

3) Number of phases.

4) Frequency.

b) Output.

1) Voltage.

2) Maximum full load current or maximum horsepower or maximum killowatts.

3) Number of phases.

4) Base frequency and frequency range (applies only to alternating current outputs).

6.2DV.2.1.2 Equipment incorporating circuitry for motor field supply shall be rated in field voltage and maximum current capability of the supply.

6.2DV.2.1.3 For single motor operation only, when the equipment is intended for control of a range of motor ratings, the motor power rating and associated input current rating of the controller shall be provided for each intended motor.

6.2DV.2.1.4 Equipment which operates intermittently shall include a duty cycle rating.

6.2DV.2.1.5 PDS/CDM/BDM shall have one or more of the following input voltage ratings:

a) Straight voltage rating – The rating shall be the line-to-line voltage, for example, 460 or 480 volts.

b) Slash voltage rating – The rating shall have two values, the line-to-line voltage and the line-to-ground voltage, for example, 460Y/267 or 480Y/277 volts.

6.2DV.3 D2 *Modification to add the following:*

6.2DV.3.1 Class 2 circuit markings

6.2DV.3.1.1 A Class 2 power source shall be durably marked where visible after INSTALLATION to indicate the class of supply and its electrical rating. A Class 2 power source not evaluated for use in wet locations shall be marked "Not for use in wet locations" or the equivalent.

6.2DV.3.1.2 A secondary circuit intended to be supplied from a Class 2 transformer or power source in the field shall be marked "Class 2" next to the voltage rating of the device (for example, 30 Vac, Class 2), or the equivalent.

6.2DV.3.1.3 A secondary circuit evaluated to the requirements in DVC.1.8.1 or DVC.1.8.2 of Annex DVC shall be provided with INSTALLATION instructions that specify the use of the isolating source and ratings of the overcurrent protective devices required to be installed in the field.

6.2DV.4 D2 ***Modification to add the following:***

6.2DV.4.1 Multiple manufacturing locations

6.2DV.4.1.1 When the manufacturer produces or assembles power conversion equipment at more than one factory, each finished item of equipment shall have a distinctive marking, by which it is identifiable as the product of a particular factory.

6.3 Information for installation and commissioning

6.3.1 General

Safe and reliable installation is the responsibility of the installer, machine builder, and/or user. The manufacturer of any part of the PDS shall provide information to support this task. This information shall be unambiguous, and may be in diagrammatic form.

6.3.1DV.1 D2 ***Modification to add the following:***

Where marking or information is provided in accordance with location designation "H" as noted in the footnote section of Table 28DV, the following marking or equivalent is provided on the device or on an information sheet provided with the equipment, "WARNING – Operation of this equipment requires detailed INSTALLATION and operation instructions provided in the INSTALLATION/Operation manual intended for use with this product.

a) If the marking information is provided on an electronic storage device included with the product, the marking shall additionally include the following text, "This information is provided on the USB storage device or other storage device included in the container this device was packaged in. It should be retained with this device at all times. A hard copy of this information may be ordered at (###) ###-#### ", where the manufacturer's phone number is provided.

b) If the marking information is provided via the manufacturer's website on the world wide web, the marking shall additionally include the following text, "The installation/operation manual (revision # or version #) is available via the internet at [URL]. A hard copy of this information may be ordered at (###) ###-####". The manufacturer's phone number is provided. The URL shall take the installer/operator directly to an internet page containing a direct link to the manual. The manual shall be unrestricted and in a file format that is commonly used and downloadable.

6.3.1DV.2 D2 ***Modification:***

Markings required in this document shall include all of the text as specified and may also include diagrammatic representation. Text in languages other than as specified may also be provided.

6.3.2 Mechanical considerations

The following drawings shall be prepared by the manufacturer:

• dimensional drawing, including mass information;

• mounting drawing.

Dimensions, mass, etc., shall be in SI units.

6.3.2DV D2 *Modification:*

English units may be used.

6.3.3 Environment

The following environmental conditions shall be specified, for operation, transportation and storage:

• climatic (temperature, humidity, altitude, pollution, ultra-violet light, etc.);

• mechanical;

• electrical.

NOTE Environmental categories as specified in IEC 60721 may be used where appropriate.

6.3.3DV D2 *Modification:*

6.3.3DV.1 Power conversion equipment evaluated in accordance with 5.2DV.4 shall be marked "Maximum Surrounding Air Temperature __°C".

6.3.3DV.2 The optional markings, "Suitable for Installation in a Compartment Handling Conditioned Air" or "Suitable for Use in Other Environmental Air Space in Accordance with Section 300.22 (C) of the National Electrical Code" shall only be marked on power conversion equipment that has been evaluated in accordance with requirements for plenum rated drives.

6.3.4 Handling and mounting

In order to prevent injury or damage, the installation documents shall include warnings of any hazards which can be experienced during installation. Where necessary, instructions shall be provided for:

• packing and unpacking;

• moving;

• lifting;

• strength and rigidity of mounting surface;

• fastening;

• provision of adequate access for operation, adjustment and maintenance.

When PDS surfaces at temperatures exceeding 90 °C are close to mounting surfaces, the installation manual shall contain a warning to consider the combustibility of the mounting surface.

6.3.5 Motor and driven equipment

6.3.5DV DE *Deletion:*

This information is not required.

6.3.5.1 Motor selection

Where necessary for CDM/BDM, information on suitable motor specifications (for example, based on IEC 60034-1) shall be provided. The possible influence on motor insulation of reflections of the PWM output waveform shall be taken into consideration.

6.3.5.2 Motor integrated sensors

Insulation requirements shall be identified (see 4.3.5 and 4.3.6).

6.3.5.3 Critical torsional speeds

When required, the PDS supplier shall provide all relevant motor information to enable critical torsional speeds to be identified (see 4.5.2.2).

6.3.5.4 Transient torque analysis

When required, the PDS supplier shall provide all relevant electrical and mechanical information to enable transient torque analysis to be performed (see 4.5.2.3).

6.3.6 Connections

6.3.6.1 General

Information shall be provided to enable the installer to make safe electrical connection to the PDS. This shall include information for protection against hazards (for example, electric shock or availability of energy) that may be encountered during installation, operation or maintenance.

6.3.6.2 Interconnection and wiring diagrams

The installation and maintenance manuals shall include details of all necessary connections, together with a suggested interconnection diagram.

6.3.6.2DV D2 *Modification to add the following:*

6.3.6.2DV.1 Equipment incorporating two or more separate circuits that are capable of being connected to separate power supplies and that are intended to be connected to a common power supply shall be marked “All circuits must have a common disconnect and

be connected to the same pole of the disconnect," or with an equivalent wording. The wiring diagram of the equipment shall illustrate a typical connection of the various circuits connected to the common power supply.

6.3.6.2DV.2 Equipment employing a special fitting for the connection to a specific wiring system shall be marked to indicate that it must be installed with such a wiring system.

6.3.6.3 Conductor (cable) selection

The Installation manual shall define the voltage and current levels for all connections to the PDS/CDM/BDM, together with cable insulation requirements. These shall be worst-case values, taking into account overcurrent and overload conditions and the possible effects of non-sinusoidal currents.

6.3.6.4 Terminal capacity and identification

The installation and maintenance manuals shall indicate the range of acceptable conductor sizes and types (solid or stranded) for all terminals, and also the maximum number of conductors which can simultaneously be connected. For USER TERMINALS, the manuals shall specify the requirements for tightening torque values and also the insulation temperature rating requirements for the conductor or cable.

The identification of all USER TERMINALS shall be marked on the PDS/CDM/BDM, either directly or by a label attached close to the terminals.

6.3.6.4DV D2 *Modification:*

6.3.6.4DV.1 Tightening torque

6.3.6.4DV.1.1 Tightening torque values shall be indicated in English (Metric) units. The tightening torque for a field-wiring terminal shall be as specified by the power conversion equipment manufacturer and shall be marked as specified in 6.3.6.4DV.1.4, except as noted in 6.3.6.4DV.1.3. Except as noted in 6.3.6.4DV.1.2, the specified tightening torque shall not be less than 90 percent of the value employed in the static heating test as specified in the requirements in the Standard for Wire Connectors, UL 486A-486B or the Standard for Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors, UL 486E, for that wire size corresponding to the ampere rating of the power conversion equipment.

6.3.6.4DV.1.2 The value of tightening torque is not required to be 90 percent of the value specified when the connector is investigated in accordance with UL 486A-486B or UL 486E, with the lesser assigned torque value.

6.3.6.4DV.1.3 A field-wiring terminal intended only for the connection of a CONTROL CIRCUIT conductor is not required to be marked with a value of tightening torque when tested in accordance with the applicable requirements in UL 486A-486B or UL 486E, with a value of tightening torque of 7 lbf·in (0.8 N·m).

6.3.6.4DV.1.4 With reference to 6.3.6.4DV.1.1, equipment shall be marked to show a range of values or a nominal value of tightening torque in pound-inches to be applied to the clamping screws of all terminal connectors for field wiring. The marking is able to be located adjacent to the terminal or on the wiring diagram.

6.3.6.4DV.1.5 Equipment shall be marked to indicate the temperature rating, 60 °C only, 60/75 °C, or 75 °C only, used in the evaluation of the power field wiring terminals. Control terminals are not required to be marked to indicate the temperature rating.

6.3.6.4DV.1.6 Field wiring terminals with aluminum bodied connectors or intended for use with aluminum wire shall be marked AL7CU or AL9CU as appropriate based on the results of the temperature test (see Table 15DV footnote j, k and l).

6.3.6.4DV.1.7 A terminal for the connection of a grounded supply circuit conductor shall be identified by means of a metallic plated coating substantially white in color and shall be readily distinguishable from the other terminals, or proper identification of the terminal for the connection of the grounded supply circuit conductor shall be clearly shown in some other manner, such as on an attached wiring diagram. When wire leads are provided, the lead intended to be connected to a grounded supply circuit shall have a white or gray color and shall be readily distinguishable from other leads.

6.3.6.4DV.1.8 A single white terminal – in other than a single-pole device – for the connection of an ungrounded conductor shall not be provided, however, two or more white terminals may be provided when:

a) It does not make any difference how line connections are made;

b) It is obvious which terminal is intended for the connection of the grounded conductor; or

c) The line connections are plainly indicated on a wiring diagram.

6.3.6.4DV.1.9 When low-voltage equipment or a part of low-voltage equipment is intended to be field wired, the equipment shall comply with the following:

a) When it is intended to become only part of a Class 1 circuit the terminals shall be marked accordingly;

b) When it is intended to become only part of a Class 2 circuit wired with Class 1 wire, the terminals shall be marked accordingly;

c) When Low-voltage switching or power-consuming equipment or a part of equipment is intended to become part of a Class 2 circuit only, the terminals shall be marked accordingly;

d) A low-voltage power-supply device that includes a transformer is not required to be marked to indicate that it is acceptable for use in a Class 2 circuit only;

e) Low-voltage equipment or a part of equipment that is intended for connection to either a Class 1 or a Class 2 circuit is not required to be marked.

6.3.6.4DV.1.10 Equipment having field-wiring terminals shall be marked:

a) "Use Copper Conductors Only" when the terminal, other than a CONTROL CIRCUIT terminal, is intended only for connection to copper wire.

b) "Use Aluminum Conductors Only" when the terminal is intended only for connection to aluminum wire.

c) "Use Copper or Aluminum Conductors" or "Use Copper, Copper-Clad Aluminum, or Aluminum Conductors" when the terminal is intended for connection to either copper or aluminum wire.

d) "Use Copper-Clad Aluminum or Copper Conductors" when the terminal is intended for connection to either copper or copper-clad aluminum wire.

6.3.6.4DV.1.11 A wiring terminal that is not intended to receive a conductor one size larger than that specified in 4.3.8.8.2DV.5 shall be marked to restrict its use to the smaller size conductor.

6.3.6.4DV.1.12 When leads, wire binding screws, or pressure wire connectors are not provided on the equipment as shipped, the equipment shall be marked stating which pressure wire connector or component terminal kits are intended for use with the equipment. A wire connector of the type specified in the marking is able to be installed in the equipment at the factory with instructions, when required to effect proper connection of the conductor. A terminal kit shall carry an identifying marking, wire size, and manufacturer's name or trademark.

6.3.6.4DV.1.13 A control with direct-current motor ratings that does not comply with the requirements in 4.3.8.8.2DV.1(e) shall be marked with the word "WARNING" and the following or the equivalent, "Do not connect to a circuit supplied by a single-phase, half-wave rectifier"; and a control that does not comply with the requirements in 4.3.8.8.2DV shall be marked with the word "WARNING" and the following or the equivalent, "Do not connect to a circuit supplied by a single-phase rectifier of the half-wave or full-wave type."

6.3.6.4DV.1.14 A field wiring terminal of power conversion equipment intended for GROUP INSTALLATION, as described in 5.2.3.6DV.1.1.2, shall be marked to restrict its use to conductors that have a maximum size of that used when tested in accordance with 5.2.3.6DV.1.1.1.

6.3.6.5 Protection requirements

The installation, users and maintenance manuals shall identify any accessible parts at voltages greater than ELV, and shall describe the insulation and separation provisions required for protection. Accessible ELV parts of a PDS/CDM/BDM which are of PROTECTIVE CLASS 0 shall be clearly identified, and instructions provided in the installation manual to increase the protection against indirect contact.

The manuals shall also indicate the precautions to be taken to ensure that the safety of ELV connections is maintained during installation.

The manuals shall provide instructions for the use of PELV CIRCUITS within a ZONE OF EQUIPOTENTIAL BONDING.

The installation, users, and maintenance manuals shall identify all external terminals relating to circuits protected by one of the methods of 4.3.4.2 to 4.3.4.4.

6.3.6.5DV D2 *Modification:*

Requirement for insulation and separation provisions are only applicable to USER TERMINALS and are based on circuits exceeding DECISIVE VOLTAGE CLASS A.

6.3.6.6 Earthing

The installation manual shall specify requirements for safe earthing of the PDS/CDM/BDM.

The installation and maintenance manuals for HIGH-VOLTAGE PDS shall provide instructions for the use of an earthing switch to ensure safe access during maintenance.

Terminals for connection of the PROTECTIVE EARTHING CONDUCTOR shall be clearly and indelibly marked with the symbol IEC 60417-5019 (2006-08) (see Annex H), or with the letters PE, or by the colour coding green or green-yellow. The indication shall not be placed on or fixed by screws, washers or other parts which might be removed when conductors are being connected.

Equipment of PROTECTIVE CLASS II shall be marked with symbol IEC 60417-5172 (2003-02) (see Annex H). Where such equipment has provision for the connection of an earthing conductor for functional reasons (see 4.3.5.6) it shall be marked with symbol IEC 60417-5018 (2006-10) (see Annex H).

6.3.6.6DV D1 *Modification to add the following:*

6.3.6.6DV.1 A pressure wire connector intended for connection of a field-installed equipment grounding conductor shall be green colored or plainly identified, such as being marked “G,” “GR,” “GRD,” “Ground,” “Grounding,” or similar designation, or with the grounding symbol ⏚ (IEC Publication 60417, Symbol 5019). The use of the symbol without the circle is permitted (symbol 5017 of IEC 60417). The notation “PE” or “PEN” shall not be used as the sole means marking of identifying the terminal.

6.3.6.6DV.2 The marking required for enclosures that are intended for field assembly of the bonding means in accordance with 4.3.5.3.1DV.2.1.3 shall:

a) Be located where visible during INSTALLATION, such as inside the cover; and

b) Consist of the word “WARNING” and the following or the equivalent, “Bonding between conduit connections is not automatic and must be provided as a part of the installation”; or the word “WARNING” and the following or equivalent, “Nonmetallic enclosure does not provide grounding between conduit connection. Use grounding bushings and jumper wires.”

6.3.6.6DV.3 An enclosure of insulating material that has no means for continuity of grounding between any conduit provision shall be marked that only one conduit is to be connected to the enclosure.

6.3.6.7 PROTECTIVE EARTHING CONDUCTOR current

Where the TOUCH CURRENT in the PROTECTIVE EARTHING CONDUCTOR (see 4.3.5.5.2) exceeds 3,5 mA a.c. or 10 mA d.c., this shall be stated in the installation and maintenance manuals. In addition, a caution symbol ISO 7000-0434 (2004-01) (see Annex H) shall be placed on the product, and a notice shall be provided in the installation manual to instruct the user that the minimum size of the PROTECTIVE EARTHING CONDUCTOR shall comply with the local safety regulations for high PROTECTIVE EARTHING CONDUCTOR current equipment.

The installation and maintenance manuals shall indicate compatibility with RCDs (see 4.3.10).

When 4.3.10 b) applies, a caution notice and the symbol ISO 7000-0434 (2004-01) (see Annex H) shall be provided in the user manual, and the symbol shall be placed on the product. The caution notice shall be: *“This product can cause a d.c. current in the protective earthing conductor. Where a residual current-operated protective (RCD) or monitoring (RCM) device is used for protection in case of direct or indirect contact, only an RCD or RCM of Type B is allowed on the supply side of this product..”* (See 6.4.3 for general requirements for labels, signs and signals.)

6.3.6.7DV D2 *Deletion:*

This does not apply.

6.3.6.8 Special requirements

Any particular cable and connection requirements shall be identified in the installation and maintenance manuals.

6.3.6.8DV D1 *Modification to add the following:*

6.3.6.8DV.1 Instructions and markings pertaining to accessories

6.3.6.8DV.1.1 The equipment markings shall include identification of an accessory to be attached in the field, or a reference to a separate publication that identifies all such accessories. For equipment such as an open device for which the required marking is on a separate sheet, the accessory information is also capable of being on the separate sheet.

6.3.6.8DV.1.2 When a new accessory has been designed for an existing product, the accessory shall be marked with the identification of the equipment on which it is intended to be used.

6.3.6.8DV.1.3 An accessory that is not shipped from the factory in the same carton as the equipment with which it is intended to be used shall be plainly marked with:

a) The manufacturer’s name, trademark, or other descriptive marking by which the organization responsible for the product is identifiable;

b) The catalog number or equivalent; and

c) The electrical rating. The electrical rating of the accessory is not required to be on the accessory when the accessory electrical rating is marked on the equipment for which it is intended.

