

IEEE Standard Test Specifications for Surge-Protective Devices (SPDs) for Use on the Load Side of the Service Equipment in Low-Voltage (1000 V and Less) AC Power Circuits

IEEE Power & Energy Society

Sponsored by the
Surge Protective Devices Committee

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IEEE Standard Test Specifications for Surge-Protective Devices (SPDs) for Use on the Load Side of the Service Equipment in Low-Voltage (1000 V and Less) AC Power Circuits

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of the

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Abstract: Surge-protective devices (SPDs) intended to be installed on the load side of the service equipment connected to 50 Hz or 60 Hz AC power circuits rated at 1000 V (root mean squared [rms]) or less are the focus of this standard. Performance characteristics and standard methods for testing and rating are established for these devices, which may be composed of any combination of components. The tests in this standard are aimed at providing comparisons among the variety of SPDs available.

Keywords: C62.62, combination wave, current-driven test, disconnecter, induced failure, maximum continuous operating voltage (MCOV), nominal discharge current, one-port SPD, operational duty cycle, ring wave, service equipment, short-circuit current rating (SCCR), SPD Type, surge protection, surge tests, surge-protective device (SPD), temporary overvoltage (TOV), transient voltage-surge suppressor (TVSS), two-port SPD, Type 1 SPD, Type 2 SPD, Type 3 SPD, Type 4 SPD

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Introduction

This introduction is not part of IEEE Std C62.62-2010, IEEE Standard Test Specifications for Surge-Protective Devices (SPDs) for Use on the Load Side of the Service Equipment in Low-Voltage (1000 V and Less) AC Power Circuits.

The purpose of this standard is to provide users, independent laboratories, and manufacturers with a test specification applicable to SPDs intended for limiting transient overvoltages that can appear on alternating current (ac) power circuits of 1000 V (root mean squared [rms]) or less. The standard contains test specifications that allow the user to compare various SPDs. It is one of several documents based in part on IEEE Std C62.41.2™-2002^a that characterizes the surge environment to which low-voltage ac power circuits are exposed.

The surge tests described herein are not intended to duplicate lightning or other naturally occurring transients specifically; rather, they provide a method of evaluation and comparison of SPDs. The surge tests included in this standard have been time and application proven to provide a good and fair evaluation of SPDs.

The interest in low-voltage ac SPDs has grown with the trend to protect sophisticated electrical and electronic equipment that is exposed and susceptible to surges from the environment and generated within the electrical system itself. This standard provides test methods for SPDs.

This test specification has evolved from its original form, IEEE Std C62.62-2000, in that the title and scope have changed. The new title and scope limit the application of this document to SPDs intended for installation on the load side of the service equipment. IEEE Std C62.34™ [B6]^b covers test specifications for SPDs intended for installation on the line side of the service equipment (referred to as Type 1 SPDs by other standards).

Furthermore, the following table summarizes a comparison of tests from the previous revision of the standard to this one:

IEEE Std C62.62-2000	IEEE Std C62.62-2010
Surge Response Voltage Test: 100 kHz Ring Wave Test Combination Wave Test Other waveforms per IEEE Std C62.41-1991	Surge Tests: 100 kHz Ring Wave Test Combination Wave Test Current-Driven Tests Voltage-Surge Tests Nominal Discharge Current Test
Maximum Continuous Operating Voltage (MCOV) Test	Maximum Continuous Operating Voltage (MCOV) Test
Maximum Single Withstand Surge Current Test	Nominal Discharge Current Test/Operational Duty Cycle Test
Minimum Surge Life Test	Nominal Discharge Current Test/Operational Duty Cycle Test
Voltage Regulation Test	Voltage Regulation Test
Load Current Capability Test	Rated Load Current Test
Protection Status Indication Test	—
Standby Power Dissipation Test	Standby Power Consumption Test (Informative Annex)
Insulation Resistance Test	Insulation Resistance Test (Informative Annex)
Dielectric Withstand Test	Dielectric Withstand Test (Informative Annex)
Failure Safety Mode Test	Short-Circuit Current Rating Test Intermediate Current Test (Informative Annex) Limited Current Abnormal Overvoltage Test (Informative Annex)

^a Information on references can be found in Clause 2.

