IEEE Standard Test Specifications for Surge-Protective Devices for Low-Voltage AC Power Circuits

Sponsor

Surge Protective Devices Committee
of the
IEEE Power Engineering Society

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Abstract: This standard establishes methods for testing and measuring the performance characteristics for surge-protective devices used in low-voltage ac power circuits. Definitions are stated that apply specifically to surge-protective devices. The testing requirements are categorized into two groups, in which a minimum set of basic tests (BTs) are prescribed for all surge-protective devices within the scope of its documents, supplemented by additional tests (ATs) that might be needed to establish particular application requirements.
Keywords: discharge voltage, electromagnetic interference (EMI), flashover, impulse, lightning, surge-protective devices

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Introduction

(This introduction is not a part of IEEE Std C62.62-2000, IEEE Standard Test Specifications for Surge-Protective Devices for Low-Voltage AC Power Circuits).

The purpose of this standard is to provide users, independent laboratories, and manufacturers with a test specification applicable to surge-protective devices intended for limiting transient overvoltages that can appear on ac power circuits of 1000 V (rms) or less. The standard contains test specifications that allow the user to compare different surge-protective devices. It is one of several successor documents to IEEE Std C62.41-1991, which characterized the surge voltage environment to which low-voltage ac power circuits are exposed.

The interest in low-voltage ac surge-protective devices has grown with the trend to use highly sophisticated electrical and electronic equipment that is exposed and susceptible to surges from the environment. This standard provides an overview of test methods for protective devices.

Suggestions for improvements to this Standard will be welcomed. They should be sent to the Secretary, IEEE-SA Standards Board, Institute of Electrical and Electronics Engineers, 3 Park Avenue, New York, NY 10016-5997.

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IEEE Standard Test Specifications for Surge-Protective Devices for Low-Voltage AC Power Circuits

1. Overview

1.1 Scope

This standard applies to surge-protective devices intended to be installed on the load side of the main service disconnect packaged to be connected to 50 Hz or 60 Hz ac power circuits rated at 1000 V (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.

Many of the tests described in this standard may stress a surge-protective device. Care should be taken to ensure that stressed devices are not compared with unstressed devices unless that is the desired intent. The suppression characteristics of some surge-protective devices change with successive surging as well as with changes in the environment. These changes may be permanent in nature. Selection and careful organization of appropriate tests can reduce the quantity of test samples needed.

The voltage and energy levels employed in the majority of the tests described in this standard are hazardous and appropriate cautions must be exercised in their performance.

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, intended for limiting transient overvoltages that can appear on ac power circuits of 1000 V (rms) or less.

2. References

This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

Accredited Standards Committee C2-1997, National Electrical Safety Code® (NESC®).[1]

[1]The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

ANSI C84.1-1995, American National Standard for Voltage Ratings for Electric Power Systems and Equipment (60 Hz).[2]

IEEE Std C62.1-1989 (Reaff 1994), IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits.[3]

IEEE Std C62.2-1989 (Reaff 1994), IEEE Guide for Application of Gapped Silicon-Carbide Surge Arresters for Alternating Current Systems.

IEEE Std C62.11-1999, IEEE Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits (>1 kV).

IEEE Std C62.31-1987 (Reaff 1998), IEEE Standard Test Specifications for Gas Tube Surge-Protective Devices.

IEEE Std C62.33-1982 (Reaff 1994), IEEE Standard Test Specifications for Varistor Surge-Protective Devices.

IEEE Std C62.35-1987 (Reaff 1993), IEEE Standard Test Specifications for Avalanche Junction Semiconductor Surge-Protective Devices.

IEEE Std C62.41-1991 (Reaff 1995), IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.

IEEE Std C62.42-1992 (Reaff 1999), IEEE Guide for the Application of Gas Tube and Air Gap Arrester Low-Voltage (Equal to or Less than 100 Vrms or 1200 Vdc) Surge-Protective Devices.

IEEE Std C62.45-1992 (Reaff 1998), IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits.

IEEE Std 4-1995, IEEE Standard Techniques for High-Voltage Testing.

NFPA 70-1999, The National Electrical Code® (NEC®).[4]

UL 1449-1996, Standard for Transient Voltage Surge Suppressors, Second Edition.[5]

3. Definitions

The following definitions apply specifically to surge-protective devices and do not necessarily cover other applications.

3.1 certification tests: Tests run on a regular, periodic basis to verify that selected key performance characteristics of a product, or representative samples thereof, have remained within performance specifications.

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[2]ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (http://www.ansi.org/).

[3]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

[4]NFPA publications are published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA (http://www.nfpa.org/).

[5]UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/).

3.2 clamping voltage: The peak voltage across the surge-protective device measured under conditions of a specified surge current and specified current waveform.

3.3 combination surge: *See:* **combination wave.**

3.4 combination wave: A surge delivered by an instrument that has the inherent capability of applying a 1.2/50-voltage wave across an open-circuit, and delivering an 8/20-current wave into a short circuit. The instantaneous impedance to which the combination wave is applied determines the exact wave that is delivered. The peak magnitudes of the voltage or current wave shall be specified. *Syn:* **combination surge.**

3.5 crest (peak) value: The maximum absolute value that a wave, surge, or impulse attains.

3.6 design tests: Tests made by the manufacturer on each design to establish the performance characteristics and to demonstrate compliance with the appropriate standards of the industry. Once made, they need not be repeated unless the design is changed (so as to modify performance).

3.7 dielectric withstand voltages: The maximum voltage that may be applied between line or phase terminals and the neutral or ground terminals (or the device enclosure) without causing electrical failure or breakdown of the device insulation.

3.8 discharge current: The surge current that flows through the surge-protective device when conduction occurs.

3.9 discharge current withstand rating: The specified magnitude and wave shape of a discharge current that can be applied to a surge-protective device a specified number of times without causing damage or degradation beyond specified limits.

3.10 discharge voltage: The voltage that appears across other terminals of a surge-protective device during passage of discharge current.

3.11 discharge voltage-current characteristic: The variation of the crest values of discharge voltage with respect to discharge current.