6.3.6.8DV.1.4 An accessory shall be provided with INSTALLATION and wiring instructions.

6.3.6.8DV.1.5 When an overload-protective device is provided within an enclosure that does not have a hinged cover, and a kit is available for resetting the device from outside the enclosure, in accordance with DVD.2.4.8.2(d) the kit number shall be marked on the enclosure or in the INSTALLATION instructions.

6.3.6.8DV.2 Instructions pertaining to connection to photovoltaic (PV) modules

6.3.6.8DV.2.1 Adjustable speed POWER DRIVE SYSTEMS, or their elements intended to receive power partially or fully from photovoltaic modules or panels shall specify that the photovoltaic modules or panels used shall comply with UL 1703. Products that require the use of specific PV module sources shall specify the manufacturer and model of the modules or panels. The instructions shall provide the maximum open circuit voltage and short circuit current rating of each input which is intended for use with a PV source.

6.3.6.8DV.2.2 A BDM/CDM/PDS’s ratings shall not directly utilize or reference UL 1703 PV module nameplate ratings. The standard PV module abbreviations "I_{sc}" and "V_{oc}" shall not be used to state ratings for a drive intended for use with PV.

NOTE I_{sc} and V_{oc} are associated with STC (standard test condition) ratings for PV modules in accordance with NFPA 70 (National Electrical Code) clauses 690.8 and 690.9.

6.3.6.8DV.2.3 The installation instructions for the equipment shall indicate that wiring between PV modules, PV panels or PV arrays and the equipment input shall be in compliance with NEC article 690. If the PV modules, panels, or arrays are not included with the BDM/CDM/PDS, the installation instructions shall specify that the BDM/CDM/PDS be used only with PV panels in compliance with UL 1703.

6.3.7 Overcurrent or short-circuit protection

Where external devices are necessary to protect against overcurrent or short-circuit, the installation manual shall specify the required characteristics (see also 5.2.2.2, 5.2.3.6.2, 5.2.4.2).

When the CDM/BDM complies with the requirement of 4.3.9, the manufacturer shall state that the ELECTRONIC POWER OUTPUT SHORT-CIRCUIT PROTECTION CIRCUITRY meets the requirements of IEC 60364-4-41:2005/AMD1:–, Clause 411.

In addition, the manufacturer shall specify under which conditions the ELECTRONIC POWER OUTPUT SHORT-CIRCUIT PROTECTION CIRCUITRY can be applied (e.g. limit of cable length, wire size, shielded or not shielded, protective earth impedance, supply earthing system).

6.3.7DV.1 D2 *Modification:*

6.3.7DV.1.1 For open type BDM/CDM, when overcurrent protective devices are included in the fault path on the output of a DC link, the installation instruction shall specify that the protective device be included in the same overall enclosure as the BDM/CDM.

6.3.7DV.1.2 The second paragraph is not applicable because compliance with IEC 60364-4-41:2005/AMD1 is not applicable in the United States.

6.3.7DV.1.3 The third paragraph is not applicable.

6.3.7DV.2 D2 *Modification to add the following:*

A drive protected by fuses (either semiconductor or non-semiconductor types), circuit breakers (either inverse-time or instantaneous trip types), or Type E combination motor controllers, sized in accordance with 5.2.3.6.2DV.4.1.6, 5.2.3.6.2DV.4.1.9, 5.2.3.6.2DV.4.1.7, 5.2.3.6.2DV.4.1.8, 5.2.3.6.2DV.4.1.11, 5.2.3.6.2DV.4.1.12, or 5.2.3.6.2DV.4.1.14 shall be marked as noted below:

a) For non-semiconductor fuse types, the marking shall include the Class – when other than Class H or K5 – and the voltage and current or voltage and percent of the full-load motor output current rating.

b) For semiconductor fuse types, the marking shall include the fuse manufacturer and fuse model number (no fuse rating marking is required). This marking shall also state that the drive controller and overcurrent protection device must be integrated within the same OVERALL ASSEMBLY;

c) For current limiting circuit breakers, the marking shall include voltage and current or voltage and percent of the full-load motor output current rating. The marking shall also include the manufacturer and model number of the circuit breaker;

d) For non-current limiting inverse-time circuit breaker types, the marking shall include voltage and current or voltage and percent of the full-load motor output current rating;

e) For instantaneous trip circuit breaker types, the marking shall include the breaker manufacturer and breaker model number (no breaker rating marking is required). This marking shall also state that the drive controller and overcurrent protection device must be integrated within the same OVERALL ASSEMBLY; or

f) For Type E combination motor controllers, the marking shall include the motor controller manufacturer, model number, RATED VOLTAGE and rated HP.

6.3.7DV.3 D2 *Modification to add the following:*

6.3.7DV.3.1 Branch circuit short circuit protection

6.3.7DV.3.1.1 Power conversion equipment shall be marked "Suitable For Use On A Circuit Capable Of Delivering Not More Than ___________ rms Symmetrical Amperes, ___________ Volts Maximum." The ampere rating is not to be more than the value for which the controller was tested in accordance with 5.2.3.6. When tested in accordance with 5.2.3.6.2.1DV.4, the marking shall also include the following or the equivalent:

a) "When Protected by ___________ Class Fuses," or

b) "When Protected By A Circuit Breaker Having An Interrupting Rating Not Less Than ___________ rms Symmetrical Amperes, ___________ Volts Maximum."

6.3.7DV.3.1.2 Power conversion equipment provided with SOLID STATE SHORT CIRCUIT PROTECTION in accordance with 4.3.9DV.2.3 shall be marked "Integral solid state short circuit protection does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the National Electrical Code and any additional local codes," or the equivalent.

6.3.7DV.3.1.3 Reference to relevant International Standards is not required.

6.3.7DV.3.2 Branch circuit short circuit protection for GROUP INSTALLATION

6.3.7DV.3.2.1 For GROUP INSTALLATION, power conversion equipment as described in 5.2.3.6DV.1.1.2 shall be marked with the following or the equivalent:

a) When tested using both fuses and circuit breakers of the maximum allowable size: "Suitable for motor GROUP INSTALLATION on a circuit capable of delivering not more than ____ rms symmetrical amperes, ____ V max." When tested with other than Class H or K5 fuses, the marking shall additionally state: "When protected by Class ___ fuses." When specified for a high fault short circuit rating, the marking shall additionally state: "Class ___ fuses" or "A circuit breaker having an interrupting rating not less than ___rms symmetrical amperes, ___ V maximum;"

b) When tested using only fuses rated at the maximum size specified in 5.2.3.6DV.1.1.3(b), the marking shall additionally state: "When protected by fuses" or, when tested with other than Class H or K5 fuses, "When protected by Class ___ fuses." When specified for a high fault short circuit rating, "When protected by Class ___ fuses;"

c) When tested using branch circuit protective devices rated less than the maximum size specified in 5.2.3.6DV.1.1.3(b), the marking shall additionally state: “when protected by (A) with a maximum rating of (B)” where:

A) The type of overcurrent protective devices, either “fuses” or “a circuit breaker.” When tested with other than Class H or K5 fuses, “Class ___ fuses.” When specified for a high fault short circuit rating, “Class ___ fuses” or “A circuit breaker having an interrupting rating not less than ___rms symmetrical amperes, ___ V maximum;”

B) The maximum ampere rating of the overcurrent protective device used for the tests in 5.2.3.6DV.1.3 and 5.2.3.6DV.1.5, Breakdown of Components Test – GROUP INSTALLATION for Standard Fault Currents, or 5.2.3.6DV.1.4 and 5.2.3.6DV.1.6, Breakdown of Components Test – GROUP INSTALLATION for High Fault Currents.

6.3.7DV.3.2.2 Power conversion equipment provided with solid state short circuit protection in accordance with 4.3.9DV.2.3 and intended for GROUP INSTALLATION as described in 5.2.3.6DV.1.1.2, shall be marked in accordance with 6.3.7DV.3.1.2, or the equivalent.

6.3.7DV.4 D2 *Modification to add the following:*

6.3.7DV.4.1 CONTROL CIRCUIT protection

6.3.7DV.4.1.1 In accordance with 4.3.8.1DV.1.1.5, when the additional wiring protection is not required due to the rating or trip setting of an instantaneous trip circuit breaker used as the branch circuit short circuit protection, then the drive shall be provided with a marking or instructions indicating the maximum wiring protective device size required by Table 4.3.8.1DV.1.

6.3.7DV.4.1.2 Regarding the requirement in 4.3.8.1DV.1.1.6(f), when a supplementary fuse is being relied upon for compliance with this requirement, then a replacement marking or instructions shall be provided that includes the voltage and current rating of the fuse.

6.3.7DV.4.1.3 In accordance with 4.3.8.1DV.1.1.7, when a field installed accessory kit is being relied upon to provide the additional wiring protection, then the drive shall be provided with a marking or instructions to identify this kit.

6.3.7DV.4.1.4 Regarding the requirement in 4.3.8.1DV.1.1.8, when a fuse (other than supplementary) is being relied upon to provide the additional wiring protection and when the fuse-holder accepts a fuse having a higher current rating than required by 4.3.8.1DV.1.1.6, then the drive shall be provided with a marking or instructions identifying the maximum fuse size.

6.3.7DV.5 D2 *Modification to add the following:*

6.3.7DV.5.1 High available fault current – damage warning

6.3.7DV.5.1.1 Power conversion equipment intended for use on circuits having high available fault currents as indicated in 5.2.3.6.2.1DV.2.2 shall be marked with the word “WARNING” and the following or equivalent, “The opening of the branch-circuit protective device may be an indication that a fault current has been interrupted. To reduce the risk of

fire or electric shock, current-carrying parts and other components of the controller should be examined and replaced if damaged. If burnout of the current element of an overload relay occurs, the complete overload relay must be replaced."

6.3.7DV.6 D2 *Modification to add the following:*

6.3.7DV.6.1 Cord-connected equipment overcurrent protection

6.3.7DV.6.1.1 When required by 4.3.8.7DV.5.4, cord-connected equipment shall be marked with the voltage and ampere rating of the required overcurrent protection.

6.3.8 Motor overload protection and overtemperature protection

6.3.8.1 CDM/BDM not incorporating internal ELECTRONIC MOTOR OVERLOAD and overtemperature PROTECTION

If the CDM/BDM does not incorporate ELECTRONIC MOTOR OVERLOAD or motor overtemperature PROTECTION, the installation manual shall indicate that these motor protection features are not provided.

6.3.8.1DV D2 *Modification:*

See Table 28DV for marking locations.

6.3.8.2 CDM/BDM incorporating internal ELECTRONIC MOTOR OVERLOAD and overtemperature protection

If required by 4.4.6, the installation and maintenance manuals of CDM/BDM incorporating internal overload protection shall provide all of the following information:

a) protection in multiple of current setting;

b) tripping time;

c) instructions for adjustment.

If the internal ELECTRONIC MOTOR OVERLOAD PROTECTION has THERMAL MEMORY RETENTION, the installation and maintenance manuals of CDM/BDM shall provide information about the behaviour. When the THERMAL MEMORY RETENTION is adjustable, the manuals shall be provided with instructions for adjustment.

If the internal ELECTRONIC MOTOR OVERLOAD PROTECTION does not have THERMAL MEMORY RETENTION, information shall be provided in the installation and maintenance manuals.

If the internal ELECTRONIC MOTOR OVERLOAD PROTECTION is speed sensitive, the installation and maintenance manuals of CDM/BDM shall provide information about the behaviour. When the speed sensitivity is adjustable, the manuals shall be provided with instructions for adjustment.

If the internal ELECTRONIC MOTOR OVERLOAD PROTECTION is not speed sensitive, information shall be provided in the installation and maintenance manuals.

6.3.8.2DV D2 *Modification:*

See Table 28DV for marking locations.

6.3.9 Commissioning

If COMMISSIONING TESTS are necessary to ensure the electrical and thermal safety of a PDS, information to support these tests shall be provided for each part of the PDS. This information can depend on the specific INSTALLATION, and close cooperation between manufacturer, installer, and user can be required.

Commissioning information shall include references to hazards that might be encountered during commissioning, for example those mentioned in 6.4 and 6.5.

6.3.9DV D2 *Deletion:*

These requirements are not considered part of the specifications for certification.

6.4 Information for use

6.4.1 General

The user's manual shall include all information regarding the safe operation of the PDS/CDM/BDM. In particular, it shall identify any hazardous materials and risks of electrical shock, overheating, explosion, excessive acoustic noise, etc.

The manual should also indicate any hazards which can result from reasonably foreseeable misuse of the PDS.

6.4.1DV D2 *Modification to replace 6.4.1 with the following:*

For certification purposes, identification in the manual of those hazards and risks specifically addressed in this standard is considered to be sufficient.

6.4.2 Adjustment

The user's manual shall give details of all safety-relevant adjustments intended for the user. The identification or function of each control or indicating device and fuse shall be marked adjacent to the item. Where it is not possible to do this on the product, the information shall be provided pictorially in the manual.

Maintenance adjustments may also be described in this manual, but it shall be made clear that they should only be made by qualified personnel.

Clear warnings shall be provided where excessive adjustment could lead to a hazardous state of the PDS/CDM/BDM.

Any special equipment necessary for making adjustments shall be specified and described.

6.4.3 Labels, signs and signals

6.4.3.1 General

Labelling shall be in accordance with good ergonomic principles so that notices, controls, indications, test facilities, fuses, etc., are sensibly placed and logically grouped to facilitate correct and unambiguous identification.

All safety related equipment labels shall be located so as to be visible after installation or readily visible by opening a door or removing a cover.

Where a hazard is present after the removal of a cover, a warning label shall be placed on the equipment. The label shall be visible before the cover is removed.

Labels shall:

• wherever possible, use international symbols as given by ISO 3864, ISO 7000 or IEC 60417;

• if no international symbol is available, be worded in an appropriate language or in a language associated with a particular technical field;

• be conspicuous, legible and durable;

• be concise and unambiguous;

• state the hazards involved and give ways in which risks can be reduced.

When instructing the person(s) concerned as to

what to avoid: the wording should include “no”, “do not”, or “prohibited”;

• **what to do**: the wording should include “shall”, or “must”;

• **the nature of the hazard**: the wording should include “caution”, “warning”, or “danger”, as appropriate;

• **the nature of safe conditions**: the wording should include the noun appropriate to the safety device.

Safety signs shall comply with ISO 3864.

The signal words indicated hereinafter shall be used and the following hierarchy respected:

• **DANGER** to call attention to a high risk, for example: “High voltage”

• **WARNING** to call attention to a medium risk, for example: “This surface can be hot.”

• **CAUTION** to call attention to a low risk, for example; “Some of the tests specified in this standard involve the use of processes imposing risks on persons concerned.”

Danger, warning and caution markings on the PDS shall be prefixed with the word “DANGER”, “WARNING”, or “CAUTION” as appropriate in letters not less than 3,2 mm high. The remaining letters of such markings shall be not less than 1,6 mm high.

6.4.3.1DV D2 *Modification:*

6.4.3.1DV.1 A marking on the product or in the instruction manual that is intended to inform the user of a risk of injury to persons or property damage shall comply with 6.4.3.1 in addition to 6.4.3.1DV.2 – 6.4.3.1DV.11.

6.4.3.1DV.2 The location of the cautionary markings and instructions shall be in accordance with Table 28DV.

6.4.3.1DV.3 Required cautionary markings shall not be located solely on a part that is removable unless removal of the part impairs the operation or appearance of the equipment.

6.4.3.1DV.4 Unless specifically identified in this standard, the use of international symbols or signs is not required.

6.4.3.1DV.5 The signal word hierarchy shall be observed as a minimum. For example, "Danger" may be substituted for either "Warning" or "Caution" but not vice versa.

6.4.3.1DV.6 The Standard for Product Safety Signs and Labels, NEMA Z535.4 provides additional information with respect to markings, symbols, and color coding.

6.4.3.1DV.7 Letter heights are applicable to PDS, CDM and BDM.

6.4.3.1DV.8 A cautionary marking intended to instruct the operator shall be legible and visible to the operator during normal operation of the equipment. A marking that provides servicing instructions shall be legible and visible when such servicing is being performed.

6.4.3.1DV.9 Permanence of Marking – All markings that are required to be on the product shall be molded, die-stamped, paint-stenciled, stamped or etched metal that is permanently secured, or indelibly stamped lettering on a pressure-sensitive label secured by adhesive. Usage, handling, storage, and similar conditions to which the product is exposed are to be applied in the determination of the permanency of a marking in accordance with the Standard for Marking and Labeling Systems, UL 969.

6.4.3.1DV.10 Unless specified otherwise in individual marking requirements, when deciding which signal word to use, the following definitions apply:

DANGER – Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.

WARNING – Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

Caution – Indicates a potentially hazardous situation which, if not avoided, could result in minor or moderate injury.

Notice – Indicates a potentially hazardous situation which, if not avoided, could result in property damage or other situation not related to personal injury.

6.4.3.1DV.11 The signal word "NOTICE" shall not be used when a risk of personal injury is involved.

6.4.3.2 Isolators

Where an isolating device is not intended to interrupt load current, a warning shall state:

DO NOT OPEN UNDER LOAD.

The following requirements apply to any supply isolating device which does not disconnect all sources of power to the PDS.

• If the isolating device is mounted in an equipment enclosure with the operating handle externally operable, a warning label shall be provided adjacent to the operating handle stating that it does not disconnect all power to the PDS.

• Where a control circuit disconnector can be confused with power circuit disconnectors due to size or location, a warning label shall be provided adjacent to the operating handle of the control circuit disconnector stating that it does not disconnect all power to the PDS.

6.4.3.2DV D2 *Modification to replace 6.4.3.2 with the following:*

These requirements are applicable to PDS, CDM and BDM.

6.4.3.3 Visual and audible signals

Visual signals such as flashing lights, and audible signals such as sirens, may be used to warn of an impending hazardous event such as the driven equipment start-up and shall be identified.

It is essential that these signals:

• are unambiguous;

• can be clearly perceived and differentiated from all other signals used;

• can be clearly recognized by the user;

• are emitted before the occurrence of the hazardous event.

It is recommended that higher frequency flashing lights be used for higher priority information.