^b The numbers in brackets correspond to those of the bibliography in Annex B.

Response to Front of Wave Test	Front of Wave Test (Informative Annex)
—	Maximum Operating Temperature Withstand Test
—	Load-Side Short-Circuit Test
—	Load-Side Surge Withstand Test
—	Operational Voltage Test (Informative Annex)
—	Grounding Continuity Test (Informative Annex)
—	Leakage Current Test (Informative Annex)

Although a number of the tests from the previous revision also appear in this revision, many have been modified. Another important revision is the formatting of the test specifications to include the rationale, purpose, test procedure and setup, and expected results.

Annex A (informative) describes additional tests that may be used to establish particular application requirements but are not a requirement of this document and provides supplemental information regarding the subject of SPDs.

Recently, new terminology has been introduced to describe SPDs—in particular, the SPD “Type.” This terminology is included and defined in this publication. To provide clarification to the user of this document, Type 1 SPDs (generally used for the line side of the service equipment—seemingly out of the scope of this document) are included. The rationale for inclusion is that Type 1 SPDs are also permitted to be used on the load side of the service equipment (within the scope of this document) as well as the line side.

Directly correlating the ANSI/UL 1449-2006 [B2] SPD Types to the location categories as described in IEEE Std C62.41.2-2002 is sometimes complicated due to the overlap of the boundaries of the location categories. The illustration of the IEEE Location Categories Concept is included in A.15 for reference.

Generally, Type 1 SPDs are intended for use in Category C locations; however, application of Type 1 SPDs is not limited to the Category C location. They may also be used on the load side of the service equipment, which includes Category B and Category A.

Furthermore, Type 2 SPDs are intended for the load side of the service equipment but can have the same ratings as a Type 1 SPD. The fuzzy boundary between Category C and Category B overlaps at the service equipment; therefore, Type 2 SPDs may be considered for both Category C and Category B.

Type 3 SPDs are generally expected to be used in Category A locations. However, because Type 3 SPDs are direct plug-in or cord-connected SPDs for use with convenience outlets, they may be located in the Category C/Category B boundary (a convenience outlet located close to the service equipment), and the corresponding tests for those locations may be considered.

Type 4 SPDs may be intended as Type 1 SPDs, Type 2 SPDs, or Type 3 SPDs and must be considered based on their intended application.

From Clause 1 of IEEE Std C62.41.2-2002:

There are no specific models that are representative of all surge environments; the complexities of the real world need to be simplified to produce a manageable set of standard surge tests. To this end, a surge environment classification [location categories] scheme is presented. This classification provides a practical basis for the selection of waveforms and amplitudes of surge voltages and surge currents that may be applied to evaluate the surge withstand capability of equipment [SPDs, in this case] connected to these power circuits. It is most important to recognize that proper coordination of equipment capability and environment characteristics is required: each environment and the equipment to be protected have to be characterized and the two reconciled.

WARNING

Surge testing of electrical or electronic equipment presents potentially hazardous situations for both personnel and equipment. The surge test equipment can generate potentially lethal voltage surges. Furthermore, a catastrophic failure of the EUT might result in a fire or explosion. Only qualified personnel should perform the tests, with safety precautions enforced according to all national codes as well as the applicable safety directives and prescriptions of the organization where the tests are performed. Testing should not be performed unattended. More specific aspects of safety precautions are discussed in 5.1.

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1. Overview

1.1 Scope

This standard applies to surge-protective devices (SPDs) intended to be installed on the load side of the service equipment connected to 50 Hz or 60 Hz alternating current (ac) power circuits rated at 1000 V (root mean squared [rms]) or less. Performance characteristics and standard methods for testing and rating are established for these devices, which may be composed of any combination of components. The tests in this standard are aimed at providing comparisons among the variety of surge-protective devices available.

