

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Low-voltage electrical installations –
Part 4-44: Protection for safety – Protection against voltage disturbances and
electromagnetic disturbances**

**Installations électriques à basse tension –
Partie 4-44: Protection pour assurer la sécurité – Protection contre les
perturbations de tension et les perturbations électromagnétiques**

<https://standards.iteh.ai/catalog/standards/iec/1f91dcf3-83f0-47a7-97b8-d77b26f641ab/iec-60364-4-44-2007>



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2015 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

More than 60 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue

Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 15 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary

Plus de 60 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.



IEC 60364-4-44

Edition 2.1 2015-09
CONSOLIDATED VERSION

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Low-voltage electrical installations –
Part 4-44: Protection for safety – Protection against voltage disturbances and
electromagnetic disturbances**

**Installations électriques à basse tension –
Partie 4-44: Protection pour assurer la sécurité – Protection contre les
perturbations de tension et les perturbations électromagnétiques**

<https://standards.iteh.ai/catalog/standards/iec/1f91dcf3-83f0-47a7-97b8-d77b26f641ab/iec-60364-4-44-2007>

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 33.100.10; 33.100.20; 91.140.50

ISBN 978-2-8322-2916-3

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

REDLINE VERSION

VERSION REDLINE



**Low-voltage electrical installations –
Part 4-44: Protection for safety – Protection against voltage disturbances and
electromagnetic disturbances**

**Installations électriques à basse tension –
Partie 4-44: Protection pour assurer la sécurité – Protection contre les
perturbations de tension et les perturbations électromagnétiques**

<https://standards.iteh.ai/catalog/standards/iec/1f91dcf3-83f0-47a7-97b8-d77b26f641ab/iec-60364-4-44-2007>

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
440.1 Scope.....	8
440.2 Normative references.....	8
441 (Vacant).....	9
442 Protection of low-voltage installations against temporary overvoltages due to earth faults in the high-voltage system and due to faults in the low-voltage system	9
442.1 Field of application.....	9
442.1.1 General requirements.....	10
442.1.2 Symbols.....	10
442.2 Overvoltages in LV-systems during a high-voltage earth fault	11
442.2.1 Magnitude and duration of power-frequency fault voltage.....	12
442.2.2 Magnitude and duration of power-frequency stress voltages.....	13
442.2.3 Requirements for calculation of limits	14
442.3 Power-frequency stress voltage in case of loss of the neutral conductor in a TN and TT system	14
442.4 Power-frequency stress voltage in the event of an earth fault in an IT system with distributed neutral	14
442.5 Power-frequency stress voltage in the event of a short-circuit between a line conductor and the neutral conductor	15
443 Protection against transient overvoltages of atmospheric origin or due to switching.....	15
443.1 General	15
443.2 Classification of impulse withstand voltages (overvoltage categories).....	15
443.2.1 Purpose of classification of impulse withstand voltages (overvoltage categories).....	15
443.2 Void.....	16
443.3 Arrangements for overvoltage control.....	16
443.3.1 Inherent overvoltage control.....	16
443.3.2 Protective overvoltage control.....	16
443.3 Terms and definitions.....	16
443.4 Required impulse withstand voltage of equipment.....	16
443.4 Overvoltage control.....	17
443.5 Risk assessment method	17
443.6 Classification of rated impulse voltages (overvoltage categories).....	19
443.6.1 Purpose of classification of rated impulse voltages (overvoltage categories).....	19
443.6.2 Relationship between impulse withstand Rated impulse voltages of equipment and overvoltage categories.....	20
444 Measures against electromagnetic influences	23
444.1 General	23
444.2 (void).....	24
444.3 Definitions	24
444.4 Mitigation of electromagnetic interference (EMI).....	25
444.4.1 Sources of EMI.....	25
444.4.2 Measures to reduce EMI.....	25
444.4.3 TN-system	27
444.4.4 TT system.....	31

444.4.5	IT system	32
444.4.6	Multiple-source supply.....	33
444.4.7	Transfer of supply	36
444.4.8	Services entering a building.....	38
444.4.9	Separate buildings.....	39
444.4.10	Inside buildings	39
444.4.11	Protective devices	41
444.4.12	Signal cables.....	41
444.5	Earthing and equipotential bonding.....	41
444.5.1	Interconnection of earth electrodes.....	41
444.5.2	Interconnection of incoming networks and earthing arrangements.....	42
444.5.3	Different structures for the network of equipotential conductors and earthing conductors.....	42
444.5.4	Equipotential bonding networks in buildings with several floors	44
444.5.5	Functional earthing conductor.....	45
444.5.6	Commercial or industrial buildings containing significant amounts of information technology equipment.....	46
444.5.7	Earthing arrangements and equipotential bonding of information technology installations for functional purposes	46
444.6	Segregation of circuits	47
444.6.1	General.....	47
444.6.2	Design guidelines	47
444.6.3	Installation guidelines.....	48
444.7	Cable management systems	49
444.7.1	General.....	49
444.7.2	Design guidelines.....	49
444.7.3	Installation guidelines.....	50
445	Protection against undervoltage	52
445.1	General requirements	52
Annex A (informative) Explanatory notes concerning 442.1 and 442.2.....		
Annex A (informative) Examples of calculated risk level CRL for the use of SPDs.....		55
Annex B (informative) Guidance for on overvoltage control by SPDs applied to overhead lines		57
Annex C (normative) Determination of the conventional length, d.....		
Annex C (informative) List of notes concerning certain countries.....		61
Bibliography.....		63
Figure 44.A1 – Representative schematic sketch for possible connections to earth in substation and LV-installation and occurring overvoltages in case of faults		11
Figure 44.A2 – Tolerable fault voltage due to an earth-fault in the HV system		13
Figure 443.1 – Illustration of an installation showing the lengths to consider		19
Figure 44.R1 – By-pass conductor for screen reinforcement to provide a common equipotential bonding system		26
Figure 44.R2 – Example of a substitute or by-pass equipotential bonding conductor in a TT-system.....		27
Figure 44.R3A – Avoidance of neutral conductor currents in a bonded structure by using the TN-S system from the origin of the public supply up to and including the final circuit within a building		28

Figure 44.R3B – Avoidance of neutral conductor currents in a bonded structure by using a TN-S system downstream of a consumer’s private supply transformer	29
Figure 44.R4 – TN-C-S system within an existing building installation	30
Figure 44.R5 – TT system within a building installation	31
Figure 44.R6 – IT system within a building installation	32
Figure 44.R7A – TN multiple-source power supply with a non-suitable multiple connection between PEN and earth	33
Figure 44.R7B – TN multiple source power supplies to an installation with connection to earth of the star points at one and the same point	34
Figure 44.R8 – TT multiple-source power supplies to an installation with connection to earth of the star points at one and the same point	35
Figure 44.R9A – Three-phase alternative power supply with a 4-pole switch	36
Figure 44.R9B – Neutral current flow in a three-phase alternative power supply with an unsuitable 3-pole switch	37
Figure 44.R9C – Single-phase alternative power supply with 2-pole switch.....	38
Figure 44.R10 – Armoured cables and metal pipes entering the buildings (examples)	39
Figure 44.R11 – Illustration of measures in an existing building	40
Figure 44.R12 – Interconnected earth electrodes	41
Figure 44.R13 – Examples of protective conductors in star network	42
Figure 44.R14 – Example of multiple meshed bonding star network	43
Figure 44.R15 – Example of a common meshed bonding star network	44
Figure 44.R16 – Example of equipotential bonding networks in structures without lightning protection systems	45
Figure 44.R17A – Separation between power and information technology cables for cable route lengths ≤ 35 m	48
Figure 44.R17B – Separation between power and information technology cables for cable route lengths > 35 m	48
Figure 44.R18 – Separation of cables in wiring systems.....	49
Figure 44.R19 – Cable arrangements in metal cable-trays	50
Figure 44.R20 – Continuity of metallic system components	51
Figure 44.R21 – Location of cables inside metallic construction elements	51
Figure 44.R22 – Connection of metallic sections.....	52
Figure 44.Q – Examples of how to apply d1, d2 and d3 for the determination of d
Table 44.A1 – Power-frequency stress voltages and power-frequency fault voltage in low-voltage system.....	12
Table 44.A2 – Permissible power-frequency stress voltage	14
Table 443.1 – Calculation of f_{env}	18
Table 44.B 443.2 – Required rated impulse withstand voltage of equipment U_W	23
Table B.1 – Different possibilities for IT systems.....

INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE ELECTRICAL INSTALLATIONS –

**Part 4-44: Protection for safety –
Protection against voltage disturbances and
electromagnetic disturbances**

FOREWORD

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

This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 60364-4-44 edition 2.1 contains the second edition (2007-08) [documents 64/1600/FDIS and 64/1609/RVD] and its amendment 1 (2015-09) [documents 64/2032/FDIS and 64/2073/RVD].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 60364-4-44 has been prepared by IEC technical committee 64: Electrical installations and protection against electric shock.

The document 64/1600/FDIS, circulated to the National Committees as Amendment 3, led to the publication of the new edition.

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

A list of all the parts in the IEC 60364 series, under the general title *Low-voltage electrical installations*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

The reader's attention is drawn to the fact that Annex C lists all of the "in-some-country" clauses on differing practices of a less permanent nature relating to the subject of this standard.

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.

The contents of the corrigenda of May 2010 and October 2011 have been included in this copy.

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

INTRODUCTION

Part 4-44 of IEC 60364 covers the protection of electrical installations and measures against voltage disturbances and electromagnetic disturbances.

The requirements are arranged into four clauses as follows:

- Clause 442 Protection of low-voltage installations against temporary overvoltages due to earth faults in the high-voltage system and due to faults in the low-voltage system
- Clause 443 Protection against overvoltages of atmospheric origin or due to switching
- Clause 444 Measures against electromagnetic influences
- Clause 445 Protection against undervoltage

iTeh Standards
(<https://standards.iteh.ai>)
Document Preview

[IEC 60364-4-44:2007](https://standards.iteh.ai/catalog/standards/iec/1f91dcf3-83f0-47a7-97b8-d77b26f641ab/iec-60364-4-44-2007)

<https://standards.iteh.ai/catalog/standards/iec/1f91dcf3-83f0-47a7-97b8-d77b26f641ab/iec-60364-4-44-2007>

LOW-VOLTAGE ELECTRICAL INSTALLATIONS –

Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances

440.1 Scope

The rules of this Part of IEC 60364 are intended to provide requirements for the safety of electrical installations in the event of voltage disturbances and electromagnetic disturbances generated for different specified reasons.

The rules of this part are not intended to apply to systems for distribution of energy to the public, or power generation and transmission for such systems (see the scope of IEC 60364-1) although such disturbances may be conducted into or between electrical installations via these supply systems.

440.2 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.

IEC 60038:1983/2009, *IEC standard voltages*

IEC 60050-604:1987, *International Electrotechnical Vocabulary – Chapter 604: Generation, transmission and distribution of electricity – Operation*

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

IEC 60364-4-41:2005, *Electrical installations of buildings – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-5-53:2001, *Electrical installations of buildings - Part 5-53: Selection and erection of electrical equipment - Isolation, switching and control*

IEC 60364-5-53:2001/AMD1:2002

IEC 60364-5-53:2001/AMD2:2015

IEC 60364-5-54:2002, *Electrical installations of buildings – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective bonding conductors*¹

IEC 60479-1:2005, *Effects of current on human beings and livestock – Part 1: General aspects*

IEC 60664-1:2007, *Insulation co-ordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60950-1, *Information technology equipment – Safety – Part 1: General requirements*

IEC 61000-2-5:1995, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 5: Classification of electromagnetic environments – Basic EMC publication*

IEC 61000-6-1, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity for residential, commercial and light-industrial environments*

¹ A third edition is currently in preparation.

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61558-2-1, *Safety of power transformers, power supplies, reactors and similar products – Part 2-1: Particular requirements for tests for separating transformers and power supplies incorporating separating transformers for general applications*

IEC 61558-2-4, *Safety of power transformers, power supply units and similar – Part 2-4: Particular requirements for isolating transformers for general use*

IEC 61558-2-6, *Safety of power transformers, power supply units and similar – Part 2-6: Particular requirements for safety isolating transformers for general use*

IEC 61558-2-15, *Safety of power transformers, power supply units and similar – Part 2-15: Particular requirements for isolating transformers for the supply of medical locations*

IEC 61643 (all parts), *Low-voltage surge protective devices*

IEC 61643-11:2011, *Low-voltage surge protective devices – Part 11: Surge protective devices connected to low-voltage power systems – Requirements and test methods*

IEC 61643-22, *Low-voltage surge protective devices – Part 22: Surge protective devices connected to telecommunications and signalling networks – Selection and application principles*

IEC 61936-1, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*

IEC 62305 (all parts), *Protection against lightning – 44:2007*

IEC 62305-1, *Protection against lightning – Part 1: General principles*

IEC 62305-3, *Protection against lightning – Part 3: Physical damage to structures and life hazard*

IEC 62305-4, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

441 (Vacant)

442 Protection of low-voltage installations against temporary overvoltages due to earth faults in the high-voltage system and due to faults in the low-voltage system

442.1 Field of application

The rules of this clause provide requirements for the safety of low-voltage installation in the event of

- a fault between the high-voltage system and earth in the transformer substation that supplies the low-voltage installation,
- a loss of the supply neutral in the low-voltage system,

- a short-circuit between a line conductor and neutral,
- an accidental earthing of a line conductor of a low-voltage IT-system.

The requirements for the earthing arrangement at the transformer substation are given in IEC 61936-1.

442.1.1 General requirements

As Clause 442 covers faults between a high-voltage line and the earth in the HV/LV substation, it gives rules for the designer and installer of the substation. It is necessary to have the following information concerning the high-voltage system:

- quality of the system earthing;
- maximum level of earth fault current;
- resistance of the earthing arrangement.

The following subclauses consider four situations as proposed in 442.1, which generally cause the most severe temporary overvoltages such as defined in IEC 60050-604:

- fault between the high-voltage system(s) and earth (see 442.2);
- loss of the neutral in a low-voltage system (see 442.3);
- accidental earthing of a low-voltage IT system (see 442.4);
- short-circuit in the low-voltage installation (see 442.5).

442.1.2 Symbols

In Clause 442 the following symbols are used (see Figure 44.A1):

- I_E part of the earth fault current in the high-voltage system that flows through the earthing arrangement of the transformer substation.
- R_E resistance of the earthing arrangement of the transformer substation.
- R_A resistance of the earthing arrangement of the exposed-conductive-parts of the equipment of the low-voltage installation.
- R_B resistance of the earthing arrangement of the low-voltage system neutral, for low-voltage systems in which the earthing arrangements of the transformer substation and of the low-voltage system neutral are electrically independent.
- U_0 in TN- and TT-systems: nominal a.c. r.m.s. line voltage to earth
in IT-systems: nominal a.c. voltage between line conductor and neutral conductor or mid point conductor, as appropriate
- U_f power-frequency fault voltage that appears in the low-voltage system between exposed-conductive-parts and earth for the duration of the fault.
- U_1 power-frequency stress voltage between the line conductor and the exposed-conductive-parts of the low-voltage equipment of the transformer substation during the fault.
- U_2 power-frequency stress voltage between the line conductor and the exposed-conductive-parts of the low-voltage equipment of the low-voltage installation during the fault.

NOTE 1 The power-frequency stress voltage (U_1 and U_2) is the voltage that appears across the insulation of low-voltage equipment and across surge protective devices connected to the low-voltage system.