NOTE IEC 60073 provides guidance on recommended flashing rates and on/off ratios.

6.4.3.3DV D2 *Deletion:*

These requirements are not considered part of the specifications for certification.

6.4.3.4 Hot surfaces

Surfaces which can exceed the temperature limits of Table 16 shall be marked with the warning symbol IEC 60417-5041 (2002-10) (see Annex H). The user's manual shall also contain this information.

6.4.3.4DV D2 ***Modification to replace 6.4.3 with the following:***

All enclosure surfaces subject to casual contact and in excess of the maximum temperatures specified in Table 16 shall be marked “WARNING” and the following or equivalent: “Hot Surface – Risk of Burn”.

6.4.3.5 Equipment marking

The identification of each control or indicating device and fuse shall be marked adjacent to the item. Replaceable fuses shall be marked with their rating and time characteristics. Where it is not possible to do this on the product, the information shall be provided pictorially in the manual.

Appropriate identification shall be marked on or adjacent to each movable connector.

Test points shall be individually marked with the circuit diagram reference.

The polarity of any polarized devices shall be marked adjacent to the device.

The diagram reference and if possible the function shall be marked adjacent to each pre-set control in a position where it is clearly visible while the adjustment is being made.

6.4.3.5DV D2 ***Modification:***

6.4.3.5DV.1 Time characteristics for fuses refers only to non-time delay and time delay ratings.

6.4.3.5DV.2 Where the physical characteristics of devices or connectors determine the polarity, no marking is required. Polarity markings are only required for user or maintenance replaceable components.

6.5 Information for maintenance

6.5DV D2 ***Modification to add the following:***

6.5DV.1 When more than one disconnect switch is required to disconnect all power within a control assembly or compartment, the assembly or compartment shall be marked with the word “WARNING” and the following or the equivalent, “Risk of Electric Shock – More than one disconnect switch is required to de-energize the equipment before servicing.”

6.5DV.2 The marking required by 6.5DV.1 shall be in a permanent location on the outside of the equipment or on a stationary fixed, nonremovable part inside the equipment. The cover is not considered to be a stationary fixed, nonremovable part.

6.5DV.3 Enclosures provided with removable covers, as noted in DVD.2.4.8.2(e), shall be marked “WARNING” and the following: “RISK OF SHOCK – Disconnect Power Before Removing Cover.”

6.5.1 General

Safety information shall be provided in the maintenance manual including, as appropriate, the following:

• preventive maintenance procedures and schedules;

• safety precautions during maintenance (for example, the use of earthing switches for HIGH-VOLTAGE PDS);

• location of LIVE PARTS that can be accessible during maintenance (for example, when covers are removed);

• adjustment procedures;

• subassembly and component repair and replacement procedures;

• any other relevant information.

NOTE 1 These may best be presented as diagrams.

NOTE 2 A list of special tools should be provided, when appropriate.

6.5.1DV D2 *Modification:*

A maintenance manual is not required and the items specified are only provided when applicable. Information typically provided includes commissioning and adjustment information and instructions on renewable or resettable components.

6.5.2 Capacitor discharge

When the requirements of the first sentence of 4.3.11 are not met, the warning symbol IEC 6041-5036 (2002-10) 7 (see Annex H) and an indication of the discharge time (for example, 45 s, 5 min) shall be placed in a clearly visible position on the enclosure, the capacitor protective barrier, or at a point close to the capacitor(s) concerned (depending on the construction). The symbol shall be explained and the time required for the capacitors to discharge after the removal of power from the PDS shall be stated in the installation and maintenance manuals.

6.5.2DV D2 *Modification:*

The marking shall be located where clearly visible to the user prior to accessing the charged circuit. The marking shall include the following: "WARNING – Risk of Electric Shock," followed by instructions to discharge the specific capacitor or indicating the time required for the capacitor to discharge to a level below 50 V DC.

6.5.3 Auto restart/bypass connection

If a CDM/BDM can be configured to provide automatic restart or bypass connection, the installation, user and maintenance manuals shall contain appropriate warning statements.

A PDS which is set to provide automatic restart or bypass connection after the removal of power shall be clearly identified at the INSTALLATION.

6.5.3DV D1 *Modification:*

The requirement in the first paragraph also applies to a PDS that can be configured to provide automatic restart or bypass connection. The second paragraph is outside of the jurisdiction of a product certifier.

6.5.4 PT/CT connection

A PDS which has monitoring or control functions using a potential transformer (PT) supplied from high voltage, or a current transformer (CT) supplied from a high current connection, shall be clearly marked to show the possible hazards of voltage transients upon disconnection of the secondary circuit. The hazards shall also be described in the installation and maintenance manuals.

6.5.4DV D2 *Modification:*

Identification and warning statements are only required in manuals.

6.5.5 Other hazards

The manufacturer shall identify any components and materials of a PDS which require special procedures to prevent hazards.

6.5.5DV D1 *Modification:*

A live heat sink or other part mistaken as dead metal and exposed to persons shall be marked with the word "CAUTION" and the following or equivalent, "Risk of Electric Shock – Plates (or other word describing the type of part) are live – Disconnect Power Supply Before Servicing." The marking shall be located on the LIVE PART.

Annex A
(informative)

Examples of protection in case of direct contact

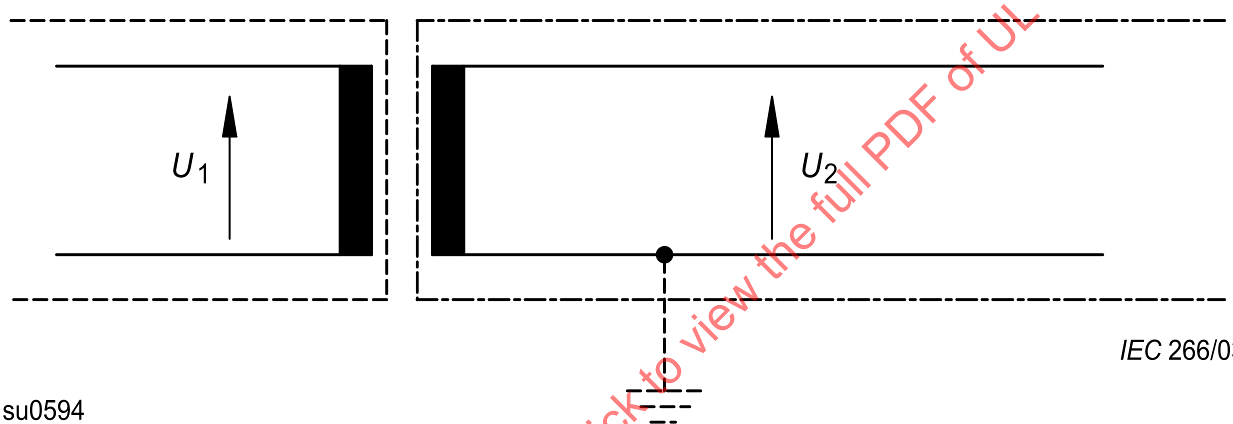
A.1 General

Figure A.1 to Figure A.3 show examples of the methods used for protection in case of dir ect contact (see 4.3.4).

- - - - - - - -	Protection against direct contact
– · – · – · – · – · – · – · –	PROTECTIVE SEPARATION from circuits requiring protection against direct contact

A.2 Protection by means of DVC A

(See 4.3.4.2.)



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su0594

Key

U_1: hazardous voltage, earthed or unearthed.

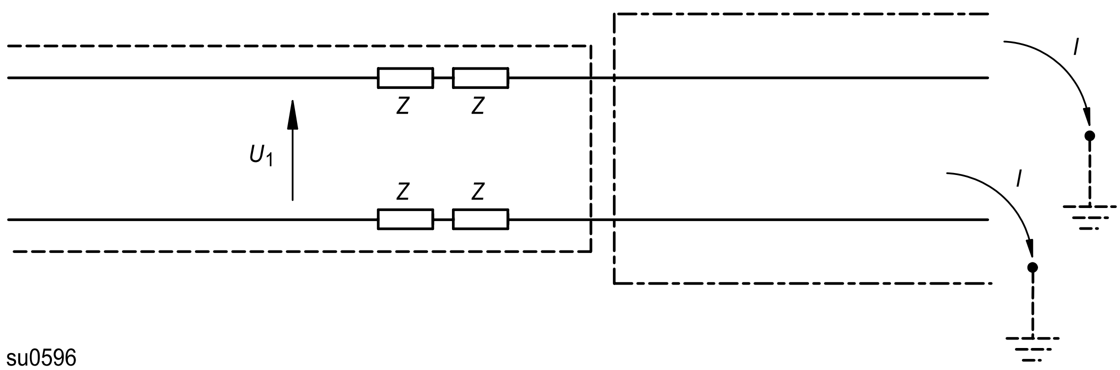
U_2: ≤ 30 V a.c.

Figure A.1

Protection by DVC A, with PROTECTIVE SEPARATION

A.3 Protection by means of PROTECTIVE IMPEDANCE

(See 4.3.4.3.)



su0596

IEC 267/03

Key

U_1: hazardous voltage, earthed or unearthed.

$I \leq$ 3,5 mA a.c., 10 mA d.c.

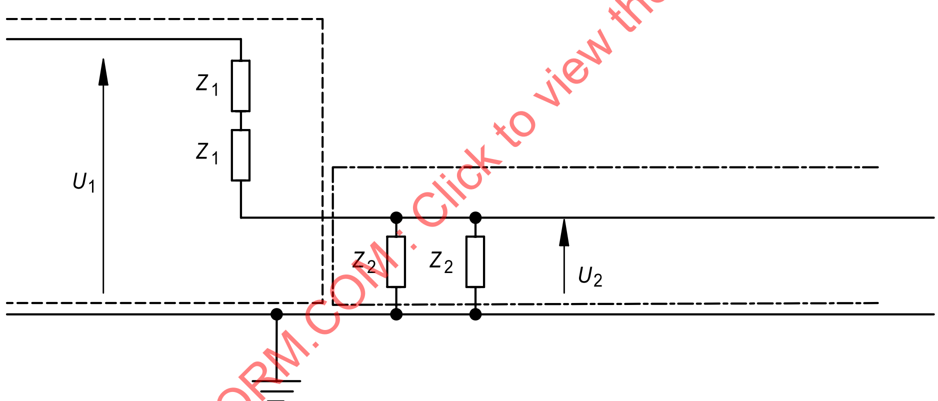
NOTE To provide protection in single-fault conditions, $I = U_1/Z$

Figure A.2

Protection by means of PROTECTIVE IMPEDANCE

A.4 Protection by using limited voltages

(See 4.3.4.4.)



su0597

IEC 268/03

Key

U_1: hazardous voltage, earthed.

U_2: ≤ 30 V a.c., 60 V d.c.

NOTE To provide protection in single-fault conditions, $U_2 = U_1Z_2/(2Z_1 + Z_2)$ or $U_2 = U_1Z_2/2(Z_1 + Z_2/2)$.

Figure A.3

Protection by using limited voltages

Annex B
(informative)

Examples of overvoltage category reduction

B.1 General

The following Figure B.1 to Figure B.13 are intended as illustrations of the requirements in Table 4, 4.3.6.2 and 4.3.6.3. They are not intended as indications of good design practice.

———————	Protection against direct contact
— — —	Conductive accessible parts
– · – · – · – ·	Protective separation
SPD	Surge protection device (example of measure to reduce transient overvoltages)
OVC	Overvoltage category

B.2 Insulation to the surroundings (see 4.3.6.2)

B.2.1 Circuits connected directly to the supply mains (see 4.3.6.2.2)

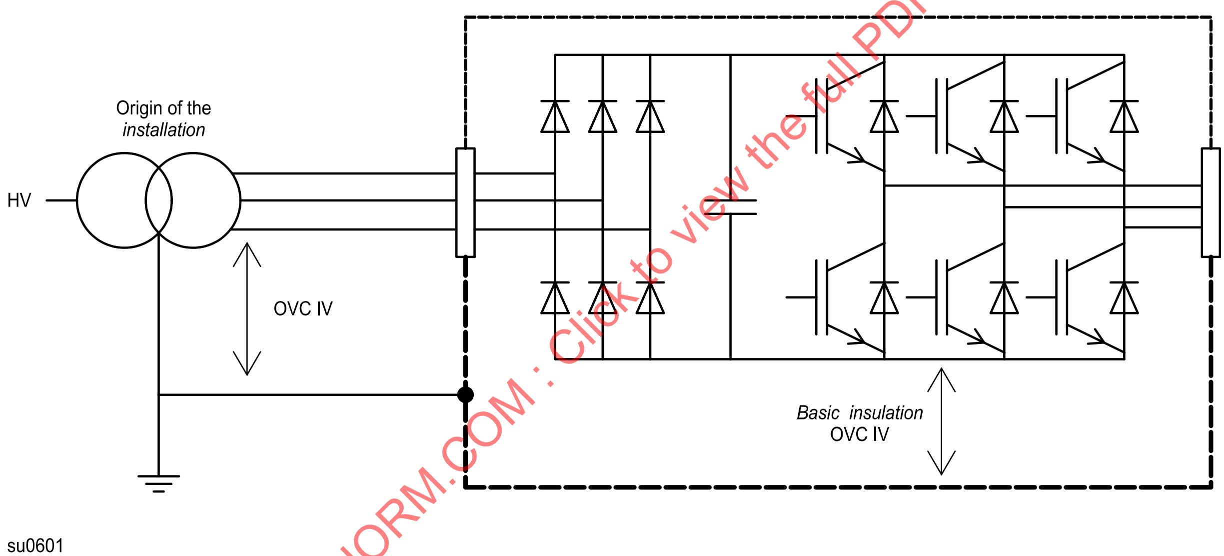
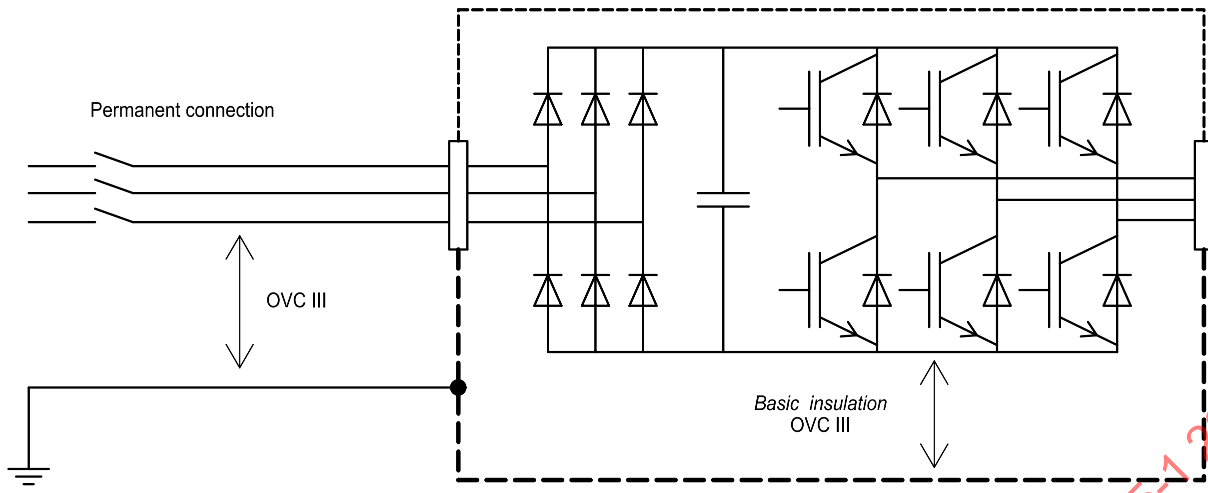


Figure B.1

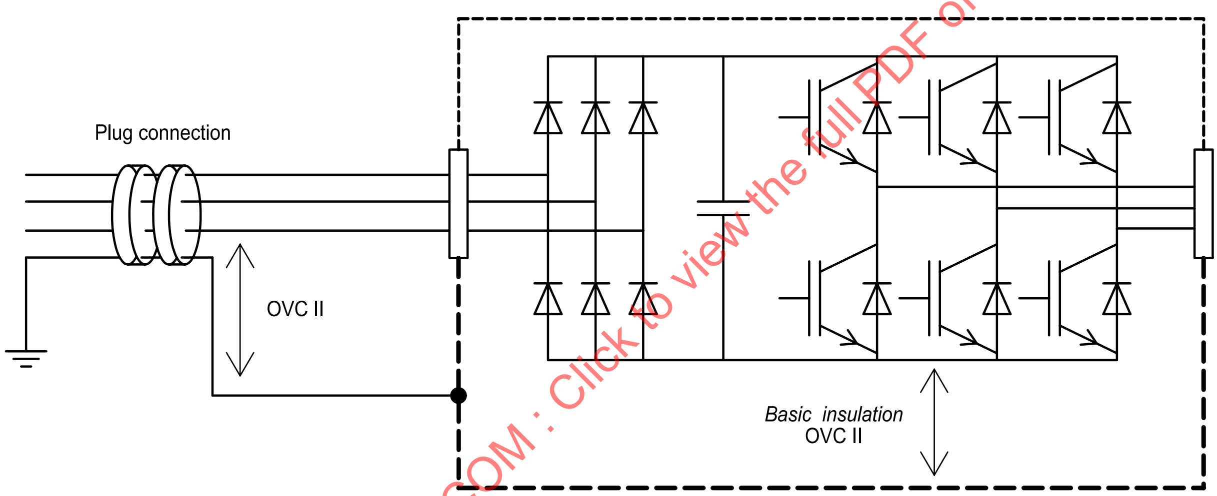
BASIC INSULATION evaluation for circuits connected directly to the origin of the INSTALLATION supply mains



su0602

Figure B.2

BASIC INSULATION evaluation for circuits connected directly to the supply mains



su0603

Figure B.3

BASIC INSULATION evaluation for equipment not permanently connected to the supply mains