1.2 Purpose

The purpose of this standard is to provide users, independent laboratories, and manufacturers with test methods and test specifications applicable to low-voltage surge-protective devices used on the load side of the service equipment, intended for limiting transient overvoltages that can appear on ac power circuits of 1000 V (rms) or less.

2. Normative references

The following referenced documents and URLs are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std C62.41.2™-2002, IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits.^{1,2}

IEEE Std C62.45™-2002, IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. *The IEEE Standards Dictionary: Glossary of Terms & Definitions* should be referenced for terms not defined in this clause.³

circuit interrupt device: A device whose purpose is to interrupt the flow of power, usually in response to a fault.

degradation: Change of original performance parameters as a result of exposure of the SPD to surge, service, or unfavorable environment. (IEC 61643-1, Ed. 2.0, 2005 [B4]⁴)

in-line surge-protective device (SPD): A two-port surge-protective device (SPD) connected in series between the power supply and a load where the load current passes through the conductive terminals of the SPD such that the removal of the SPD opens the circuit but has no intended impedance.

measured limiting voltage: The maximum magnitude of voltage that is measured across the terminals of the surge-protective device (SPD) during the application of a series of impulses of specified wave shape and amplitude. (IEEE Std C62.34-1996 [B6])

mode of protection: Surge-protective device (SPD) protective components may be connected line to line, line to earth, line to neutral, or neutral to earth, and any combination thereof. (IEC 61643-1, Ed. 2.0, 2005 [B4])

nominal system voltage: A nominal value assigned to designate a system of a given voltage class. (IEEE Std C62.62-2000⁵)

one-port surge-protective device (SPD): A surge protective device (SPD) connected in shunt with the circuit to be protected.

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⁴ The numbers in brackets correspond to those of the bibliography in Annex B.

⁵ Information on references can be found in Clause 2.

service equipment: The necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the load end of service conductors to a building or other structure, or an otherwise designated area, and intended to constitute the main control and cutoff of the supply. (National Electrical Code[®] (NEC[®]) (NFPA 70) [B9])

short-circuit current rating (SCCR) of a surge-protective device (SPD): The level at which a surge-protective device (SPD) is suitable for use on an ac power circuit that is capable of delivering not more than the declared root-mean-square symmetrical current at a declared voltage during a short-circuit condition. (IEEE Std C62.72TM-2007 [B8])

surge-protective device (SPD): A device that is intended to limit transient overvoltages and divert surge current, or both. It contains at least one nonlinear component. (IEEE Std C62.34-1996 [B6])

two-port surge-protective device (SPD): SPD with two sets of terminals, input and output. A specific series impedance is inserted between these terminals. (IEC 61643-1, Ed. 2.0, 2005 [B4])

Type 1 surge-protective device (SPD)⁶: Permanently connected SPDs intended for installation between the secondary terminal of the supplying transformer and the line side of the service equipment overcurrent device, as well as the load side, including watt-hour meter socket enclosures and intended to be installed without an external overcurrent protective device. (ANSI/UL 1449-2006 [B2])

Type 2 surge-protective device (SPD)⁷: Permanently connected SPDs intended for installation on the load side of the service equipment overcurrent device; including SPDs located at the branch panel. (ANSI/UL 1449-2006 [B2])

Type 3 surge-protective device (SPD)⁸: Point of utilization SPDs, installed at a minimum conductor length of 10 m (30 ft) from the service equipment to the point of utilization, for example, cord-connected, direct plug-in, receptacle type, and SPDs installed at the utilization equipment being protected. The distance (10 m) is exclusive of conductors provided with or used to attach SPDs. If the nominal discharge current test is performed on a Type 3 SPD, the minimum distance from the service equipment does not apply. (ANSI/UL 1449-2006 [B2])

Type 4 surge-protective device (SPD)⁹: Component SPDs, including discrete components as well as component assemblies. (ANSI/UL 1449-2006 [B2])

3.2 Acronyms and abbreviations

ac	alternating current
EMI	electromagnetic interference
MCOV	maximum continuous operating voltage
MLV	measured limiting voltage
OCPD	overcurrent protective device
rms	root mean squared
SCCR	short-circuit current rating

⁶ Generally, Type 1 SPDs are intended for use in Category C locations; however, the application of Type 1 SPDs is not limited to the Category C location. They may also be used on the load side of the service equipment, which includes Category B and Category A (IEEE Std 62.34-1996 [B6]).