3.12 disruptive discharge: **(A)** The sudden and large increase in current through an insulating medium, due to the complete failure of the medium under the electrostatic stress. **(B)** An increase that causes explosive mechanical or electrical failure in one of the failure modes.

3.13 fault current: The current from the connected power system that flows in a short circuit.

3.14 flashover: A disruptive discharge around or over the surface of a solid or liquid insulator.

3.15 follow (power) current: The current from the connected power source that flows through a surge-protective device during and following the passage of discharge current.

3.16 grounded system: An electric system in which at least one conductor or point (usually the neutral conductor of neutral point of transformer or generator windings) is intentionally grounded, either solidly or through a grounding device.

3.17 impulse: A surge of unidirectional polarity.

3.18 impulse sparkover voltage: The highest value of voltage attained by an impulse of a designated wave shape and polarity applied across the terminals of a gap-type surge-protective device prior to the flow of discharge current.

3.19 impulse sparkover volt-time characteristic: The sparkover response of a gap-type surge-protective device, when subjected to voltage impulses that have varying magnitudes and specified wave shape and polarity.

3.20 impulse withstand voltage: The crest value of an impulse that, under specified conditions, can be applied without causing a disruptive discharge.

3.21 indoor surge-protective device: A surge-protective device that, because of its construction, shall be protected from the weather.

3.22 insulation resistance: The resistance, measured at a specified dc voltage, between any specified exposed conductive surface or line terminal (including ground) and one or more of the other line terminals of the device.

3.23 leakage current: The current flowing in the equipment-grounding conductor (including a conductive case) when the device is connected as intended to the energized power system at rated voltage.

3.24 lightning: An electric discharge that occurs in the atmosphere between clouds or between clouds and ground.

3.25 maximum continuous operating voltage (MCOV): The maximum designated root-mean-square value of power frequency voltage that may be applied continuously between the terminals of the overvoltage protective device.

3.26 maximum (highest) system voltage: The highest voltage at which a system is operated.

3.27 multi-terminal surge-protective device: A protective device that has three or more terminals, usually containing both series and parallel elements between the terminals.

3.28 nominal rate of rise (of an impulse wavefront): The slope of the line that determines the virtual zero. It is usually expressed in volts or amperes per microsecond.

3.29 nominal system voltage: A nominal value assigned to designate a system of a given voltage class.

3.30 operating duty cycle: One or more unit operations, as specified.

3.31 oscillatory surge: A surge that includes both positive and negative polarity values.

3.32 outdoor surge-protective device: A surge-protective device that is designed for outdoor use.

3.33 performance characteristics: The parameters that are essential to describe the behavior or applicability of the device under specified conditions of operation.

3.34 power-frequency overvoltage: A root-mean-square voltage in excess of the maximum (highest) system voltage that lasts longer than one cycle.

3.35 power-frequency sparkover voltage: The root-mean-square value of the lowest power-frequency sinusoidal voltage that will cause sparkover when applied across the terminals of a surge-protective device.

3.36 power-frequency withstand voltage: A specified root-mean-square test voltage, at a power frequency that will not cause a disruptive discharge.

3.37 rated peak single-surge transient current: The maximum peak current that may be applied for a single impulse (with rated line voltage also applied) without causing device failure.

3.38 rated single-surge transient energy: Energy that may be dissipated in a surge-protective device for a single impulse of maximum rated current at a specified waveshape, with rated root-mean-square voltage or rated dc voltage also applied, without causing device failure.

3.39 rated standby power dissipation: The power dissipated in a protective device while connected to an ac line that has a voltage and frequency equal to the rating of the device and that has no load current flowing and no surges applied.

3.40 rating: The designation of an operating limit for a device.

3.41 recovery voltage: The voltage that occurs across the terminals of a pole of a circuit-interrupting device upon the interruption of the current.

3.42 repetitive surge and follow-current withstand: The number of surges of specified voltage and current amplitudes and waveshapes that may be applied to a device without causing degradation beyond specified limits. The repetitive surge and follow-current withstand ratings apply to a device connected to an ac line of specified characteristics and to pulses applied at specified rates and phase angles. The effects of any cumulative heating that may occur are included.

3.43 ring wave: (100 kHz ring wave). An open-circuit voltage wave characterized by a rapid rise to a defined peak value, followed by a damped oscillation.

3.44 routine tests: Test made by the manufacturer on every device, or representative samples, or on parts or materials, as required, to verify that the product meets the design specifications.

3.45 series gap: An intentional gap(s) between spaced electrodes. The gap is in series with the valve or expulsion element of the protective device, substantially isolating the element from line or ground, or both, under normal line-voltage conditions.

3.46 service voltage: The root-mean-square phase-to-phase or phase-to-neutral voltage at the point where the electrical system of the supplier and the user are connected.

3.47 sparkover: A disruptive discharge between electrodes of a measuring gap, voltage-control gap, or protective device.

3.48 stand-by current: The current flowing in any specific conductor (including a conductive case) when the device is connected as intended to the energized power system at rated voltage with no connected load.

3.49 surge: A transient wave of current, potential, or power in an electric circuit.

3.50 surge let-through: That part of the surge that passes by a surge-protective device with little or no alteration.

3.51 surge life: The number of surges of specified voltage and current amplitudes and waveshapes that may be applied to a device without causing degradation beyond specified limits. The pulse life applies to a device connected to an ac line of specified characteristics and to surges sufficiently spaced in time to preclude the effects of cumulative heating.

3.52 surge-protective device: The generic term used to describe a device by its protective function, regardless of technology used, ratings, packaging, point of application, etc. It contains at least one nonlinear component.

3.53 surge remnant: That part of an applied surge that remains downstream of one or several protective devices.

3.54 surge response current: The current flowing in a surge-protective device during its diverting function upon occurrence of an impinging surge.

3.55 surge response voltage: The voltage that appears at the output terminals of a surge-protective device during and after a specified impinging surge, until normal stable conditions are reached.

3.56 system (circuit) voltage: The root-mean-square power frequency voltage from line-to-line as distinguished from the voltage from line-to-neutral.