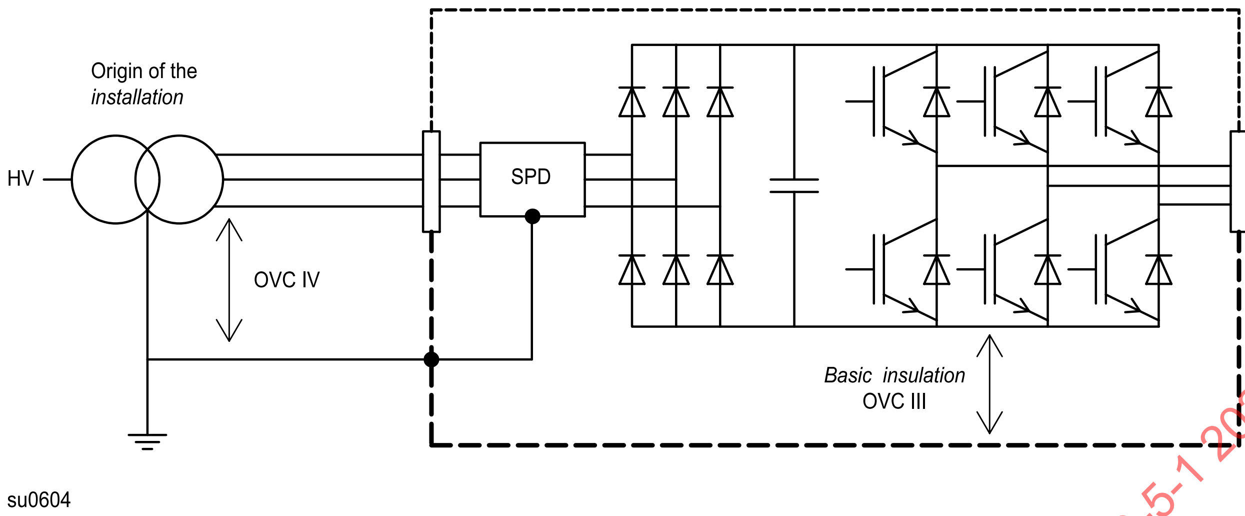


Figure B.4

BASIC INSULATION evaluation for circuits connected directly to the origin of the INSTALLATION supply mains where internal SPDs are used

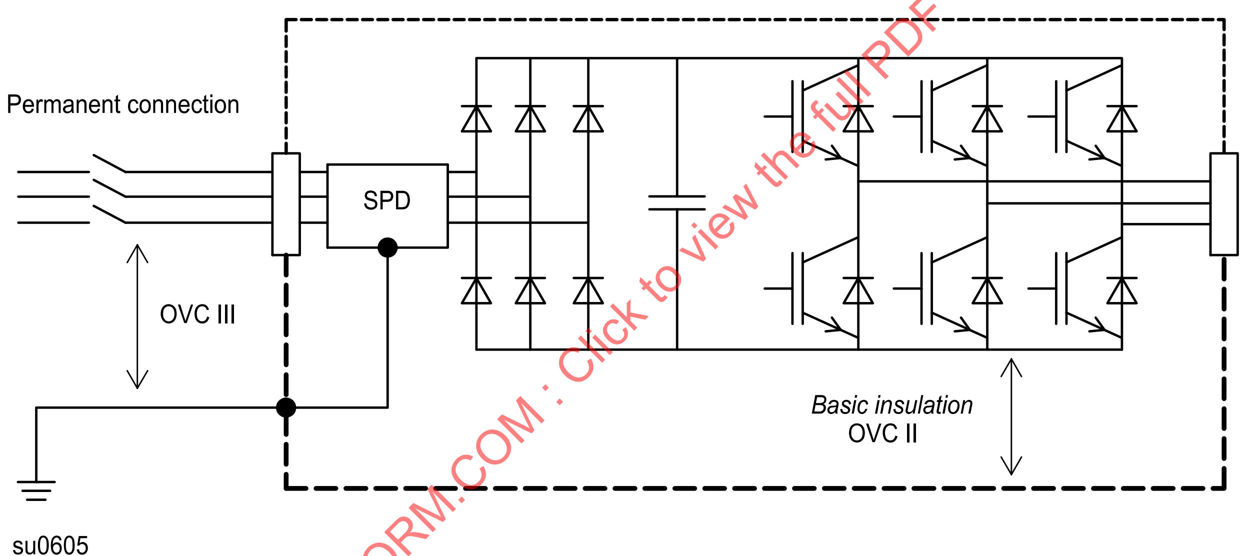


Figure B.5

BASIC INSULATION evaluation for circuits connected directly to the supply mains where internal SPDs are used

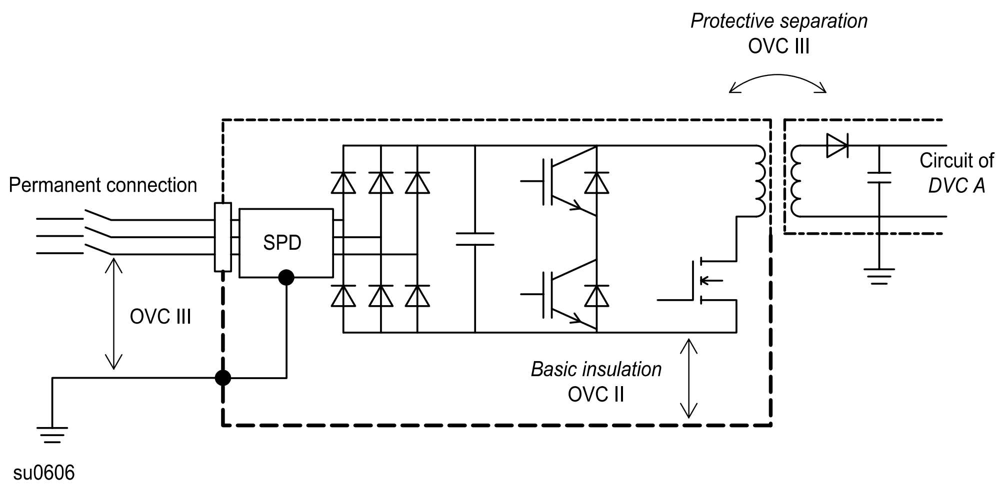


Figure B.6

Example of PROTECTIVE SEPARATION evaluation for circuits connected directly to the supply mains where internal SPDs are used

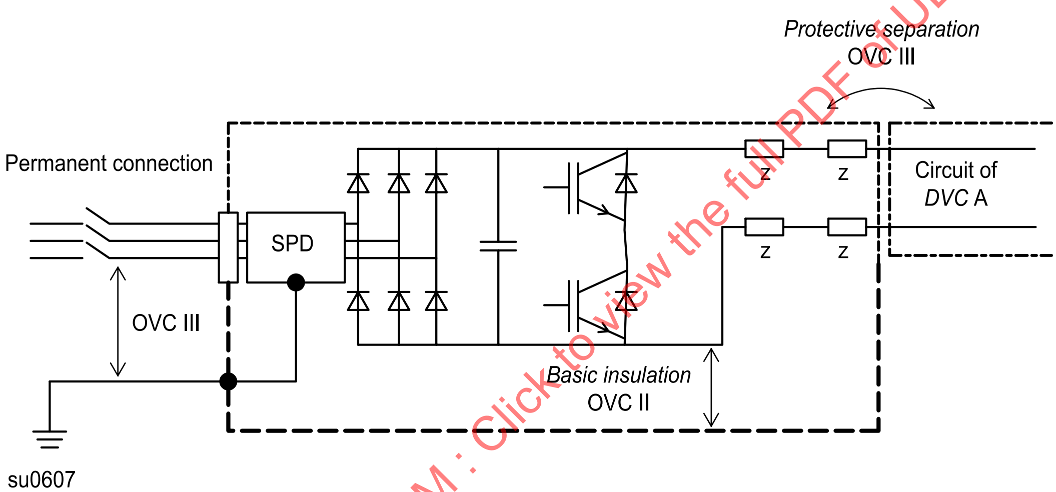


Figure B.7

Example of PROTECTIVE SEPARATION evaluation for circuits connected directly to the supply mains where internal SPDs are used

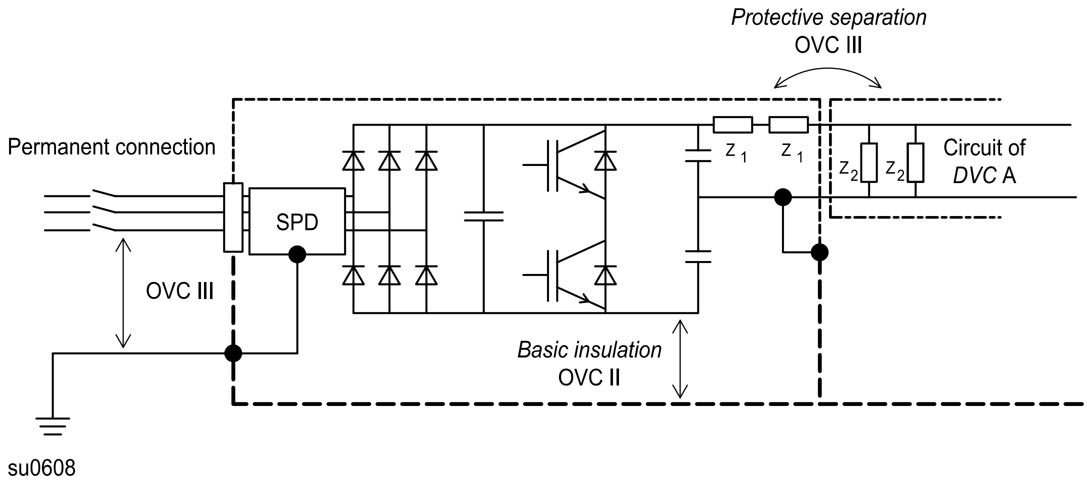


Figure B.8

Example of PROTECTIVE SEPARATION evaluation for circuits connected directly to the supply mains where internal SPDs are used

NOTE The requirements for PROTECTIVE SEPARATION in 5.2.3.1 to 5.2.3.3 are not reduced by the use of the SPD (see 4.3.6.2.2 and 4.3.6.2.3).

B.2.2 Circuits not connected directly to the supply mains (see 4.3.6.2.3)

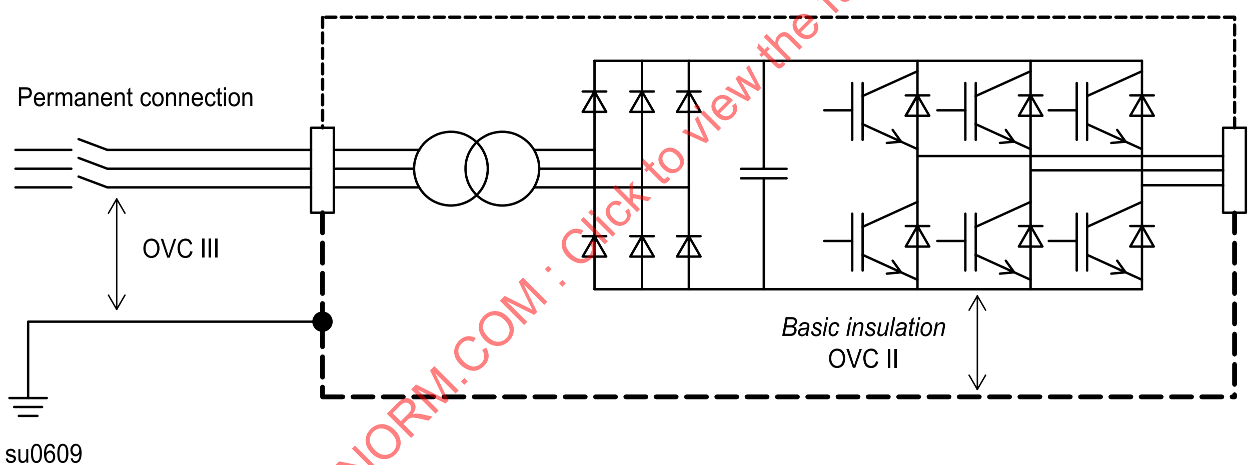
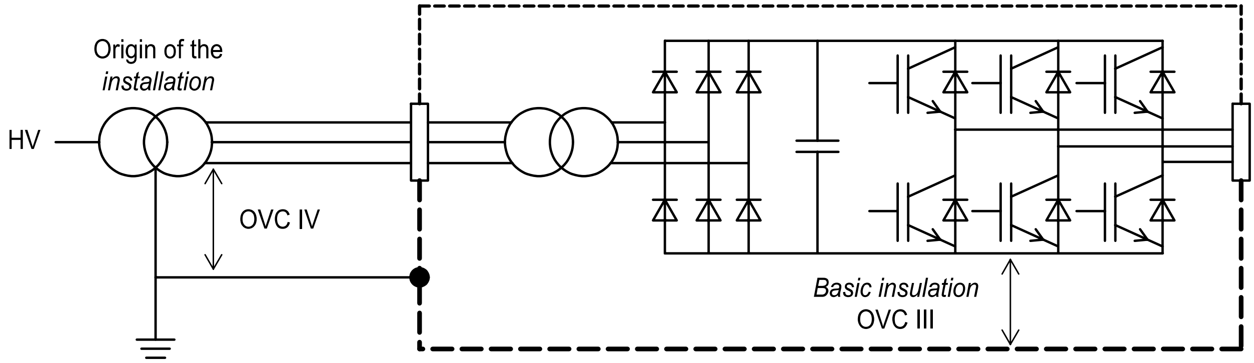


Figure B.9

BASIC INSULATION evaluation for circuits not connected directly to the supply mains



su0610

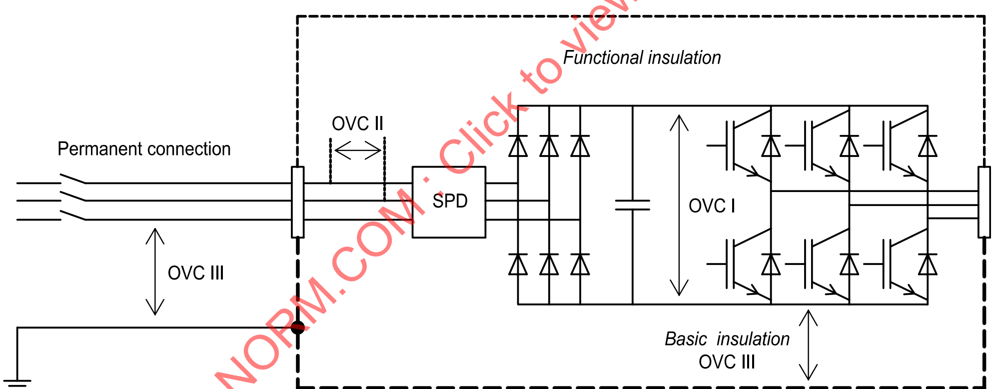
Figure B.10

BASIC INSULATION evaluation for circuits not connected directly to the supply mains

B.2.3 Insulation between circuits (see 4.3.6.2.4)

Insulation between two circuits shall be designed according to the circuit having the more severe requirement (see also Figure B.12).

B.3 FUNCTIONAL INSULATION (see 4.3.6.3)



su0611

NOTE 1 The SPD is not connected to earth, and so has no effect on the overvoltage category to earth.

NOTE 2 The requirements for FUNCTIONAL INSULATION may be further reduced by the circuit characteristics (see 4.3.6.3).

Figure B.11

FUNCTIONAL INSULATION evaluation within circuits affected by external transients

B.3DV DE *Modify to correct:*

Figure B.11 illustrates the application of FUNCTIONAL INSULATION if the circuit analysis required by 4.2 shows that failure of the insulation could not result in a hazard. If the analysis required by 4.2 does show that failure of the insulation could result in a hazard, FUNCTIONAL INSULATION shall meet the requirements and tests for BASIC INSULATION.

B.4 Further examples

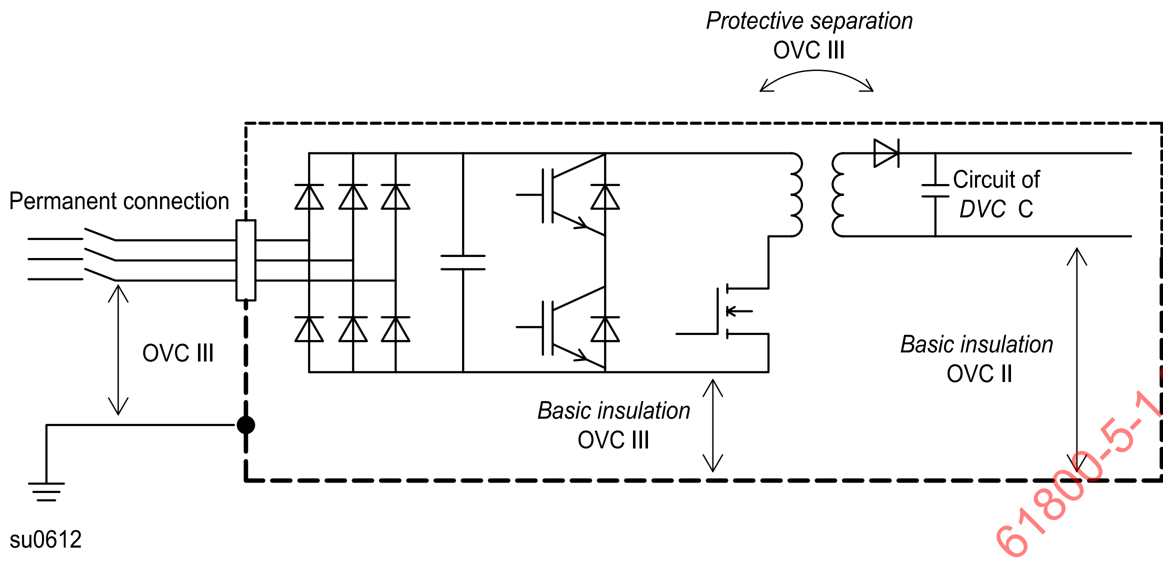


Figure B.12

BASIC INSULATION evaluation for circuits both connected and not connected directly to the supply mains