⁷ Type 2 SPDs are intended for the load side of the service equipment but can have the same ratings as a Type 1 SPD. The fuzzy boundary between Category C and Category B overlaps at the service equipment; therefore, Type 2 SPDs may be considered for both Category C and Category B.

⁸ Type 3 SPDs are generally expected to be used in Category A locations. However, because Type 3 SPDs are direct plug-in or cord-connected SPDs for use with convenience outlets, they may be located in the Category C/Category B boundary (a convenience outlet located close to the service equipment), and the corresponding tests for those locations may be considered.

⁹ Type 4 SPDs may be intended as Type 1 SPDs, Type 2 SPDs, or Type 3 SPDs and must be considered based on their intended application. Only Type 4 SPD assemblies that are applied as Type 1, 2, or 3 SPDs are covered by this standard. Individual SPD components are outside the scope of this standard.

SPD	surge-protective device
TOV	temporary overvoltage
VPR	Voltage Protection Rating

4. Service conditions

4.1 Normal service conditions

SPDs conforming to this standard shall be capable of operating under the conditions listed in the following list. These conditions shall be defined by the manufacturer or the end user, as appropriate (for standard test conditions, see 5.4):

- a) Ambient temperature range (typically -5°C to $+40^{\circ}\text{C}$)
- b) Altitude (less than 2000 m)
- c) Humidity (indoor, 30% to 90%; outdoor, determined by the interested parties)
- d) Frequency range (50 Hz or 60 Hz, ± 2 Hz)
- e) Voltage range ($+6\%$ / -13% of nominal system voltage) (ANSI C84.1-2006 [B1])

4.2 Nonstandard service conditions

The following service conditions could require special consideration in the design or application of SPDs, and they should be called to the attention of the manufacturer. When any such conditions apply, they shall be specified by the user or included in the specifications of the manufacturer:

- a) Ambient temperature differing from the normal service conditions
- b) Altitude or atmospheric pressure differing from the normal service conditions
- c) Exposure to fumes, vapors, salt spray, water, dirt, chemicals, explosive atmospheres, abnormal shock, or vibration
- d) Limitations on weight and specifications
- e) Unusual transportation or storage
- f) Seismic ratings

5. General test considerations

5.1 Safety and electromagnetic interference (EMI)

WARNING

Many of the tests indicated in this standard test specification are inherently hazardous. The precautions for personnel and property described in this clause shall be observed to reduce safety risks. Existing national safety codes and the applicable safety directives and prescriptions of the organization where the tests are being performed shall also be observed.

During the testing described in this standard, the voltage and energy levels can be hazardous, and appropriate care shall be exercised. Surge testing can generate significant amounts of EMI. For this reason,

care should be taken not to expose personnel with electrical prosthetic devices, including implanted pacemakers, to the immediate environment of a surge test.

Consideration shall also be given to the possibility of ignition or explosion within the SPD. Where an examination of the device indicates a likelihood of ignition, factors to be considered include the following:

- The amount of combustible material likely to be involved initially
- The probable rate of propagation
- The consequences of such propagation, that is, the probability of extension beyond the SPD

Appropriate precautions shall be taken to keep these factors within manageable limits. Precautions may include suitable extinguishing agents in sufficient quantity, physical separation from other combustibles, or other appropriate measures. In evaluating the possibility of explosion, consideration should be given to component failure whenever hazardous materials are available in sufficient quantity to create an explosive atmosphere.