3.57 terminals: The conducting parts provided for connecting the surge-protective device across the circuit to be protected. Terminal designations could be phase(s), neutral or ground with line and/or load designations.

3.58 time to impulse sparkover: The time between virtual zero of the voltage impulse that causes sparkover and the point on the voltage wave at which sparkover occurs. The voltage across the terminals of the surge-protective-device during the flow of discharge current and contributes to the limitation of follow current at normal power-frequency voltage.

3.59 unit operation: Discharging a surge through the surge-protective-device while the device is energized.

3.60 upset: Malfunction of a system because of electrical disturbances.

3.61 utilization voltage: The root-mean-square phase-to-phase or phase-to-neutral voltage at the line terminals of utilization equipment.

3.62 valve element: A resistor that, because of its nonlinear current-voltage characteristic, limits the voltage across the terminals of the surge-protective-device during the flow of discharge current and contributes to the limitation of follow current at normal power-frequency voltage.

3.63 valve protector: A protective device that includes a valve element.

3.64 virtual duration of wave front (applies to an impulse): The virtual value of the duration of the wave front is as follows:

a) For voltage waves with a wave front duration of less than 30 microseconds, either full or chopped on the front, crest, or tail, 1.67 times the time it takes for the voltage to increase from 30% to 90% of its crest value.
b) For voltage waves with a wave front duration of the 30 microseconds or greater, the time it takes for the voltage to increase from actual zero to maximum crest value.
c) For current waves, 1.25 times the time it takes for the current to increase from 10% to 90% of crest value.

3.65 virtual zero point (applies to an impulse): The intersection with the zero axis of a straight line drawn through points on the front of the current wave at 10% and 90% crest value, or through points on the front of the voltage wave at 30% and 90% crest value.

3.66 voltage rating: The voltage specified on the nameplate.

3.67 wave: The variation with time of current, potential, or power at any point in an electric circuit.

3.68 wave front (applies to a surge or an impulse): That part that occurs prior to the crest value.

3.69 wave shape designation: The shape of a nonrectangular impulse of current or voltage is designated by a combination of two numbers: The first, an index of the wave front, is the virtual duration of the wave front in microseconds as defined under 3.64 (virtual duration of wavefront). The second, an index of the wave tail, is the time in microseconds from virtual zero to the instant at which one-half of the crest value is reached on the wave tail. Examples are 1.2/50 and 8/20 waves.

3.70 wave tail (applies to an impulse): That part between the crest value and the end of the impulse.

4. Service conditions

4.1 Normal service conditions

Surge-protective devices conforming to this standard shall be capable of successful operation under the conditions listed in 4.1.1 and 4.1.2, the values of which may be specified by the manufacturer or user, as appropriate. (For standard test conditions, see 6.5.)

4.1.1 Physical conditions

a) Ambient temperature range
b) Atmospheric pressure range
c) Humidity conditions
d) Mechanical shock and vibration conditions

4.1.2 System conditions

a) Frequency range
b) Voltage range (see ANSI C84.1-1995)[6]
c) Available short-circuit current
d) Load current

4.2 Nonstandard service conditions

The service conditions listed in 4.2.1 and 4.2.2 may require special consideration in the design or application of surge-protective devices, and 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 manufacturer's specifications.

4.2.1 Physical conditions

a) Ambient temperature differing from the normal service conditions
b) 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

4.2.2 Unusual system conditions

a) Frequency differing from normal service conditions
b) Voltage excursions beyond normal service conditions
c) Unusual lightning and surge exposure
d) Repetitive impulses
e) Any other unusual conditions known to the user or included within the manufacturer's specifications

[6]Information on references can be found in Clause 2.

5. Safety and electromagnetic interference (EMI)

Many of the tests indicated in this standard are inherently hazardous. The safeguards for personnel and property described in this clause are essential.

Surge testing can generate significant amounts of electromagnetic interference (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.

Surge testing of surge-protective devices is best conducted only in an area dedicated solely to that purpose. The boundaries of the area should be clearly defined and appropriately marked. Where possible, the area should be fenced in 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 grounded. Consideration should be given to the possibility of the surge flashing over to circuits or metallic parts that were not intended to be surged. 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.

When the surge-protective device 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 has to be safe 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 allow safe access between tests.

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

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

a) The amount of combustible material likely to be involved initially
b) The probable rate of propagation
c) The consequences of such propagation; i.e., the probability of extension beyond the surge-protective device

Appropriate precautions should be taken to keep these factors within manageable limits. Precautions may consist of suitable extinguishing agents, in sufficient quantity, or 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 issues to consider 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 surge-protective device, 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 surge-protective device surge testing. On occasion, a component will 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 of sufficient thickness should be provided.

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 over-emphasized; safeguarding personnel has to be the prime consideration.

6. General test considerations

6.1 Safety

Voltage and energy levels are hazardous and appropriate care shall be exercised. See Clause 5 for details.

6.2 Surge-protective device test specimens

New and clean surge-protective devices shall be used for each test unless otherwise specified.

6.3 Connection

Connection terminals on the surge-protective device shall be clearly marked to facilitate correct connections to the user's circuit.

6.4 Mounting

The surge-protective device shall be mounted in the position for which it was designed to be used.

6.5 Standard test conditions

The tests in this standard are aimed at providing comparisons among the variety of surge-protective devices available. Comparison of the test results between two or more protective devices may be valid only if the tests have been performed under identical test conditions that are tailored to the intended use.

In the absence of other specific environmental standards, the following test conditions are recommended:

a) *Temperatures*—25 ˚C, +/– 5 ˚C
b) *Relative humidity*—Less than 85%
c) *Altitude*—Less than 2000 m
d) *Voltage*—Sinusoidal waveform, less than 5% total harmonic distortion
e) *Voltage (rms) tolerance*—According to ANSI C84.1-1995
f) *Frequency*—50 or 60 Hz, ±2 Hz
g) *Test wave shapes*—Per IEEE Std C62.41-1991
h) *Test metho*d—Per IEEE Std C62.45-1992

6.6 Categorization of tests

The following two test categories have been established and defined:

a) *Basic tests (BTs)*—Minimum tests that are required to establish the basic performance of the surge-protective device.
b) *Additional tests (ATs)*—Other tests that are needed to establish particular application requirements.