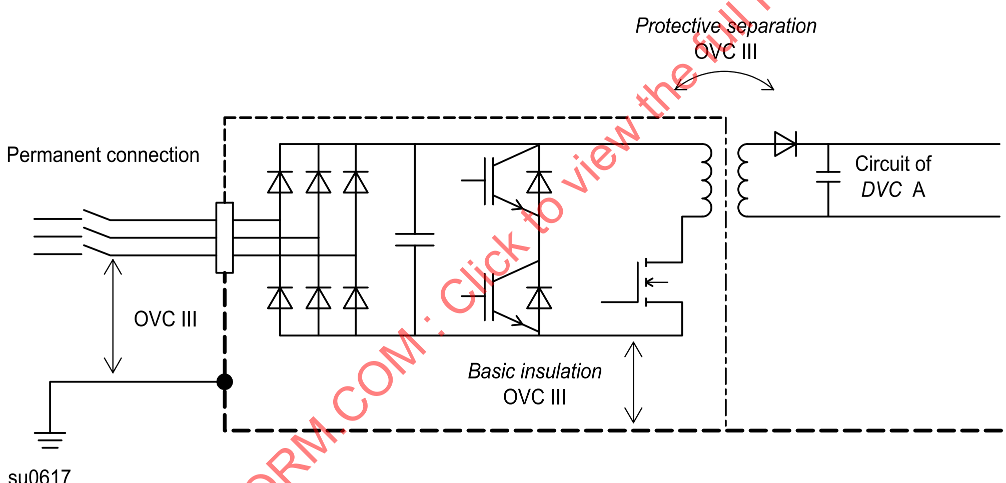


Figure B.13

Insulation evaluation for accessible circuit of DVC A

Annex C
(normative)

Measurement of clearance and creepage distances

C.1 Measurement

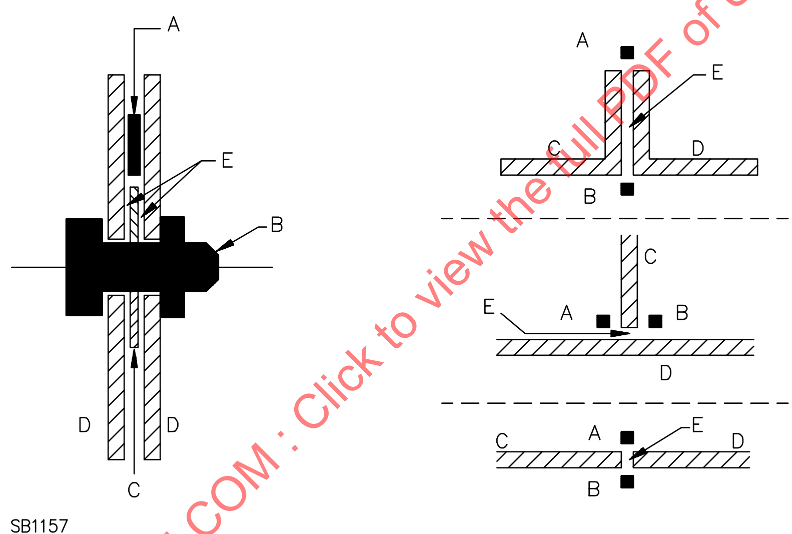
Clearance and creepage distances shall be measured as illustrated in the examples contained in Example C.1 to Example C.14.

C.1DV D2 ***Modification to add requirements for clamped joints:***

A clamped joint is a joint between two pieces of insulation that are under pressure, as shown in Figure C.1DV.1. Adhesives, cements, and similar materials, when used to effect a seal in place of a tightly mated joint, shall comply with the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C.

Figure C.1DV.1

Clamped joint



Parts A, B – LIVE PARTS of opposite polarity, or a LIVE PART and grounded metal part with spacing through the crack between C and D less than required in DVF.2 or DVF.5.

Parts C, D – Insulating barriers clamped tightly together so that the dielectric strength between A and B is greater than the equivalent air spacing.

Part E – The clamped joint.

C.2 Relationship of measurement to pollution degree

The "*X*" values are a function of pollution degree and shall be as specified in Table C.1. If the associated permitted clearance is less than 3 mm, the *X* value is one-third of the clearance.

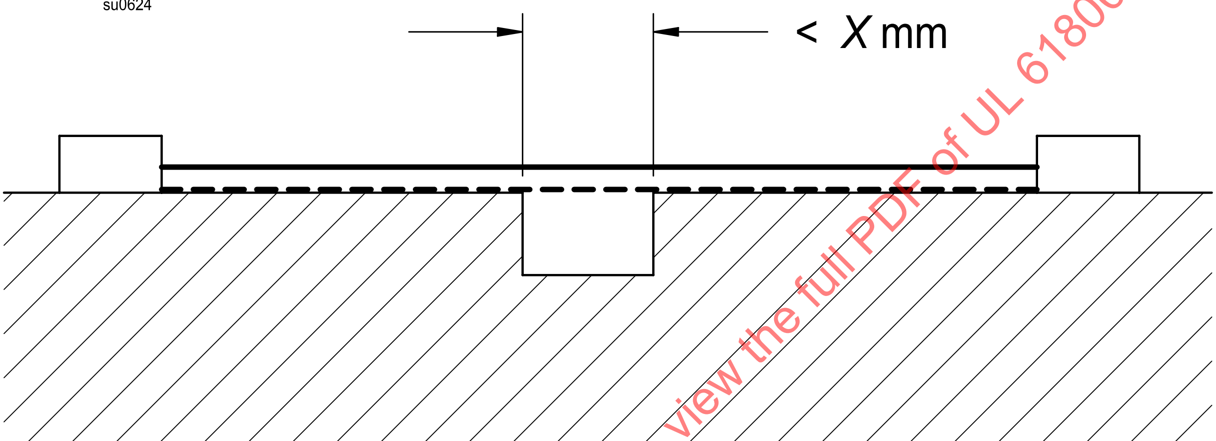
Table C.1
Width of grooves by pollution degree

Pollution degree	*X* value mm
1	0,25
2	1,0
3	1,5

C.3 Examples

In the Example C.1 to Example C.14 below, clearance and creepage distances are denoted as follows:

su0624

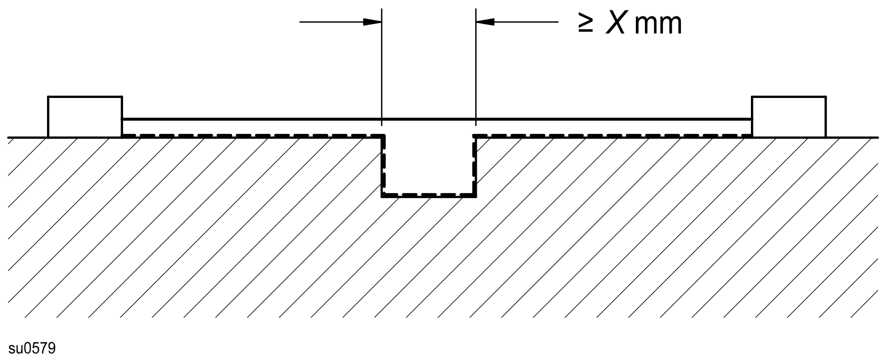


su0578 *IEC* 269/03

Example C.1

Condition: the path under consideration includes a parallel, diverging or converging-sided groove of any depth with a width less than *X* mm.

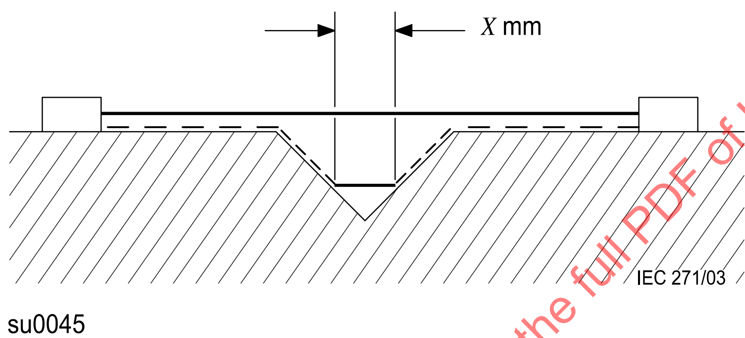
Rule: creepage distance and clearance are measured directly across the groove as shown.



Example C.2

Condition: Path under consideration includes a parallel or diverging-sided groove of any depth with a width equal to or more than *X* mm.

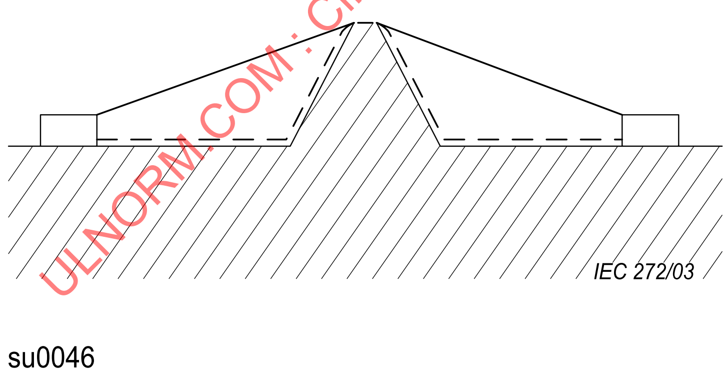
Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove.



Example C.3

Condition: Path under consideration includes a V-shaped groove with a width greater than *X* mm.

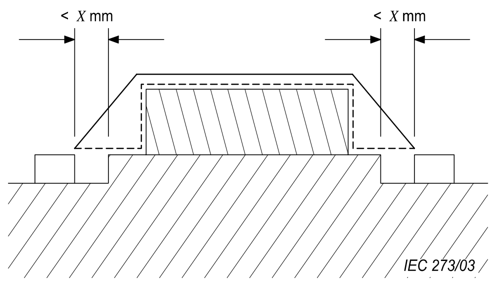
Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove but "short-circuits" the bottom of the groove by *X* mm link.



Example C.4

Condition: Path under consideration includes a rib.

Rule: Clearance is the shortest air path over the top of the rib. Creepage path follows the contour of the rib.

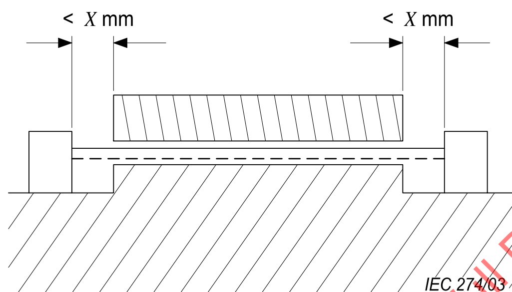


su0047

Example C.5

Condition: Path under consideration includes a cemented joint with grooves less than X mm wide on each side.

Rule: Clearance is the shortest air path over the top of the joint. Creepage distance is measured directly across the grooves and follows the contour of the joint.

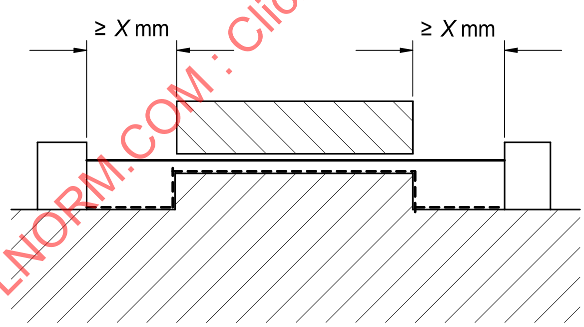


su0048

Example C.6

Condition: Path under consideration includes an uncemented joint with grooves less than *X* mm wide on each side.

Rule: Creepage and clearance path is the “line of sight” distance shown.

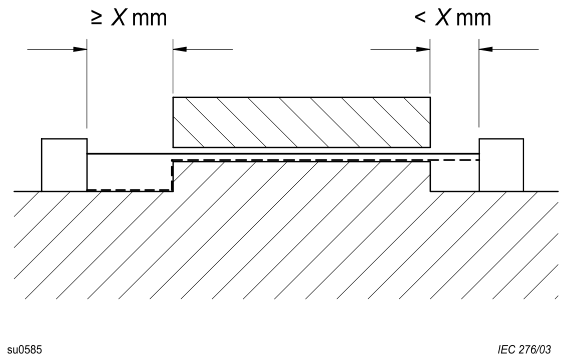


su0584

Example C.7

Condition: Path under consideration includes an uncemented joint with grooves equal to or more than *X* mm wide on each side.

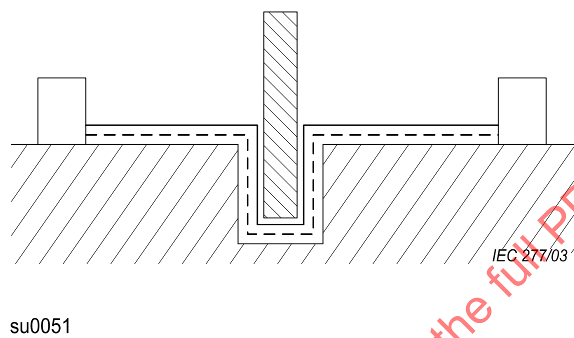
Rule: Clearance is the “line of sight” distance. Creepage path follows the contour of the grooves.



Example C.8

Condition: Path under consideration includes an uncemented joint with a groove on one side less than *X* mm wide and the groove on the other side equal to or more than *X* mm wide.

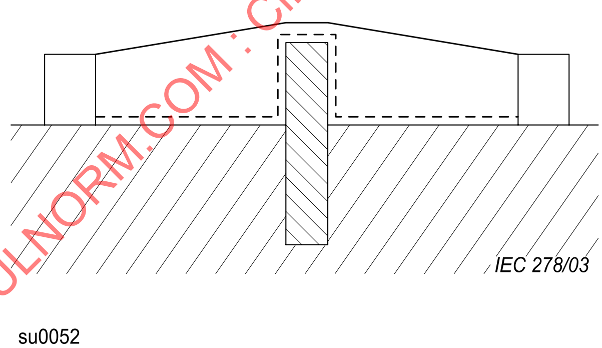
Rule: Clearance and creepage paths are as shown.



Example C.9

Condition: Path under consideration includes an uncemented barrier when path under the barrier is less than the path over the barrier.

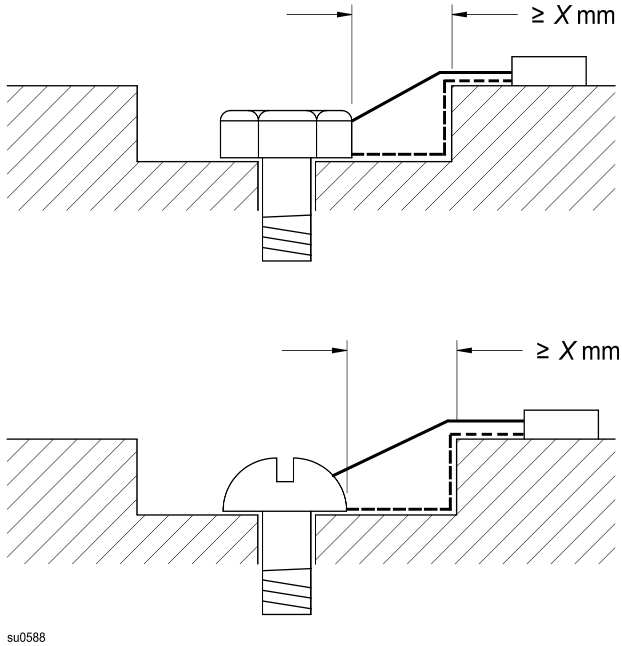
Rule: Clearance and creepage paths follow the contour under the barrier.



Example C.10

Condition: Path under consideration includes an uncemented barrier when path over the barrier is less than the path under the barrier.

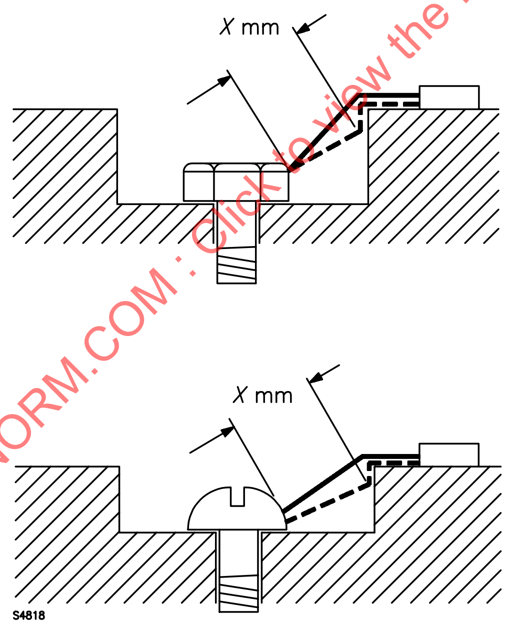
Rule: Clearance is the shortest air path over the top of the barrier. Creepage path follows the contour of the barrier.



Example C.11

Condition: Path under consideration includes a gap between head of screw and wall of recess which is equal to or more than *X* mm wide.

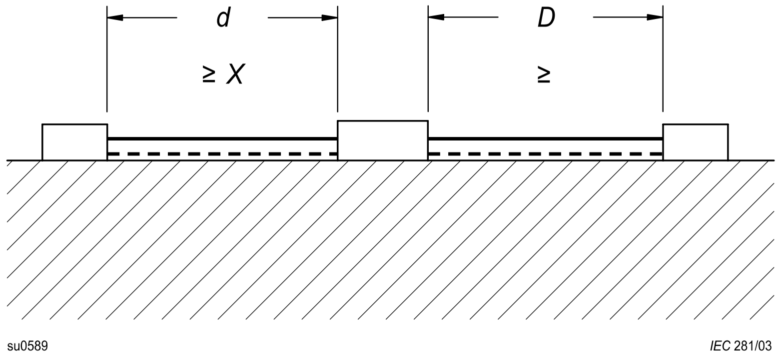
Rule: Clearance is the shortest air path through the gap and over the top surface. Creepage path follows the contour of the surfaces.



Example C.12

Condition: Path under consideration includes a gap between head of screw and wall of recess which is less than *X* mm wide.

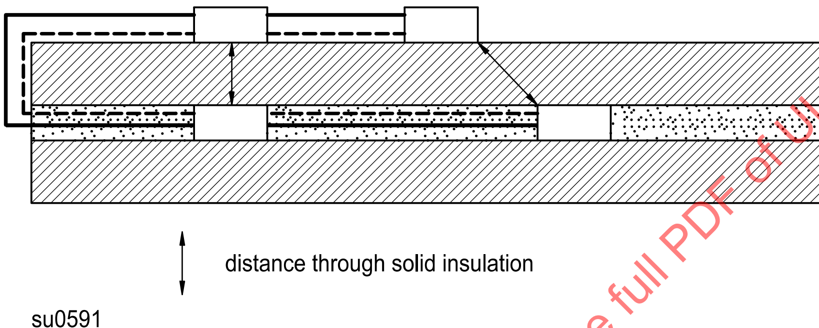
Rule: Clearance is the shortest air path through the gap and over the top surface. Creepage path follows the contour of the surfaces but “short -circuits” the bottom of the recess by *X* mm link.