All surge testing shall be conducted by technically qualified personnel who are aware of the hazards of such testing. The voltage and current levels generally associated with surge testing are well above those considered lethal. Some considerations are the possibility of an accidental discharge of the surge generator, the consequences of a flashover to an unfavorable circuit, the possibility of a charge being trapped in the SPD, or the consequence of a violent component failure. Testing personnel should never stand in the line of sight of components on printed circuit boards or panels with the enclosure open during SPD surge testing. On occasion, a component can unexpectedly fail in an explosive manner during surge testing. Fragments of the ruptured case and the component might cause injury to personnel in the vicinity. If visual observation is desired, a suitable transparent barrier shall be provided.

Surge testing of SPDs is best conducted only in an area dedicated solely to that purpose. The boundaries of the area should be clearly defined and appropriately marked. The surge test area should be kept free of all materials, meters, and test setups that are not associated with the surge test being conducted (see the example in A.14). Where possible, the area should be isolated and equipped with electrical or mechanical interlocks, or both, on all entrances into the test area and on removable barrier panels. All metal fences and barriers should be bonded to the grounding system. Consideration should be given to the possibility of the surge flashing over to circuits or metallic parts that were not intended to be surged.

When the SPD can be enclosed in an effective barrier, the preceding requirements for installation are easier to satisfy. This barrier may simply be sufficient separation—including separation from the floor, which should be presumed to contain conduit or other metal. Alternatively, the entire barrier may be made up of physical insulation. In either case, it should be complete, except where it is penetrated for insertion of input or output lines and measurements probes; and it must be able to provide adequate protection for a peak voltage equal to at least twice the peak of the incident test surge. (Circuits in breakdown at or near the surge peak can oscillate at high frequencies. Such oscillatory flashovers can thereby increase effective applied peaks by a factor approaching two.) Interlocks should be provided to minimize risks associated with access between tests.

Capacitors in the test circuit or the device under test can retain a trapped charge. Suitable bleeders or short-circuiting devices should be provided to protect the operator against any such trapped charge after passage of the test surge.

EMI from surge testing could conceivably cause malfunction of robots and other automatic equipment, and such equipment should be isolated from the immediate vicinity of surge testing operations.

The importance of conducting surge tests in a prudent manner cannot be overemphasized; safeguarding personnel has to be the prime consideration.

5.2 SPD test specimens

New SPDs shall be used for each test unless otherwise specified. Previously tested samples may be used provided all parties concerned agree. In the event of a failure with a previously tested sample, a new sample shall be used to repeat the test, if the test is to be repeated.

Many of the tests described in this standard could stress an SPD. Stressed devices should not be compared with unstressed devices unless that is the intent. The suppression characteristics of some SPDs change with successive testing as well as with changes in the environment. The changes can be permanent in nature. Selection and careful organization of appropriate tests can reduce the quantity of test samples needed.

5.3 Connection

Connection terminals or wires on the SPD shall be clearly marked to facilitate correct connections to the user's circuit. Connections should be made utilizing the manufacturer's specifications (i.e., conductor size, torque, etc.).

5.4 Standard test conditions

The tests in this standard are intended to provide comparisons among the variety of SPDs available. A comparison of the test results between two or more surge protective devices could be valid only if the tests have been performed under identical test conditions that are tailored to the intended use.

In the absence of specified environmental standards, the following test conditions and test setups are recommended:

- a) Ambient temperature: 20 °C, ± 5 °C
- b) Relative humidity: less than 85%
- c) Altitude: less than 2000 m
- d) Voltage (rms) tolerance (of nominal): +6%/–13% (ANSI C84.1-2006 [B1])
- e) Frequency: 50 Hz or 60 Hz, ± 2 Hz
- f) Test wave shapes: reference IEEE Std C62.41.2™-2002
- g) Test method: per IEEE Std C62.45™-2002

5.5 Failure modes

Device failure is considered to have occurred when any component fails or changes its characteristics in such a way as to inhibit ordinary power flow or fail to provide protection as specified.

Failure modes might include the following:

- a) Shorting or opening of any protective circuitry (including a fuse, thermal protective device, or circuit breaker)
- b) Unintended flashover
- c) Failure of a component in any one stage of a multistage unit
- d) Increase in power follow current or leakage current beyond specifications