The performance characteristics may be applicable under several of the following test conditions:

— Fixed line voltage, fixed load, input surge
— Fixed line voltage, fixed load, no input surge
— Fixed line voltage, changing load, input surge
— Fixed line voltage, changing load, no surge

6.7 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 include the following:

a) Shorting or opening of any component
b) Flashover
c) Failure of a component in any one stage of a multi-stage unit
d) Increase in power-follow or leakage currents beyond specifications
e) Overheating which results in a hazardous condition
f) Irreversible change in characteristics of any component beyond the specification limit

7. Performance characteristics and test descriptions

The following performance characteristics and their associated tests were developed to assist in evaluating the relative performance of surge-protective devices.

NOTE—Test procedures should be conducted in accordance with Clause 6.

7.1 Surge response voltage test (BT)

The purpose of this test is to ensure that the voltage appearing at the output terminals of a surge-protective device does not exceed a specified maximum value for a given severity level, both during and after the impinging surge, until normal, stable conditions are reached.

NOTE—See Annex B and IEEE Std C62.45-1992.

7.1.1 Test description

The surges applied to the protective device to measure its surge response voltage shall be the combination wave, the 100 kHz ring wave, or other waveforms per IEEE Std C62.41-1991.

When the combination wave is used, the peak amplitudes of the open-circuit voltage and available short-circuit current waves shall be specified by the supplier or user of the protective device as appropriate, in accordance with specific severity levels.

When the 100 kHz ring wave is used, the peak open-circuit voltage and the short-circuit current amplitude shall be specified by the supplier or the user of the protective device, as appropriate, in accordance with specific severity levels.

7.2 Maximum continuous operating voltage (MCOV) (BT)

This is the maximum designated (rms) value of power frequency voltage that may be applied continuously between the terminals of the device. This voltage rating is based on the limitation of the device, as defined in 6.7, for the maximum ambient temperature at which the devices are expected to operate.

7.2.1 Test description

The purpose of this test is to verify that the device is capable of meeting reliability assurance requirements as specified by the manufacturer or user. Practical considerations dictate acceleration of the test by subjecting the device to the maximum continuous operating voltage (MCOV) at higher temperatures as noted below. However, a clear, unequivocal determination of this parameter is essential to reliable application of the devices, in view of the highly nonlinear response of metal-oxide varistors (MOVs) to changes in the applied voltage. For instance, a ±2% tolerance in the test voltage (not an unusual value for many test conditions) will result in a 350% change in current for a device with an exponent on the order of 30 (typical of varistors).

The test chamber environment shall be closely regulated and maintain a temperature within ±3 °C. Given the extreme sensitivity of the current to variations in voltage, it would be a fallacy to allow a tolerance of ±2% on the voltage. For a quoted MCOV applied at the low end of the tolerance, the device would receive an optimistic rating, while at the high end of the tolerance, the device would receive an overly conservative rating. Therefore, to avoid any misunderstanding or dispute over the rating, it will be prudent to specify an absolute minimum test voltage, as determined by a true-rms voltmeter of the so-called 5-1/2 digit type, with uncertainty of 0.2%, while monitoring the waveform to ascertain that it is sinusoidal.

Individual fusing of the devices is recommended. In the absence of special requirements, an ambient temperature of 85 °C and a duration of 1000 hours are recommended for these tests.

7.3 Maximum single withstand surge current test (BT)

This is a high-current impulse test intended to ensure the survival and integrity of a surge-protective device and its components when the rated peak single pulse is applied to specified terminals. Fuses that may be contained within the surge-protective device shall neither be removed nor bypassed for this test. Unless otherwise specified, this test is applied to a non-energized surge-protective device.

7.3.1 Test description

A single surge of 8/20 waveform, whose peak current is not less than the peak single pulse rating of the device under test, shall be applied to all specified terminals without device failure. Refer to 6.7.

7.4 Minimum surge life with line voltage applied (BT)

The purpose of this test is to assure that a protective device will not fail before a useful life has been obtained. This is established by requiring that the device survive without failure a minimum number of specified surges spaced sufficiently far apart so that cumulative heating will not occur.

7.4.1 Test description

The line side terminals of the device shall be connected to an ac power source of nominal system voltage (ANSI C84.1-1995) that has appropriate phase configuration, frequency, and short circuit current; alternatively, the rated maximum continuous operating voltage for the device under test may be specified. Surges shall be applied to the device, using appropriate test methods outlined in IEEE Std C62.45-1992. Each surge shall

a) Be a combination surge with a specified voltage and current magnitude.
b) Have the same polarity as the power-frequency waveform at the surge instant.
c) Be applied 90 (+0, –15) electrical degrees following the previous ac voltage zero crossing.

The maximum time between successive surges shall be 2 min. Testing shall continue until the specified number of surges have been applied or until the device fails.

Separate devices shall be used for each current level and each polarity tested.

7.5 Voltage regulation (BT)

Voltage regulation is a measure of the change in voltage at the output terminals of a device when a load is connected to its output terminals. This test is for load voltage regulation. The load on the output terminals is changed from zero to rated full-load of the device under test. In the absence of other specifications, the load is assumed to be essentially resistive.

7.5.1 Test description

The input terminals are connected to a stable source (+2%) of rated voltage and frequency. The input and output voltages are measured. A rated resistive full-load is connected to the output terminals. The input voltage is adjusted to its earlier reading. The output voltage is measured.

The voltage regulation is given by the following:

$$\frac{V\ (\text{no load}) - V\ (\text{full load})}{V\ (\text{no load})} \times 100$$

The above equation is expressed in percent. All voltages are measured using true-rms reading instruments.

7.6 Load current capability (AT)

The purpose of this test is to verify that a series-connected surge-protective device can safely conduct its rated full-load current to a load connected to its output.