Example C.13

Condition: Path under consideration includes an isolated part of conductive material.

Rule: Clearance and creepage paths are the sum of *d* plus *D*.



Example C.14

Condition: Path under consideration includes inner layer of PWB.

Rule: For the inner layer(s), the distance between adjacent tracks on the same layer is treated as creepage distance for pollution degree 1 and clearance as in air (see 4.3.6.8.4.1).

Annex D
(informative)

Altitude correction for clearances

Clearances in air are a function of the atmospheric pressure according to Paschen's Law. Clearance distances provided in Table 9 are valid up to 2000 m above sea level. Clearances above 2000 m must be multiplied by the factor provided in Table D.1.

Table D.1
Correction factor for clearances at altitudes between 2 000 m and 20 000 m

(see 4.3.6.4.1)

Altitude m	Normal barometric pressure kPa	Multiplication factor for clearances
2 000	80,0	1,00
3 000	70,0	1,14
4 000	62,0	1,29
5 000	54,0	1,48
6 000	47,0	1,70
7 000	41,0	1,95
8 000	35,5	2,25
9 000	30,5	2,62
10 000	26,5	3,02
15 000	12,0	6,67
20 000	5,5	14,50

Impulse tests performed below 2000 m altitude for the purpose of verifying air clearances must use test voltages which have been corrected for air pressure (altitude). Test voltages which have been corrected for three altitudes are provided in Table D.2. Altitude correction of test voltage is not required for impulse testing of solid insulation. The voltage values of Table D.2 apply for the verification of clearances only.

Table D.2
Test voltages for verifying clearances at different altitudes

Impulse voltage (from Table 7) kV	Impulse test voltage at sea level kV	Impulse test voltage at 200 m altitude kV	Impulse test voltage at 500 m altitude kV
0,33	0,36	0,36	0,35
0,50	0,54	0,54	0,53
0,80	0,93	0,92	0,90
1,50	1,8	1,7	1,7
2,50	2,9	2,9	2,8
4,00	4,9	4,8	4,7
6,00	7,4	7,2	7,0
8,00	9,8	9,6	9,4
12,00	15	14	14

Table D.2 Continued on Next Page

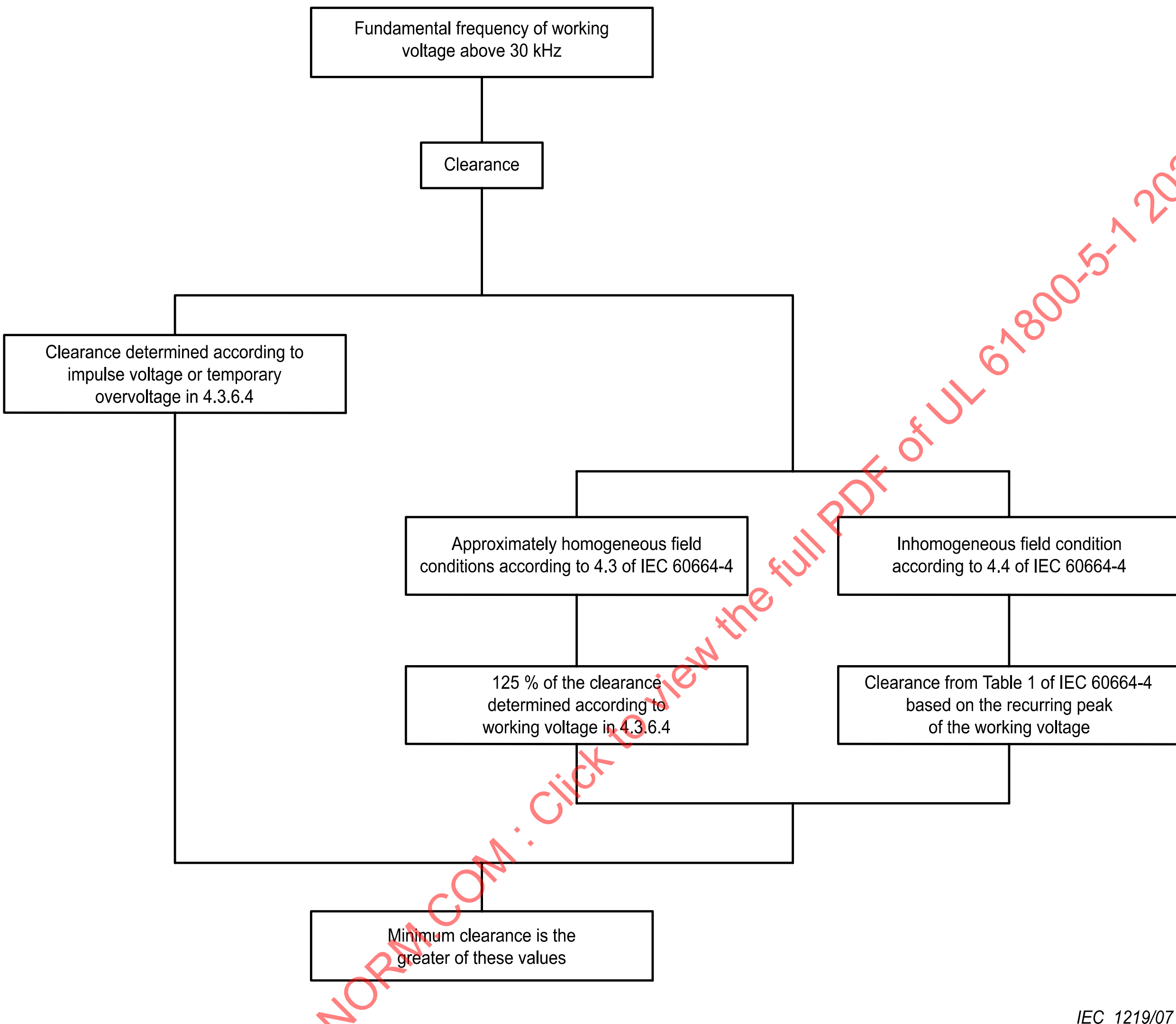
Table D.2 Continued

Impulse voltage (from Table 7) kV	Impulse test voltage at sea level kV	Impulse test voltage at 200 m altitude kV	Impulse test voltage at 500 m altitude kV
NOTE 1 Explanations concerning the influencing factors (air pressure, altitude, temperature, humidity) with respect to electric strength of clearances are given in 4.1.1.2.1.2 of IEC 60664-1.			
NOTE 2 When testing clearances, associated solid insulation will be subjected to the test voltage. As the impulse test voltage is increased with respect to the rated impulse voltage, solid insulation will be designed accordingly. This results in an increased impulse withstand capability of the solid insulation.			
NOTE 3 Values given above have been rounded from the calculation in subclause 4.1.1.2.1.2 of IEC 60664-1.			

Annex E
(informative)

Clearance and creepage distance determination for frequencies greater than 30 kHz

E.1 Clearance



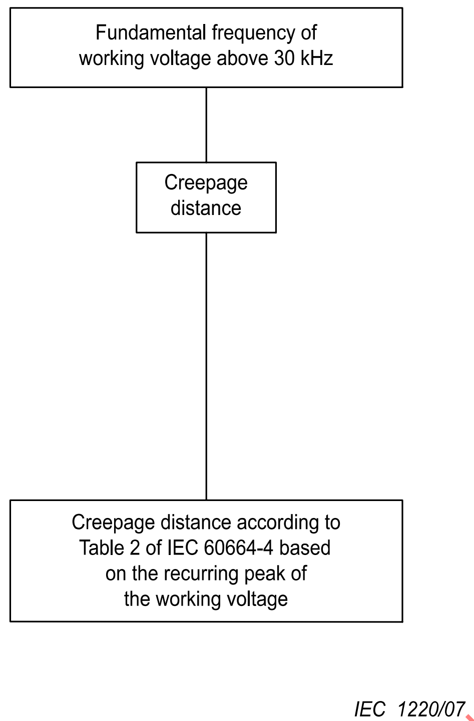
su0613

NOTE For frequencies exceeding 30 kHz, an approximately homogeneous field is considered to exist when the radius of curvature *r* of the conductive parts is equal or greater than 20 % of the clearance. The necessary radius of curvature can only be specified at the end of the dimensioning procedure.

Figure E.1

Determination of clearance for frequencies greater than 30 kHz

E.2 Creepage distance



su0622

Figure E.2

Determination of creepage for frequencies greater than 30 kHz

Table E.1
Minimum values of clearances in air at atmospheric pressure for inhomogeneous field conditions (Table 1 of IEC 60664-4)

Peak voltage [a] kV	Clearance mm
≤ 0,6 [b]	0,065
0,8	0,18
1,0	0,5
1,2	1,4
1,4	2,35
1,6	4,0
1,8	6,7
2,0	11,0

[a] For voltages between the values stated in this table, interpolation is permitted.

[b] No data is available for peak voltages less than 0,6 kV.

Table E.2
Minimum values of creepage distances for different frequency ranges (Table 2 of IEC 60664-4)

Peak voltage	Creepage distance [a b] (mm)						
kV	30 kHz < ƒ ≤ 100 kHz	ƒ ≤ 0,2 MHz	ƒ ≤ 0,4 MHz	ƒ ≤ 0,7 MHz	ƒ ≤ 1 MHz	ƒ ≤ 2 MHz	ƒ ≤ 3 MHz
0,1	0,0167						0,3
0,2	0,042					0,15	2,8
0,3	0,083	0,09	0,09	0,09	0,09	0,8	20
0,4	0,125	0,13	0,15	0,19	0,35	4,5	
0,5	0,183	0,19	0,25	0,4	1,5	20	
0,6	0,267	0,27	0,4	0,85	5		
0,7	0,358	0,38	0,68	1,9	20		
0,8	0,45	0,55	1,1	3,8			
0,9	0,525	0,82	1,9	8,7			
1	0,6	1,15	3	18			
1,1	0,683	1,7	5				
1,2	0,85	2,4	8,2				
1,3	1,2	3,5					
1,4	1,65	5					
1,5	2,3	7,3					
1,6	3,15						
1,7	4,4						
1,8	6,1						

[a] The values for the creepage distances in the table apply for pollution degree 1. For pollution degree 2 a multiplication factor of 1,2 and for pollution degree 3 a multiplication factor 1,4 shall be used.

[b] Interpolation between columns is permitted.

Annex F
(informative)

Cross-sections of round conductors

Standard values of cross-section of round copper conductors are shown in Table F.1, which also gives the approximate relationship between ISO metric and AWG/MCM sizes.

Table F.1
Standard cross-sections of round conductors

	AWG/MCM	
ISO cross-section mm^2	Size	Equivalent cross-section mm^2
0,2	24	0,205
–	22	0,324
0,5	20	0,519
0,75	18	0,82
1,0	–	–
1,5	16	1,3
2,5	14	2,1
4,0	12	3,3
6,0	10	5,3
10	8	8,4
16	6	13,3
25	4	21,2
35	2	33,6
50	0	53,5
70	00	67,4
95	000	85,0
–	0000	107,2
120	250 MCM	127
150	300 MCM	152
185	350 MCM	177
240	500 MCM	253
300	600 MCM	304
NOTE The dash, when it appears, counts as a size when considering connecting capacity (see 4.3.8.8.2)		

Annex G
(informative)

Guidelines for RCD compatibility

G.1 Selection of RCD type

Depending on the supply circuitry and the type of RCD (type A, AC or B – see IEC 60755), PDS and RCD/RCM can be compatible or incompatible (see 4.3.10). If circuits which can cause current with a d.c. component to flow in the PROTECTIVE EARTHING CONDUCTOR during normal operation or during failure are not separated from the environment by DOUBLE or REINFORCED INSULATION, it is considered that the PDS itself can cause smooth d.c. current and is therefore incompatible with RCDs of type A and AC.

The flow chart of Figure G.1 will help with the selection of the RCD type when using a PDS downstream of the RCD.

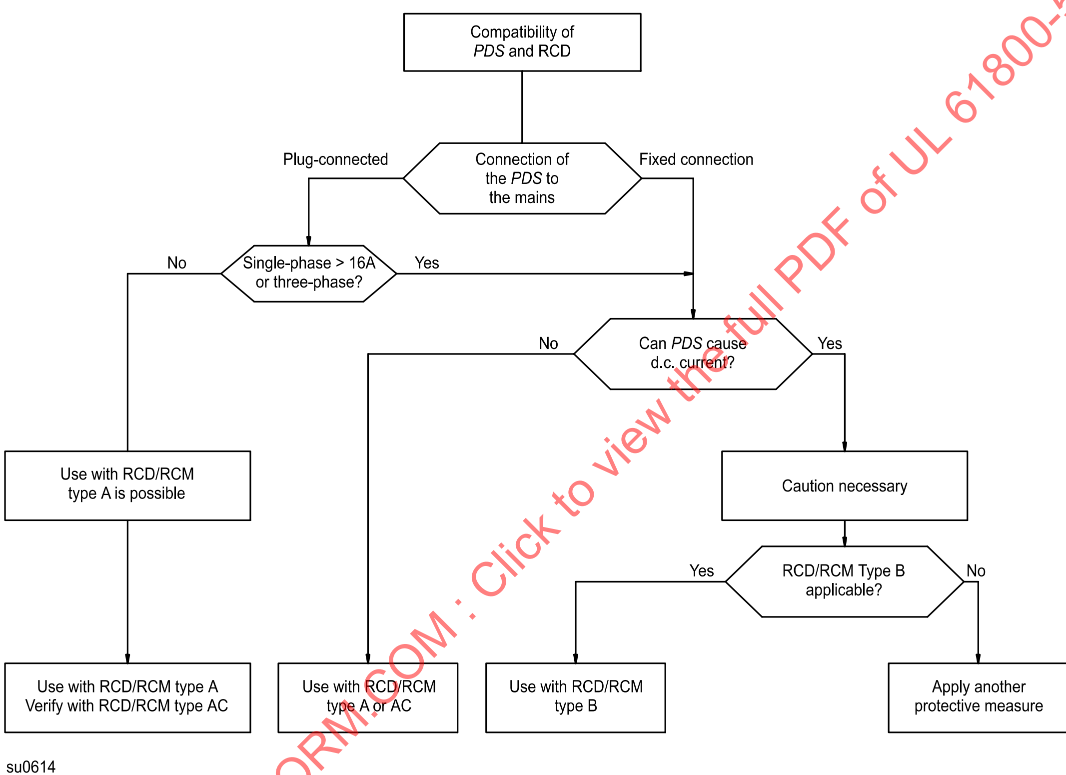
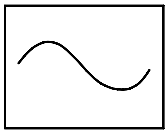


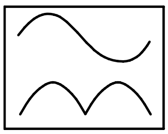
Figure G.1

Flow chart leading to selection of the RCD/RCM type upstream of a PDS

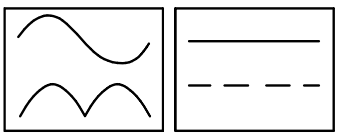
RCDs suitable to be triggered by differing waveforms of residual current are marked with the following symbols, as defined in IEC 60755:



Type AC: - a.c. current sensitive (suitable for circuits 8 and 9 of Figure G.2)



Type A: - a.c. current sensitive and pulse current sensitive (suitable for circuits 1, 4, 5, 8, 9 of Figure G.2)



Type B: - universal current sensitive (suitable for all circuits of Figure G.2)

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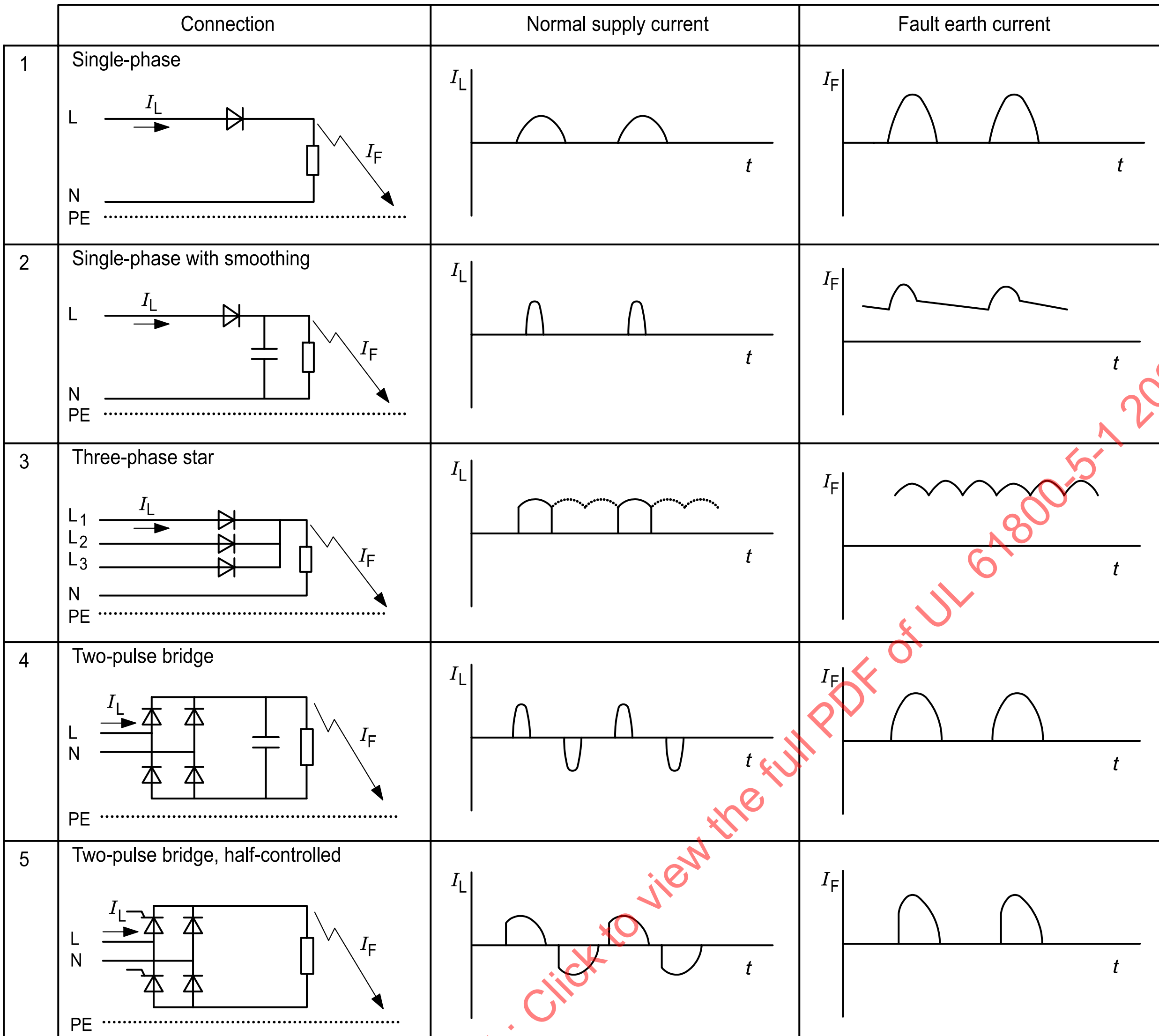
G.2 Fault current waveforms

Figure G.2 shows typical fault current waveforms for different PDS circuit configurations, used to determine RCD compatibility.



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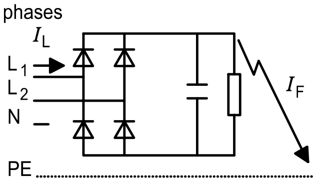
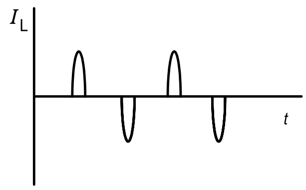
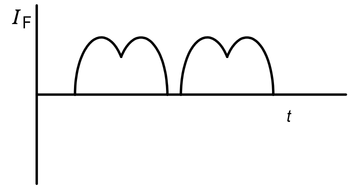
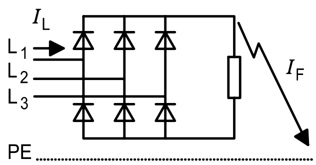
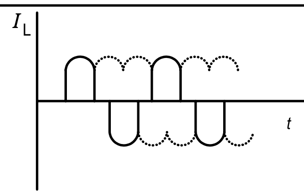
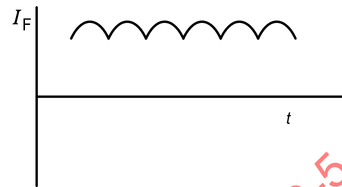
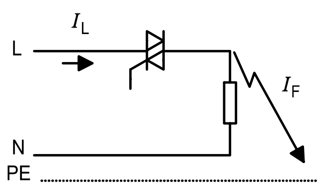
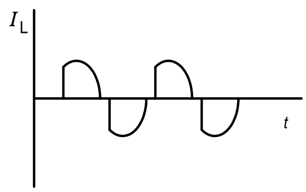
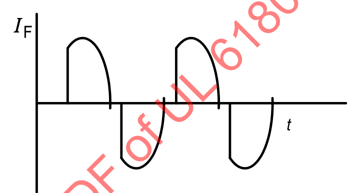
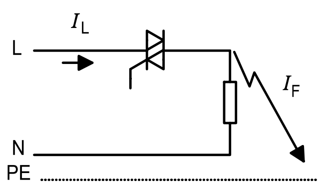
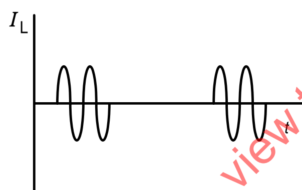
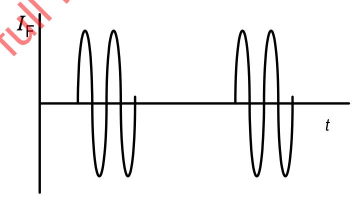
IEC 283/03

Figure G.2

Fault current waveforms in connections with semiconductor devices

(continued)

<table>
<tr><th></th><th>Connection</th><th>Normal supply current</th><th>Fault earth current</th></tr>
<tr><td>6</td><td>Two-pulse bridge between phases

</td><td>
</td><td>
</td></tr>
<tr><td>7</td><td>Six-pulse bridge

</td><td>
</td><td>
</td></tr>
<tr><td>8</td><td>Phase control

</td><td>
</td><td>
</td></tr>
<tr><td>9</td><td>Burst control

</td><td>
</td><td>
</td></tr>
</table>

IEC 1223/07

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Figure G.2

Fault current waveforms in connections with semiconductor devices

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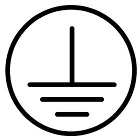
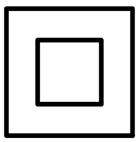
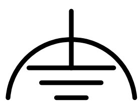
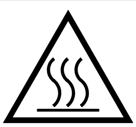
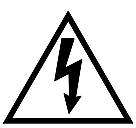
Annex H
(informative)

Symbols referred to in this part of IEC 61800

Table H.1
Symbols used

Symbol	Standard reference	Description	Subclauses
	IEC 60417-5019 (2006-08)	Protective earth; protective ground	6.3.6.6
	IEC 60417-5172 (2003-02)	Class II (double insulated) equipment	6.3.6.6
	IEC 60417-5018 (2006-10)	Functional earthing; functional grounding	6.3.6.6
	ISO 7000-0434 (2004-01)	Caution	6.3.6.7
	IEC 60417-5041 (2000-10)	Caution, hot surface	6.4.3.4
	IEC 60417-5036 (2002-10)	Dangerous voltage	6.5.2

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Annex DVA
(normative)

Normative References and Component Standards

Annex DVA DC ***Addition of new Annex DVA as follows:***

National Electrical Code, ANSI/NFPA 70

Batteries, Lithium – UL 1642

Capacitors – UL 810

Component Connectors for Use in Data, Signal, Control and Power Applications – UL 1977

Controllers, Programmable – Part 2: Equipment Requirements – UL 61131-2

Cords and Cables, Flexible – UL 62

Electrical Analog Instruments – Panel Board Types – UL 1437

Electrical Equipment, Organic Coatings for Steel Enclosures for Outdoor Use – UL 1332

Wires, Cables, and Flexible Cords, Reference Standard for – UL 1581

Enclosure for Electrical Equipment, Non-Environmental Considerations – UL 50

Enclosures for Electrical Equipment, Environmental Considerations – UL 50E

Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors – UL 486E

Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations – UL 1203

Fans, Electric – UL 507

Fittings, Conduit, Tubing, and Cable – UL 514B

Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains – UL 60384-14

Fuseholders – Part 1: General Requirements – UL 4248-1

Fuseholders – Part 4: Class CC – UL 4248-4

Fuseholders – Part 5: Class G – UL 4248-5

Fuseholders – Part 6: Class H – UL 4248-6

Fuseholders – Part 8: Class J – UL 4248-8

Fuseholders – Part 9: Class K – UL 4248-9

Fuseholders – Part 11: Type C (Edison Base) and Type S Plug Fuse – UL 4248-11

Fuseholders – Part 12: Class R – UL 4248-12

Fuseholders – Part 15: Class T – UL 4248-15

Fuses, Low-Voltage – Part 12: Class R Fuses – UL 248-12

Fuses, Low-Voltage – Part 1: General Requirements – UL 248-1

Fuses, Low-Voltage – Part 11: Plug Fuses – UL 248-11

Fuses, Low-Voltage – Part 14: Supplemental Fuses – UL 248-14

Gaskets and Seals – UL 157

Ground-Fault Sensing and Relaying Equipment – UL 1053

Industrial Control Equipment – UL 508

Information Technology Equipment – Safety – Part 1: General Requirements – UL 60950-1

Insulated Winding Wire, Single- and Multi-Layer – UL 2353

Insulation Coordination Including Clearances and Creepage Distance for Electrical Equipment – UL 840

Marking and Labeling Systems – UL 969

Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures – UL 489

Rotating Electrical Machines – General Requirements – UL 1004-1

Motors, Impedance Protected – UL 1004-2

Motors, Thermally Protected – UL 1004-3

Electric Generators – UL 1004-4

Motors, Fire Pump – UL 1004-5

Motors, Servo and Stepper – UL 1004-6

Motors, Electronically Protected – UL 1004-7

Motors, Inverter Duty – UL 1004-8

Motors, Overheating Protection for – UL 2111

Optical Isolators – 1577

Plastic Materials for Parts in Devices and Appliances, Tests for Flammability of – UL 94

Plugs, Receptacles, and Cable Connectors of the Pin and Sleeve Type – UL 1682

Power Units, Class 2 – UL 1310

Polymeric Materials – Long Term Property Evaluations – UL 746B

Polymeric Materials – Short Term Property Evaluations – UL 746A

Polymeric Materials – Use in Electrical Equipment Evaluations – UL 746C

Power Units Other Than Class 2 – UL 1012

Printed Wiring Boards – UL 796

Protectors, Supplementary, for Use in Electrical Equipment – UL 1077

Semiconductor Devices, Electrically Isolated – UL 1557

Service Equipment, Reference Standard for – UL 869A

Speed Controls, Solid-State Fans – UL 1917

Surge Protective Devices – UL 1449

Switches, Clock-Operated – UL 917

Switches, Enclosed and Dead-Front – UL 98

Switchgear and Controlgear, Low-Voltage – Part 1: General Rules – UL 60947-1

Switchgear and Controlgear, Low-Voltage – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters – UL 60947-4-1

Switchgear and Controlgear, Low-Voltage – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches – UL 60947-5-2

Systems of Insulating Materials – General – UL 1446

Temperature-Indicating and -Regulating Equipment – UL 873

Terminal Blocks – UL 1059

Terminals, Electrical Quick-Connect – UL 310

Thermistor-Type Devices – UL 1434

Transformers, Low-Voltage – Part 1: General Requirements – UL 5085-1

Transformers, Low-Voltage – Part 2: General Purpose Transformers – UL 5085-2

Transformers, Low-voltage – Part 3: Class 2 and Class 3 Transformers – UL 5085-3

Transformers, Specialty – UL 506

Wire Connectors – UL 486A-486B

Wires and Cables, Machine Tool – UL 1063

Wires and Cables, Thermoplastic-Insulated – UL 83

Annex DVB
(normative)

IEC to USA Standard References

Annex DVB D2 ***Addition of new Annex DVB as follows:***

DVB.1 In the USA, the following IEC normative reference standards do not apply.

Table DVB.1

IEC Standard Title	IEC Standard Number
Environmental testing – Part 2: Tests – Test Ca: Damp heat, steady state	IEC 60068-2-3:1969
Insulation co-ordination – Part 1: Definitions, principles and rules	IEC 60071-1:1993
Coding of indicating devices and actuators by colours and supplementary means	IEC 60073:1991
Graphical symbols for use on equipment – Part 2: Symbol originals	IEC 60417-2:1998
Low-voltage switchgear and controlgear assemblies – Part 1: Type-tested and partially type-tested assemblies	IEC 60439-1:1992
Identification of equipment terminals and of terminations of certain designated conductors, including general rules of an alphanumeric system	IEC 60445:1988
Man-machine interface (MM) - Actuating principles	IEC 60447:1993
Classification of electrical and electronic equipment with regard to protection against electric shock - Part 2: Guidelines to requirements for protection against electric shock	IEC 60536-2:1992
Graphical symbols for diagrams – Part 7: Switchgear, controlgear and protective devices	IEC 60617-7:1983
Connecting devices for low-voltage circuits for household and similar purposes – Part 1: General requirements	IEC 60998-1:1990
Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 2: Electrostatic discharge immunity test – Basic EMC publication	IEC 61000-4-2:1995
Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 3: Radiated, radio-frequency, electromagnetic field immunity test	IEC 61000-4-3:1995
Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical test transient/burst immunity test – Basic EMC publication	IEC 61000-4-4:1995
Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 5: Surge immunity test	IEC 61000-4-5:1995
Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment	CISPR 11:1990
Limits and methods of measurement of radio disturbance characteristics of information technology equipment	CISPR 22: 1993

DVB.2 In the USA, the following IEC normative references are replaced by the indicated USA Standard.

Table DVB.2

IEC Standard Title	IEC Standard Number	USA Standard Title	USA Standard Number
High-voltage test techniques	IEC 60060	Techniques for High-Voltage Testing	ANSI / IEEE 4
Thermal evaluation and classification of electrical insulation	IEC 60085:1984	Systems of Insulating Materials – General	UL 1446
Surge arresters – Part 1: Non-linear resistor type gapped surge arresters for a.c. systems	IEC 60099-1:1991	Metal-Oxide Surge Arrestors for AC Power Circuits	ANSI/IEEE C62.11
		Gapped Silicon-Carbide Surge Arrestors for AC Power Circuits	IEEE C62.1
		Surge Protective Devices	UL 1449
Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions	IEC 60112:1979	Polymeric Materials – Short Term Property Evaluations	UL 746A
		Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Guide for the determination of thermal endurance properties of electrical insulating materials	IEC 60216	Polymeric Materials – Long Term Property Evaluations	UL 746B
Low-voltage fuses – Part 1: General requirements	IEC 60269-1:1986	Low-Voltage Fuses – Part 1: General Requirements	UL 248-1
Low-voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application)	IEC 60269-2:1986	Low Voltage Fuses – Part 4: Class CC Fuses	UL 248-4
		Low Voltage Fuses – Part 5: Class G Fuses	UL 248-5
		Low Voltage Fuses – Part 6: Class H Non-Renewable Fuses	UL 248-6
		Low Voltage Fuses – Part 7: Class H Renewable Fuses	UL 248-7
		Low Voltage Fuses – Part 8: Class J Fuses	UL 248-8
		Low Voltage Fuses – Part 9: Class K Fuses	UL 248-9
		Low Voltage Fuses – Part 10: Class L Fuses	UL 248-10
		Low Voltage Fuses – Part 11: Plug Fuses	UL 248-11
		Low Voltage Fuses – Part 12: Class R Fuses	UL 248-12
		Low Voltage Fuses – Part 13: Semiconductor Fuses	UL 248-13
		Low Voltage Fuses – Part 14: Supplemental Fuses	UL 248-14

Table DVB.2 Continued on Next Page

Table DVB.2 Continued

IEC Standard Title	IEC Standard Number	USA Standard Title	USA Standard Number
		Low Voltage Fuses – Part 15: Class T Fuses	UL 248-15
		Low-Voltage Fuses – Part 17: Class CF Fuses	UL 248-17
Electrical installations of buildings – Part 4: Protection for safety – Chapter 44: Protection against overvoltages – Section 443: Protection against overvoltages of atmospheric origin or due to switching	IEC 60364-4-443:1990	National Electrical Code	ANSI/NFPA 70
Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests – Basic safety publication	IEC 60664-1:1992	Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment	UL 840
Fire hazard testing – Part 2: Test methods – Section 1/sheet 0: Glow-wire test methods – General	IEC 60695-2-1/0:1994	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Fire hazard testing – Part 2: Test methods – Section 1/sheet 1: Glow-wire end-product test and guidance	IEC 60695-2-1/1:1994	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Fire hazard testing – Part 2: Test methods – Section 1/sheet 2: Glow-wire flammability test on materials	IEC 60695-2-1/2: 1994	Plymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Fire hazard testing – Part 2: Test methods – Section 1/sheet 3: Glow-wire ignitability test on materials	IEC 60695-2-1/3:1994	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Fire hazard testing – Part 2: Test methods – Section 2: Needle-flame test	IEC 60695-2-2:1991	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Methods of test for the determination of the flammability of solid electrical insulating materials when exposed to an igniting source	IEC 60707:1981	Test for Flammability of Plastic Materials for Parts in Devices and Appliances	UL 94
Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices	IEC 60947-5-1:1997	Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices	UL 60947-5-1
Extra-heavy duty rigid steel conduits for electrical installations	IEC 60981: 1989	Electrical Rigid Metal Conduit – Steel	UL 6

Annex DVC
(normative)

Isolated Secondary Circuits and Circuits Supplied by Battery

Annex DVC D2 ***Addition of new Annex DVC as follows:***

DVC.1 Isolated Secondary Circuits

DVC.1.1 General

DVC.1.1.1 An isolated secondary circuit is a CONTROL CIRCUIT that is isolated at all points from the primary branch circuit. This isolation shall be provided by means such as a transformer, optical isolator, limiting impedance, or electro-mechanical relay.

DVC.1.1.2 An isolated secondary circuit shall comply with the following: 1) Separation of Circuits, DVC.1.1.3, 2) a.c. or d.c. voltage test of 5.2.3.2, and 3) the applicable requirements for one of the following types of isolated secondary circuits:

a) A Class 2 circuit, see DVC.1.4 and Table DVC.1; or

b) A Limited Voltage/Current circuit, see DVC.1.5 and Table DVC.1; or

c) A Limited Energy circuit, see DVC.1.6 and Table DVC.1; or

d) A Limiting Impedance circuit, see DVC.1.7and Table DVC.1; or

e) A Limited Voltage circuit, see DVC.1.8 and Table DVC.1; or

f) An Isolated Power Supply circuit, see DVC.1.9 and Table DVC.1.