7.6.1 Test Description

The surge-protective device is connected to a stable (+2%) source at rated voltage and frequency. A true-rms indicating current meter is connected in series with the output load (resistive unless otherwise specified). The output load current is increased until the surge-protective device manufacturer’s rating is attained. The test continues for 4 hours or until thermal equilibrium is observed, whichever is greater, without device failure.

7.7 Protection status indication (AT)

Protection status indication is an optional feature and shall not interfere with normal operations of the device. It provides a means to indicate the occurrence of a failure, or diminished capacity, of the protective device. Indication means may be visual, audible, or any other means appropriate to the intended use.

7.7.1 Test Description

Testing this function is limited to operational indicator tests. The tester shall simulate the surge-protective device in the failed condition, which is to be indicated. Then, the tester shall verify that the status indicators provide the appropriate response.

7.8 Standby power dissipation test (AT)

This test is used to measure the power dissipated in a protective device with no load current flowing, and no surges applied.

7.8.1 Test description

The tester shall connect an appropriate wattmeter between the line side of the device to be tested and a power source that has the rated operating voltage, frequency, and phase characteristics. Then, the tester shall measure the input power to the device with no connected load.

The wattmeter must measure true power regardless of the deviations of the voltage and current waveforms from ideal sinusoids. Wattmeter self-load power must be subtracted from the measured value.

7.9 Insulation resistance (AT)

This test measures the insulation resistance of the protective device.

7.9.1 Test description

The tester shall measure the resistance at the specified dc voltage from every exposed conductive surface to each terminal (including ground) and from each terminal to every other terminal. See IEEE Std C62.31-1987.

7.10 Dielectric withstand voltage (AT)

Devices shall be subjected to test voltages between each line-phase terminal and tied together with all of the following:

a) The ground terminal
b) The neutral terminal
c) Exposed conductive surfaces
d) Conductive foil wrapped around the enclosure if the latter is nonconductive
e) All of the other phase terminals

7.10.1 Test description

For this test, the overvoltage suppression elements and other components connected phase to neutral, phase to phase, or phase to ground are to be disconnected. In the test samples, these components may need to be removed by the manufacturer if they cannot otherwise be disconnected for test purposes.

The open-circuit 1.2/50 impulse voltage shall be 6 kV. (See UL 1449-1996.)

CAUTION: If the test voltage exceeds the clamping voltage or discharge voltage of any surge-protective device within the surge-protective device assembly, the component surge-protective device may indicate a false dielectric withstand voltage.

7.11 Failure safety mode

To evaluate failure mode(s) under abnormal system conditions a test of failure modes shall be performed as specified in UL 1449-1996. When the referenced publication is updated, the revised document shall be used.

7.11.1 Test Description

UL 1449-1996 describes the test conditions and criteria of acceptance for three types of abnormal system conditions, including the following:

a) High available fault current at 125% voltage
b) High available fault current at either 1.73 or 2.0 times line voltage
c) Controlled fault current at either 1.73 or 2.0 times line voltage

Testing of each conductor combination is recommended, and testing at additional controlled fault current levels beyond those specified in UL 1449-1996 (such as 50% and 80% of the device under test circuit rating) are advisable to yield a comprehensive assessment of response to abnormal system conditions.

7.12 Response to front of wave

The surge voltage response behavior of a surge-protective device to the front of a wave depends on the rate-of-rise of the incident wave, the impedance of the surge source, the effects of protective device internal reactance, and the response behavior of conduction mechanisms within active suppressor elements.

In other words, response to front of wave can be affected more by the test circuit conditions, including connecting lead inductance, than by the speed of response of active elements.

Furthermore, the peak value of the surge voltage response, measured under specified conditions, is the characteristic of paramount interest for surge protection purposes; see 6.5 and Annex B, Figure B.1 through Figure B.4.

Consequently, specification of response to front of wave is deemed to be potentially misleading and an unnecessary requirement for typical applications of devices within the scope of this standard. In the absence of specific requirements, it is recommended that no specification, test, measurement, calculation, or other recognition shall be given for response to front of wave.

8. Construction

8.1 Enclosure

Surge-protective devices intended for connection to low-voltage power circuits may be categorized by their installation location.

8.1.1 Devices for outdoor installation

These devices have a weather-proof enclosure. The connection may be permanent, or may use plug connectors for portable applications.

8.1.2 Devices for indoor installation

The following two categories are defined:

a) *Devices for permanent connection*—These devices are packaged in an enclosure that allows permanent connection to the building wiring system. Typical installation locations are at the service entrance [Accredited Standards Committee C2-1997, National Electrical Safety Code® (NESC®)]. or branch circuit equipment.

b) *Devices for plug-in installation*—These devices are packaged in a manner suitable for plugging into low-voltage receptacles and fitted with a matching female connector from which the load equipment can be powered. Thus, these devices might be connected on a branch circuit of undefined length.

8.2 Overcurrent protection

Coordinated overcurrent protection devices may be required with an surge-protective device in order to reduce the likelihood of fire or explosion if the device fails or if a short-circuit occurs at the output side of the surge-protective device. The overcurrent device may be located within the surge-protective device housing, or existing external devices may be employed. For example, the branch-circuit fuse or circuit breaker might suffice for indoor surge-protective devices; whereas, weather head (outdoor) devices may be protected by the transformer fuse upstream.

The interrupting rating of the overcurrent device shall exceed the short-circuit fault current available in the installation.

Annex A

(normative)

Regulatory requirements

The design, device packaging, production, quality control, and installation of these devices may be impacted by the regulations of federal, state, and local governmental agencies that have granted legal status to national electrical codes. In many cases these regulations will include requirements for construction permits, and inspection by electrical inspectors (the *authority having jurisdiction*, and provisions for products to be *Listed, Labeled*, or *Approved*).

In the United States, Article 280 of the National Electrical Code® (NEC®) (NFPA 70-1999) affects surge arresters installed on premises wiring systems. In Canada, the Canadian Electrical Code and product certification listing are administered by the Canadian Standards Association (CSA).

The authority having jurisdiction is the organization, office, or individual having statutory approval responsibility for material, equipment, and installation, or procedure. Statutory authority may be vested in a federal, state, local, or regional department, or in an individual. In many circumstances, the authority may be an insurance company, a property owner, or a commanding officer.

Equipment or material is approved if it is acceptable to the authority having jurisdiction. The authority may base acceptance on compliance with NFPA 70-1999 or other appropriate standards, or on the listing or labeling practices of product evaluation organizations.

A listing organization is a nationally recognized testing organization acceptable to the authority having jurisdiction.

Listed equipment or material is included in a list published by a listing organization concerned with product evaluation. This organization maintains periodic inspection of production of the listed equipment or material. The listing entry states either that the equipment or material meets appropriate standards, or has been tested and found suitable for use in a specified manner.

Some listing organizations require that listed equipment or material be labeled. This means that a specific label, symbol, or other identifying mark has been attached to the listed equipment or material, signifying that the manufacturer of listed equipment or material complies with appropriate standards or performance in a specified manner.

Two product categories are generally recognized when listing surge-protective devices on low-voltage ac circuits:

a) Surge arresters as covered in NEC Article 280, and tested per IEEE Std C62.1-1989 or IEEE Std C62.11-1999. Surge arresters may be connected on the line or load side of service disconnect equipment.
b) Transient voltage surge suppressors (TVSS) are tested per UL 1449-1996. TVSS may be connected only on the load side of service-disconnect equipment.

Annex B

(informative)

Figures and definitions

(This annex is not a normative part of IEEE Std C62.62-2000, IEEE Standard Test Specifications for Surge-Protective Devices for Low-Voltage AC Power Circuits).

SPD—Acronym for surge-protective device.

Surge-Response Voltage—The surge-response voltage can involve any one or a group of the following parameters:

a) Discharge voltage
b) Surge let-through
c) Voltage overshoot
d) Clamping voltage
e) Response time
f) Arc voltage
g) Impulse breakdown voltage
h) Surge remnant
i) Oscillation

Figure B.1 through Figure B.4 show idealized surge response voltages for various types of surge-protective devices.

NOTE—The circuits illustrated may not be practical representation of surge arresters or suppressors. They are shown for tutorial purposes to depict the operation of surge-protective devices and the meanings of some of the definitions in this document.

Figure B.4, in particular, features a hybrid circuit composed of a gas tube, an avalanche or varistor device, and an intermediate impedance. This circuit is shown only to illustrate the resulting clamping action that would occur. The reader is cautioned that this is not a practical application because the gas tube could pass large power-frequency currents, which would likely damage the tube and alter it protection characteristics, or cause an upstream overcurrent protector to operate, dropping power to the load.

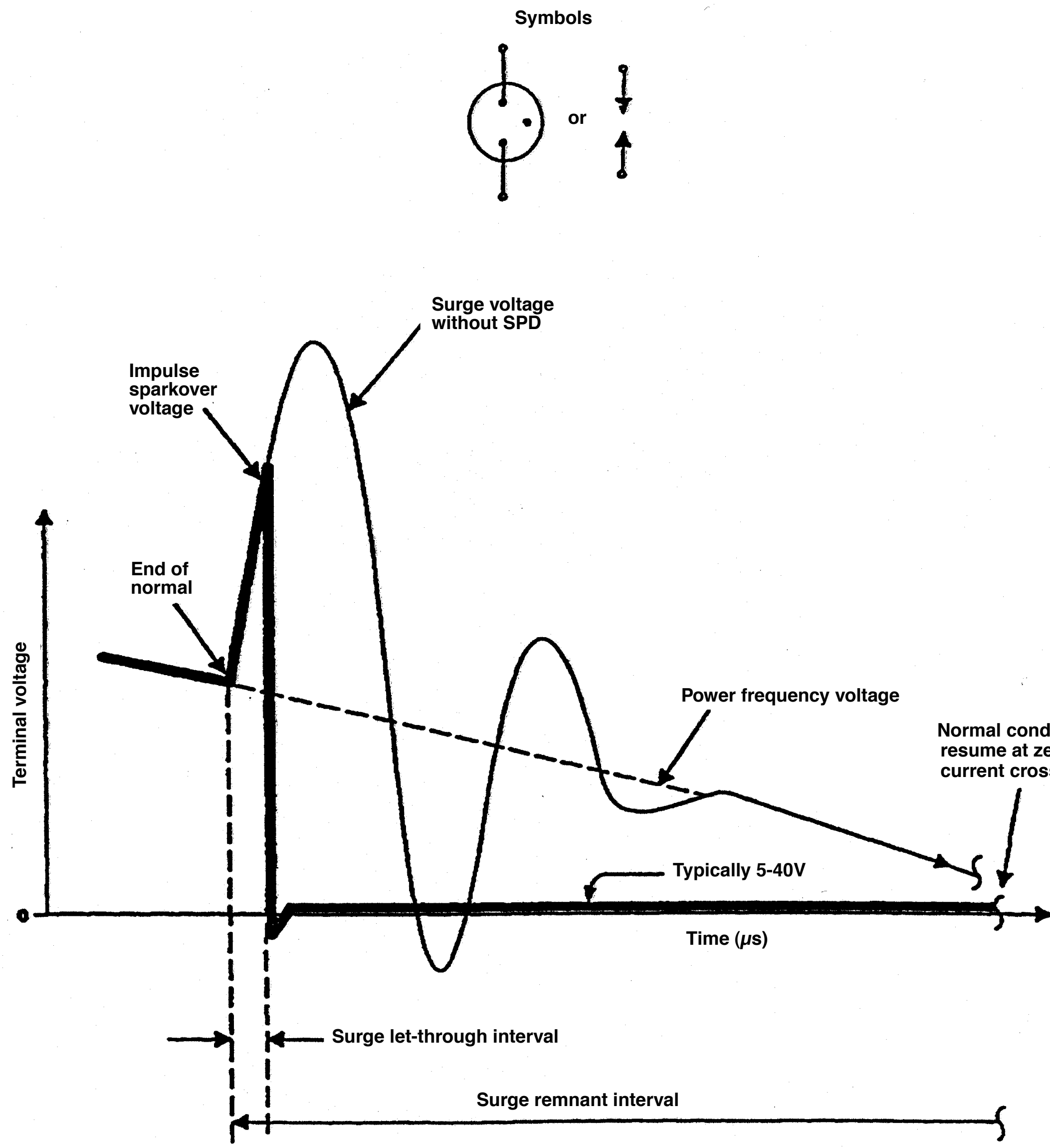

Figure B.1—Idealized surge-response voltage for gap devices

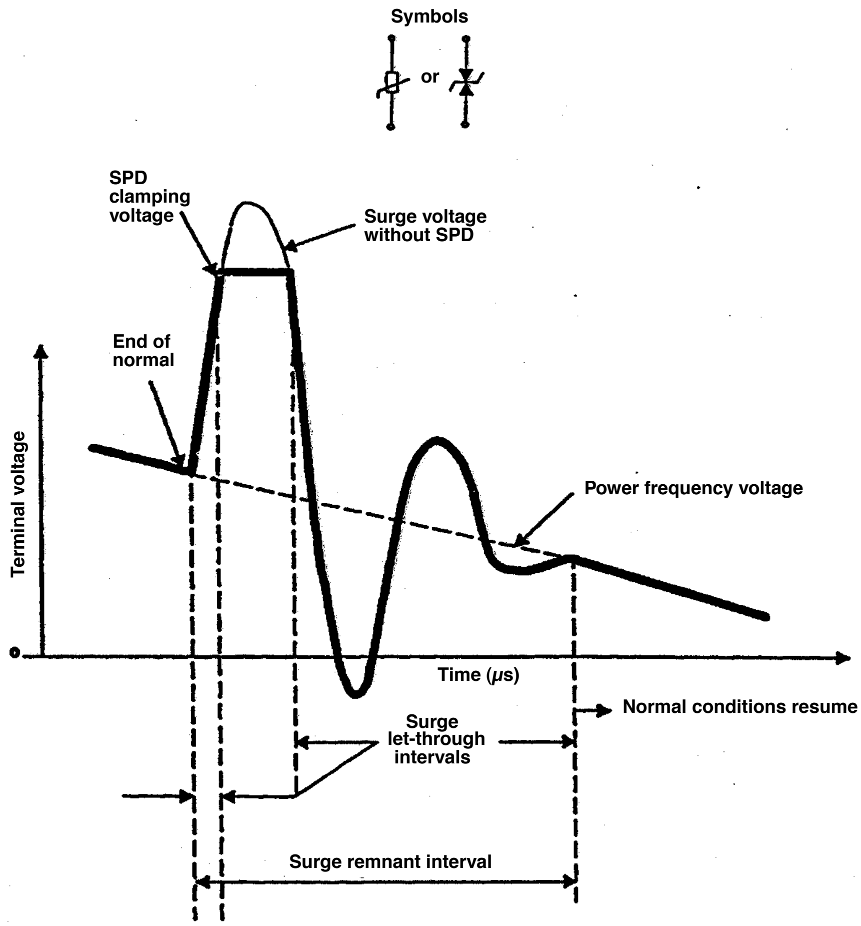

Figure B.2—Idealized surge-response voltage for gap devices

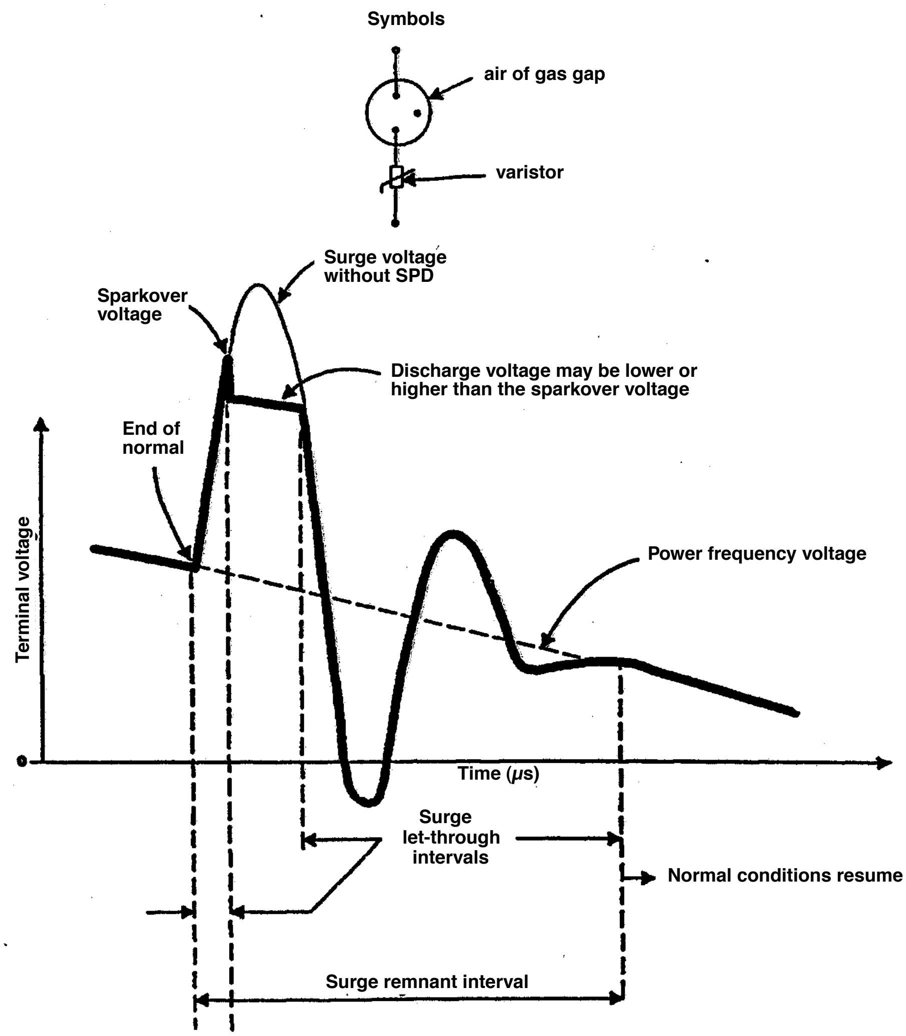

Figure B.3—Idealized surge-response voltage for metal oxide varistor or silicon avalanche devices

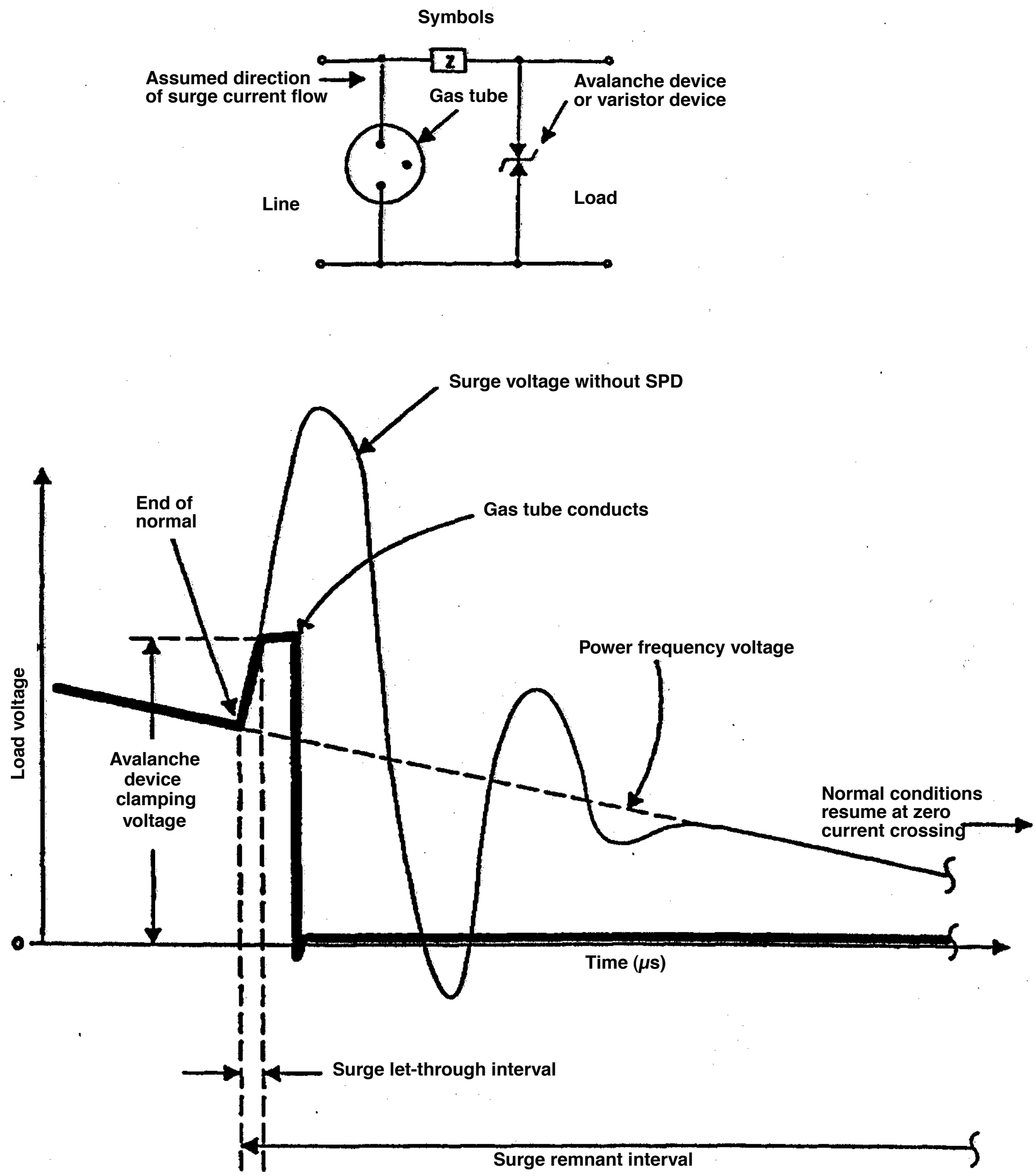

Figure B.4—Idealized surge-response voltage for multiple devices

Annex C

(informative)

Bibliography

[B1] Herr, E. et al. Reliability Evaluation and Prediction for Discrete Semiconductors, *IEEE Transactions on Reliability,* Volume R-29, # 5, August 1980.

[B2] IEEE 100-1996, *The IEEE Standard Dictionary of Electrical and Electronics Terms,* Sixth Edition.

[B3] Korn, S. R., Transients and Transient Suppressors for Power Conversion Equipment, INTELEC Conference, October 1982.

[B4] Martzloff, F. D., Coordination of Surge Protectors in Low-Voltage AC Power Circuits, *IEEE Transactions on Power Applications and Systems,* vol. PAS-99, no. 1, Jan/Feb 1980, pp. 129-133.

[B5] Martzloff, F. D., The Coupling, Propagation, and Side Effects of Surges in an Industrial Building Wiring System, *Proceedings of the IEEE Industrial Applications Society Annual Meeting,* Pittsburgh, October 1988.

[B6] Martzloff, F. D., The Propagation and Attenuation of Surge Voltages and Surge Currents in Low-Voltage AC Power Circuits, *IEEE Transactions on Power Applications and Systems,* vol. PAS-102, no. 5, May 1983.

[B7] Richman, P., Changes to Classic Surge-Test Waves Required by Back-Filters Used for Testing Powered Equipment, Proceedings of the 6th Symposium on EMC, Zurich, March 1985, pp. 413-419.

[B8] Richman, P., Single-Output Voltage and Current Generation for Testing Electronic Systems, Proceedings of the IEEE EMC Symposium, 1983, pp. 14-28.

[B9] Standler, R.B., *Protection of Electronic Circuits from Overvoltages,* Wiley-Interscience, New York, 1989.