Table DVC.1
Secondary Circuits, Differences in Evaluation

Clause		Type of Isolated Secondary Circuit								
		Class 2	Limited voltage / current	Limited energy		Limited impedance			Limited voltage	Isolated power supply
DVC.1.2	Risk of electric shock present in circuit?	No	No	No	Yes	No	No	Yes	No	Yes
DVC.1.3	Risk of thermal hazard present in circuit?	No	No	Yes	Yes	No	No	No	Yes	Yes
Electrical Characteristics of Isolated Secondary Source (ISC)										
DVC.1.4 – DVC.1.9	Maximum Voltage, ac	b	30	30	100	–	30	–	30	150
	Maximum voltage, peak	b	42.4	42.4	–	–	42.4	–	42.4	–
	Max. secondary current, A	b	8	–	–	0.005[a]	–	–	–	–
	Max. secondary power, VA	b	100	200	200	15 W	15 W	15 W	–	10k
Component Requirements within isolated Secondary Circuit (ICS)										
4.3.6.8.4	Printed Wiring Boards	–	–	c	c	–	–	–	c	x
4.3.8	Internal wiring	–	–	x	x	–	–	–	x	x
	All other components	d	d	d	d	d	d	d	d	d
Spacing Requirements for Isolated Secondary Circuit (ISC)										
4.3	Within ISC	–	–	–	–	–	–	–	–	–
	Between ISC and ground	–	–	–	x	–	e	x	–	e

Table DVC.1 Continued on Next Page

Table DVC.1 Continued

Clause		Type of Isolated Secondary Circuit								
		Class 2	Limited voltage / current	Limited energy		Limited impedance			Limited voltage	Isolated power supply
	Between ISC and enclosure or accessible parts	–	–	–	x	–	e	x	–	e
	Between ISC and other isolated circuits	x	x	x	x	x	x	x	x	x
Protection Against Direct Contact										
4.3.3	ISC requires protection against direct contact	–	–	x	x	–	–	x	x	x
Performance Requirements[f]										
Isolating Source (Such as: Transformer, Power Supply. Limiting Impedance, Battery):										
DVC.2	Secondary circuit	b	DVC.2.2	DVC.2.3	DVC.2.3	DVC.2.4	DVC.2.4	DVC.2.4	DVC.2.5	DVC.2.6
5.2.3.8	Temperature	d	d	d	d	d	d	d	d	d
5.2.3.6.4	Breakdown of components	b	x	x	x	x	x	x	x	x

NOTE – “x” indicates the requirement applies whereas “–” indicates the requirement does not apply.

[a] See DVC.1.2(b).

[b] See the Standard for Class 2 Power Units, UL 1310 or the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3, for maximum electrical characteristics and performance requirements.

[c] Printed wiring boards shall comply with the Standard for Printed-Wiring Boards, UL 796, and shall be rated V-2, V-1 or V-0.

[d] No evaluation required except the effect of heat generating compounds components in the isolated secondary circuit on adjacent components such as printed wiring boards and wiring shall be evaluated during the temperature test.

[e] See DVC.1.9.3 and DVC.1.9.4.

[f] Tests specified in this table evaluates isolating components for use with secondary circuits and does not indicate all tests applicable to the isolating components.

DVC.1.1.3 Separation of circuits

DVC.1.1.3.1 Factory installed isolated secondary circuits shall be separated from all other circuits in accordance with DVC.1.1.3.2. Insulated conductors shall be separated from wiring and uninsulated LIVE PARTS connected to other circuits. Wiring and components provided with insulation rated for the highest voltage involved are considered to be separated from each other.

DVC.1.1.3.2 Separation of insulated conductors shall be accomplished by clamping, routing, or equivalent means that provides permanent separation from insulated or uninsulated LIVE PARTS of a different circuit.

DVC.1.1.3.3 A permanent barrier shall be provided to separate field installed Class 2 conductors of secondary circuits from all other circuits.

DVC.1.1.3.4 A permanent barrier is not required when Class 1 or power conductors introduced solely to connect to equipment connected to a Class 2 circuit and:

a) Provision has been made to route the Class 1 or power circuit conductors to maintain a minimum 1/4-in (6,35-mm) separation from the conductors of the Class 2 circuit; or

b) The Class 1 or power circuit conductors operate at 150 V or less to ground and also comply with one of the following:

1) Provision has been made to enable the Class 2 circuits to be installed using Types CL3, CL3R, CL3P, or equivalent cables, and the cable conductors extending beyond the jacket can be separated by a minimum of 1/4 in (6,35 mm) or by a nonconductive sleeve or nonconductive barrier from all other conductors; or

2) The Class 2 conductors are required to be installed as a Class 1 circuit in accordance with Section 725-21 of the National Electrical Code, ANSI/ NFPA 70.

DVC.1.1.3.5 The permanent barrier in DVC.1.1.3.3 is not required for enclosures having provision for only one opening, when INSTALLATION instructions are provided that state conductors of Class 2 circuits shall be separated from conductors for Class 1 or power circuits by a continuous and firmly fixed type nonconductor, such as flexible tubing.

DVC.1.1.3.6 Where a permanent barrier is not provided, INSTALLATION instructions shall be provided to explain the wiring methods to comply with either or both of DVC.1.1.3.4 and DVC.1.1.3.5, as applicable.

DVC.1.1.3.7 Field and factory installed conductors of two or more Class 2 circuits are able to be routed within the same cable, enclosure, or raceway.

DVC.1.2 Risk of electric shock

A risk of electric shock exists within a circuit unless that circuit meets one of the following criteria:

a) The circuit is supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30V ac or 42,4 V peak; or

b) The circuit is supplied by an isolating source such that the current available through a 1 500 Ω resistor connected across any potential in the circuit (including to ground) does not exceed 5 mA.

DVC.1.3 Risk of thermal hazard

A risk of thermal hazard exists within a circuit unless that circuit meets one of the following criteria:

a) The circuit is supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30V ac or 42,4 V peak and the current available is limited to a value not exceeding 8 A measured after 1 min of operation; or

b) The circuit is supplied by an isolating source such that the power available to the circuit is limited to a value less than 15 W.

DVC.1.4 Class 2 circuits

A Class 2 circuit shall be supplied by an isolating source that complies with the requirements in the Standard for Class 2 Power Units, UL 1310, or the requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

DVC.1.5 Limited voltage/current circuit requirements

DVC.1.5.1 A Limited Voltage/Current circuit shall be supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30V ac or 42,4V peak and the current available is limited to a value not exceeding 8 A measured after 1 min of operation under any condition of loading to achieve the maximum current.

DVC.1.5.2 An isolating power supply or an isolating type transformer, tested in accordance with DVC.2.2, is able to be used to comply with this requirement. For a device that is intended to be supplied by an isolating source that complies with this requirement and that is intended to be supplied as an accessory in the field, the device shall be marked as in 6.3.6.8DV.1 through 6.3.6.8DV.1.4.

DVC.1.5.3 A secondary fuse or other such secondary circuit protective device used with an isolating source to limit the available current in accordance with DVC.1.5.1 shall be rated at not more than five amperes for secondary voltages less than or equal 20 V (peak); or 100/V A for secondary voltages over 20V and less than 30V (peak), where V is the peak open circuit voltage.

DVC.1.5.4 When a secondary fuse complying with DVC.1.5.3 and UL 248 series of standards is used, the test specified in DVC.2.2 is not required.

DVC.1.5.5 Protective devices other than those described in DVC.1.5.4 and protective devices with higher ratings than described in DVC.1.5.3 may be used if the combination of isolating source and protective device is evaluated as in DVC.2.2.

DVC.1.5.6 When the protective device complying with DVC.1.5.4 and isolating source are intended to be supplied in the field, the PDS/CDM/BDM shall be provided with INSTALLATION instructions in accordance with 6.2DV.3.1.3.

DVC.1.5.7 When the protective device and isolating source that have been found to comply with DVC.1.5.5 are intended to be supplied in the field, the PDS/CDM/BDM shall be provided with instructions or markings as required in 6.3.6.8DV.1 through 6.3.6.8DV.1.4.

DVC.1.5.8 The secondary circuit protective device is able to be provided in the primary circuit. When provided in the primary circuit, there are no restrictions on the current rating of the protective device as long as it limits the available secondary current in accordance with DVC.1.5.3.

DVC.1.5.9 When a protective device is used as specified in DVC.1.5.3 or DVC.1.5.8, this protective device shall comply with the requirements of this standard and shall be provided with an adjacent replacement marking in accordance with 6.3.7DV.1.1 or replacement instructions that includes the required voltage and current rating. The printed wiring board, wiring, and spacings prior to the point at which the voltage and current are limited shall comply with the primary circuit requirements of this standard.

DVC.1.5.10 A fixed impedance (such as a component or grouping of components in the same circuit) or a regulating network (such as used in a switching type power supply) that is used to limit the voltage and/or the available current shall comply with DVC.1.5.1. Such a fixed impedance or regulating network shall be able to function under single component fault conditions.

DVC.1.6 Limited energy circuit requirements

DVC.1.6.1 A limited energy circuit shall be supplied by an isolating source such that the maximum volt-ampere capacity available to the circuit is 200 VA or less at a maximum open circuit voltage potential of 100 V ac. The isolating source shall comply with the test described in DVC.2.3. For a device (circuit) that is intended to be supplied by an isolating source that complies with this requirement and that is intended to be supplied as an accessory in the field, the device shall be marked as in 6.3.6.8DV.

DVC.1.6.2 A primary or secondary circuit fuse or other such circuit protective device may be used to limit the maximum available volt-ampere capacity in accordance with DVC.1.6.1. There are no restrictions on the current rating of this protective device as long as it limits the available secondary volt-ampere limit in accordance with DVC.1.6.1 The protective device shall comply with the requirements of this standard and there shall be a marking in accordance with 6.3.7DV.1.1.

DVC.1.7 Limiting impedance circuit requirements

DVC.1.7.1 A limiting impedance circuit relied upon to reduce the risk of thermal hazard as defined in DVC.1.3 shall be supplied by an impedance that complies with one the following:

a) The calculated power dissipation of the impedance, as the result of a direct short applied across the circuit limited by the impedance, does not exceed the power rating of the impedance and the power dissipation is less than 15 W; or

b) The impedance shall:

1) Be rated such that the calculated power dissipation of the impedance, as the result of a direct short applied across the circuit limited by the impedance, exceeds the power rating of the impedance and is still less than 15 W; and

2) Not open or short when subjected to the effects of a direct short applied across the circuit limited by the impedance as described in DVC.2.4.1.1.

DVC.1.7.2 The 15-W power limitation of the impedance shall not be exceeded under single component fault conditions.

DVC.1.7.3 When the circuit limited by the 15-W impedance is completely enclosed without ventilation openings, the effect of single component fault conditions is not evaluated.

DVC.1.7.4 A limiting impedance, relied upon to reduce the risk of electric shock as defined in DVC.1.2, shall comply with DVC.1.7.2, DVC.1.7.6 and DVC.2.4.1.2 and one of the following:

a) The limiting impedance is connected to the high potential side of or as a voltage divider across a grounded single phase supply voltage rated not more than 150V and serves to limit the voltage within the isolated secondary circuit to be less than 30V rms or 42,4V peak within the isolated secondary circuit and also with respect to ground as determined by circuit analysis;

b) The limiting impedance is connected to each of two ungrounded supply voltage lines from a 120/240V supply or two or three ungrounded supply voltage lines from a three phase supply and serves to limit the voltage within the isolated secondary circuit to be less than 30V rms or 42,4V peak within the isolated secondary circuit and also with respect to ground as determined by circuit analysis; or the circuit shall be evaluated for voltage to ground present while connected to any primary voltage system supplying the equipment.

DVC.1.7.5 A secondary circuit supplied from a limiting impedance circuit that complies with DVC.1.7.1 and does not comply with DVC.1.7.4 shall be insulated from or have spacings to grounded metal or accessible parts.

DVC.1.7.6 The secondary circuit described in DVC.1.7.5 may have field wiring connections only if both:

a) The PDS/CDM/BDM is marked with the maximum voltage to ground that is able to be present on the field wiring connections from secondary circuit; and

b) The circuit complies with the test in DVC.2.4 when preformed between each of the field wiring terminals, of the limiting impedance circuit, to ground.

DVC.1.7.7 Where a limiting impedance is relied upon to reduce the risk of electric shock as in DVC.1.2, no individual element shall experience an electrical stress factor:

a) Greater than 0,5 during all conditions of normal operation; or

b) Greater than 1,0 after single component failure with respect to RATED VOLTAGE, current and dissipated wattage.

The electrical stress factor is defined as ratio of applied electrical characteristic to rated electrical characteristic, such as the ratio between the applied current and the rated ampacity of a component.

DVC.1.8 Limited voltage circuits

DVC.1.8.1 A limited voltage circuit shall be supplied by an isolating source that complies with the following:

a) The maximum open circuit voltage potential available to the circuit shall not be more than 30 V ac or 42,4 V peak without any limitation on the available current or volt-ampere capacity;

b) All external secondary-circuit interconnecting cables and all secondary-circuit wiring between units shall be protected against burnout and damage to the insulation resulting from any overload or short-circuit condition that is able to occur during use of the equipment. Overcurrent protection shall be provided in the secondary circuit and comply with Table 4.3.8.1DV.2, or the isolated secondary circuit shall comply with the secondary circuit test of DVC.2.5. Overcurrent protection provided in the primary circuit of the isolating source is able to serve as

protection for the secondary circuit when it complies with 4.3.14DV.1.2.1 or the secondary circuit test of DVC.2.5; and

c) These circuits are intended for use in a pollution degree 2 environment.

DVC.1.8.2 When the protective device, that complies with Table 4.3.8.1DV.2, and isolating source are intended to be supplied in the field, the device shall be marked in accordance with 6.2DV.3.1.3.

DVC.1.8.3 When the protective device and isolating source, that have been found to comply with DVC.2.5, are intended to be supplied in the field, the device shall be marked in accordance with 6.3.6.8DV.

DVC.1.9 Isolated power supply circuits

DVC.1.9.1 An isolated power supply circuit shall be supplied from the secondary of an isolating source that complies with DVC.2.6.

DVC.1.9.2 An Isolated power supply circuit shall limit surge voltage in the secondary to no more than 300 V peak when the input terminals of the PDS/CDM/BDM are subjected to a single 1,2 x 50 uS full-wave impulse with a crest value of 5 kV using a test generator with an effective internal impedance of 12 Ω. All power input terminals shall be connected together and the impulse shall be applied between this connection and ground. The equipment shall be operative at the conclusion of the test.

DVC.1.9.3 For circuits rated more than 50 V, clearances and creepage distances shall not be less than 1/8 in (3,2 mm), between LIVE PARTS of the secondary circuit and operator-accessible metal, or grounded dead metal including the enclosure. For secondary circuits rated 50 volts or less, these clearances and creepage distances shall not be less than 1/16 in (1,6 mm).

DVC.1.9.4 When spacings are less than 1/8 in (3,2 mm), the construction shall withstand, without breakdown or arc-over the application of an ac potential of twice the RATED VOLTAGE plus 1000 V (or a dc potential of 1,4 times the sum of twice the RATED VOLTAGE plus 1000 V) for 60 s between the secondary and accessible or grounded noncurrent carrying metal parts. During the test any component normally connected to ground is to be disconnected.

DVC.2 Secondary Circuits Test

DVC.2.1 General

DVC.2.1.1 Unless otherwise specified, the test measurements are to be made as follows:

a) The primary voltage supplied to the isolating source shall be not less than the operational voltage applied to the primary when the PDS/CDM/BDM is supplied at the maximum RATED VOLTAGE including any published positive tolerance, but not less than as specified in 5.2DV.1. For an isolating source with multiple primary voltage ratings, the highest voltage rating shall be used for this test. Overcurrent protective devices in the branch circuit shall not open as a result of this test.

b) The maximum open circuit voltage potential available to the secondary circuit under consideration is to be measured directly across the output terminals of the isolating source.

c) For an isolating source with multiple secondary circuits, only one secondary circuit is to be tested at a time. All other secondaries not under test are not required to be connected to a load.

d) The applicable voltage, current and volt-ampere capacity measurements shall be made directly across the secondary output terminals of the isolating source. When a tapped transformer winding is used to supply a full-wave rectifier, the measurements are to be made from either end of the winding to the tap. When the transformer is used as part of a switching-type power supply, the measurements are to be made after the transformer secondary winding rectification means.

DVC.2.2 Limited voltage/current secondary test

DVC.2.2.1 With the isolating source connected as described in DVC.2.1.1, the open circuit voltage of each secondary shall not exceed 30V rms or 42,4 V peak and the available current in the secondary shall not exceed 8 A after the 1 min test interval as described in DVC.2.2.2.

DVC.2.2.2 The current available to the secondary circuit under evaluation is to be measured by connecting a variable resistive load across the source of that secondary and then continually monitor and adjust the load as necessary to maintain a secondary current that is slightly more than 8 A during the 1 min test interval. When an available current of more than 8 A is not able to be obtained under any condition of loading, up to and including a short circuit, then the test is to be discontinued for that circuit.

DVC.2.3 Limited energy secondary test

DVC.2.3.1 With the isolating source connected as in DVC.2.1.1, the open circuit voltage of the secondary shall not exceed 100 V and the calculated volt-ampere capacity described in DVC.2.3.2 shall not exceed 200 VA.

DVC.2.3.2 The maximum volt-ampere capacity available to the secondary circuit under consideration is to be measured by connecting a variable resistive load across the source of that secondary and then measuring the voltage and current while linerarly varying the resistive load from open-circuit to short circuit during a time of no less than 1,5 min and no more than 2,5 min. The maximum available volt-ampere capacity is calculated by multiplying the simultaneously measured values of secondary voltage and secondary current. The measured values shall be obtained at least once every 0,5 s. An overcurrent protective device is permitted to operate prior to reducing the resistive load to simulate short circuit conditions. If the overcurrent protective device operates prior to 1,5 min then the volt-amperes shall also be calculated with the secondary circuit loaded so that the current through the overcurrent protective device equals its overcurrent rating.

DVC.2.4 Limiting impedance test

DVC.2.4.1 Limiting impedance abnormal test

DVC.2.4.1.1 The following test shall be performed to determine compliance with DVC.1.7.1(b). With the isolating source connected as in DVC.2.1.1, a limiting impedance shall not emit molten metal or flames or ignite cotton loosely placed over all openings of ventilated equipment or totally around OPEN TYPE equipment when the secondary of the limiting impedance is short circuited. Additional trials of this test shall be performed under single component fault conditions described in DVC.2.4.1.3.

DVC.2.4.1.2 The following test shall be performed to determine compliance with DVC.1.7.4. With the limiting impedance connected as in DVC.2.1.1, a 1500-Ω resistor is connected between the limiting impedance and ground. As a result of the test, the current measured through the 1500-Ω resistor shall not exceed 5 mA. Additional trials of this test shall be performed under single component fault conditions described in DVC.2.4.1.3.

DVC.2.4.1.3 Single component fault conditions of a circuit component of a limiting impedance include: