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Part 1—Surge Protective Device Specification Guide for Low Voltage Power Distribution Systems

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Foreword

This foreword is not part of NEMA SPD1.1—*Surge Protective Device Specification Guide for Low Voltage Power Distribution Systems—Part 1.*

A properly derived and professionally presented product specification enhances the credibility of a manufacturer as it clarifies and verifies the characteristics and capabilities of their product. A manufacturer should completely describe the product by using an accurate product specification sheet.

This guide represents the consensus of NEMA's Low Voltage Surge Protective Device (SPD) Section 5VS. It is intended to serve primarily as a guide for those who use or specify SPDs and others affiliated with the Low Voltage SPD marketplace so that uniformity of specifications, in terms of valid, understandable parameters, will improve the comprehension, application, and utilization of SPDs. The parameters will be defined in adequate detail to allow the user to make a proper interpretation of the relevant specifications and evaluation of aspects necessary for the application. The methods associated with their measure or derivation will be referenced, though most are extensively addressed, since adequate procedural definition and discussion is already available in NEMA, ANSI, IEEE, UL and IEC technical publications.

Historically, SPDs have been known as a Transient Voltage Surge Suppressors (TVSS) or Secondary Surge Arresters (SSA). To harmonize with modern technical literature and international nomenclature, the term "Surge Protective Device" or "SPD" has been adopted to refer to the same product.

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> Technical Director, Operations
> National Electrical Manufacturers Association
> 1300 North 17th Street, Suite 900
> Rosslyn, Virginia 22209

The information detailed in this guide is intended to identify the system compatibility and performance ratings of a surge protective device (SPD) that should be addressed by the manufacturer of the SPD. As such, the ratings detailed herein may not apply to every SPD and/or SPD application. In other applications, the complete list of ratings detailed herein, plus others, may be required to meet the protection needs of the end-use equipment or power distribution system.

For safety requirements of the SPD (i.e., electric shock, overcurrent protection and protection against fire hazard) this document references testing and evaluation to the appropriate safety standards. In the US, the primary standard is ANSI/UL 1449. In Canada, the primary standard is CSA C22.2, No. 269 series. In some countries, the primary standard is IEC 61643-11. The requirements of the above standards do not evaluate the effect of SPDs on connected loads, the effect of SPDs on harmonic distortion of the supply voltage, the degree of attenuation provided by SPDs, nor the adequacy of the Voltage Protection Rating of SPDs to protect specific connected equipment from upset or damage.

This Specification Guide supersedes the rescinded LS1-1992 Standard.

References to the *National Electrical Code*® (NEC) are from the 2017 Edition unless otherwise indicated. NFPA 70®, *National Electrical Code*® and NEC are registered trademarks of the National Fire Protection Association, Quincy, MA.

This document consists of: a) Specifications Introduction—Terms, definitions and acronyms, b) Specification documentation, c) SPD ratings, and d) Specification Format—a standard format is presented for specifying, defining requirements and reporting SPD specifications and applications. This Specification Guide was developed by NEMA Low Voltage Surge Protective Devices Section (5VS). The section approval of the guide does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the section was composed of the following members:

ABB Industrial Solutions	Plano, TX
ABB Power Protection, LLC.	Richmond, VA
ASCO Power Technologies	Clearwater, FL
CITEL Inc.	Miramar, FL
Eaton Corporation	Pittsburgh, PA
Emerson Automation Solutions	Rosemont, IL
Hubbell Inc.	Shelton, CT
Legrand/Pass & Seymour	Syracuse, NY
Leviton Manufacturing	Chula Vista, CA
Littelfuse, Inc.	Chicago, IL
Mersen USA	Newburyport, MA
MVC-Maxivolt	Amarillo, TX
Pentair Engineered Electrical & Fastening Solutions	Solon, OH
Phoenix Contact	Middletown, PA
Raycap, Inc.	Post Falls, ID
Schneider Electric USA	Salt Lake City, UT
Siemens Industry, Inc.	Norcross, GA
Southwire Company	Clearwater, FL
Space Age Electronics	Sterling, MA
Surge Suppression, LLC	Brooksville, FL

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Section 1
General

1.1 Scope

This specification guide is Part 1 of a series of such guides that is intended to provide guidance on the evaluation, specification and/or use of surge protective devices (SPDs) deployed in low voltage power distribution system applications. This specification guide describes a uniform specification methodology for SPDs, containing at least one non-linear component, that are connected to or within a 50/60 Hz power distribution equipment that is rated up to 1000 Vac. Such SPDs are specifically intended to mitigate the transient overvoltage effects to end-use equipment.

This guide is not intended to introduce new standards, derive tests, create an evaluation methodology, or define extensive vocabulary. It is intended to guide those who are evaluating and/or comparing the essential parameters of SPDs. The parameters being compared are measurable using available commercial test equipment and/or established standards and measurements as referenced in Section 1.2.

1.1.1 Purpose

The purpose of this specification guide is to complete the Specification Checklist included in Section 4. Sections 1-3 and the included annexes are to provide guidance and definition for the compilation of the data required to complete the Specification Checklist.

Note: Locating the checklist at the end of the guide encourages the user to consider the guidance provided ahead of the checklist.

1.2 References

The following publications are adopted in part, by reference in this publication, and are available from the organizations below.

1.2.1 Normative References

The following normative documents contain provisions, which through reference in this text, constitute provisions of this standards publication. By reference herein, these publications are adopted, in whole or in part as indicated, in this standards publication.

The Institute of Electrical and Electronics Engineers
Three Park Avenue
New York, NY 10016-5997 USA

ANSI/IEEE Std. C62.41.2	*IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and less) AC Power Circuits*
ANSI/IEEE Std. C62.45	*IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000V and Less) AC Power Circuits*
ANSI/IEEE Std. C62.62	*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*
ANSI/IEEE Std. C62.72	Guide for the Application of Surge-Protective Devices for Use on the Load Side of the Service Equipment in Low-Voltage (1000 V or Less, 50 or 60 Hz) AC Power Circuits

National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
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ANSI C84.1	*Electrical Power Systems and Equipment—Voltage Ratings (60Hz).*
NEMA 250	*Enclosures for Electrical Equipment (1000 Volts Maximum)*

Underwriters Laboratories
333 Pfingsten Road
Northbrook, IL 60062-2096 U.S.A.

ANSI/UL 1449	*Standard for Safety - Surge Protective Devices*

1.3 Definitions

Category A, B, or C: Categories (as defined by ANSI/IEEE Std. C62.41.2) used to classify the expected electrical surge environment at which the SPD might be installed. Category A refers to power outlets and long branch circuits. Category B refers to short branch circuits near the branch distribution panel, and those feeders approaching the service entrance panel. Category C refers to the area where external power services or the primary service entrance panel to the facility to those feeders approaching the distribution panel.

Combination Wave: A surge delivered by a generator which has the inherent capability of applying a 1.2/50 µs voltage wave across an open circuit, and delivering an 8/20 µs current wave into a short-circuit. The exact wave that is delivered is determined by the generator and instantaneous impedance to which the combination surge is applied.

Degradation: Change of original performance parameters as a result of exposure of the SPD to surge, service, or unfavorable environment. (ANSI/IEEE C62.62-2010)

Note: ANSI/IEEE C62.62-2010. Reprinted with permission from IEEE. Copyright IEEE 2010 - All Rights Reserved.

In-Line 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. (ANSI/IEEE C62.62-2010).

Note: 1—In-line SPDs were formerly referred to as "Kelvin-Connected SPDs."
Note: 2—ANSI/IEEE C62.62-2010. Reprinted with permission from IEEE. Copyright IEEE 2010 - All Rights Reserved.

Leakage Current: Current flowing from the live parts of the installation to earth, in the absence of an insulation fault.

Listed (certified): Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production listed equipment or materials or periodic evaluation of services, and whose listing states that the equipment, material, or services either meets appropriate designated standards or has been tested and found suitable for a specified purpose.

Maximum Continuous Operating Voltage (MCOV): The maximum rms voltage that may be continuously applied to the SPD for each connected mode.

Note: MCOV is evaluated by the certifier and is published as part of the product certification. The symbol, U_C, is used in some international standards to represent MCOV.

Measured Limiting Voltage (MLV): The maximum magnitude of voltage that is measured across the leads, terminals, receptacle contacts, or similar locations of the SPD during the application of impulses of a specified wave shape and amplitude.

Mode of Protection: An SPD's protective component(s) might be connected wherever defense is desired against transient over voltages. These can include Line to Neutral (L-N), Line to Ground (L-G), Line to Line (L-L) and Neutral to Ground (N-G).

Nominal Discharge Current (i_n) Rating: Peak value of the surge current through the SPD, selected by the manufacturer from a list of predetermined values, having a short-circuit current wave shape of 8/20 µs where the SPD remains functional after 15 surges

> Note: Nominal Discharge Current Rating is evaluated by the certifier and is published as part of the product certification.

Nominal System Voltage (V_O): A value assigned to designate a system of a given voltage class in accordance with ANSI C84.1, Table 1.

Open-Type SPD: A Type 1, 2 or 3 SPD, with an incomplete or partial enclosure and with field wiring terminals and/or leads, suitable for field installation, in accordance with the ANSI/NFPA 70 - National Electrical Code®, within a suitable enclosure. (ANSI/UL 1449)

> Note: References to the National Electrical Code® (NEC®) are from the 2017 Edition unless otherwise indicated. NFPA 70®, *National Electrical Code*®, and *NEC*® are registered trademarks of the National Fire Protection Association, Quincy, MA.

One-Port SPD: A surge protective device (SPD) connected in shunt with the circuit to be protected. (ANSI/IEEE Std C62.62)

Rated Load Current (I_L): Maximum continuous rated rms current that can be supplied to a load connected to the output of a two-port or in-line SPD.

Secondary Surge Arrester (SSA): An SPD intended for connection on the line side of the service equipment that has not been listed/certified to ANSI/UL 1449.

> Note: The term secondary surge arrester is a legacy term (often used by utilities). The term Type 1 SPD is intended to replace this term.

Service Equipment: The necessary equipment, consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the utility electric system and intended to constitute the main control and disconnect of the utility electric system. (NFPA 70®-2017, National Electrical Code®)

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Short-Circuit Current Rating (SCCR): The suitability of an SPD for use on an AC power circuit that is capable of delivering not more than a declared rms symmetrical current at a declared voltage during a short-circuit condition. (ANSI/UL 1449)

> Note: Often short-circuit current ratings are confused with surge current ratings. The two ratings are not the same.

SPD Enclosure Protection Rating: Describes the degree of environmental protection provided by the enclosure per NEMA 250 of the SPD final assembly as it leaves the manufacturing facility and is installed per manufacturers' recommendation.

SPD Location: The intended placement of the SPD, either external or internal to power distribution or end-use equipment.

Note: See also IEEE Category Locations A, B, C.

SPD Types: A term originating from ANSI/UL 1449 to describe the intended application location of the SPD, either upstream or downstream of the main overcurrent protective device of the facility. Refer to the definitions for Type 1, Type 2, and Type 3 SPDs, Type 4 Component Assembly, and Type 5 Components.

Status Indicator: A device that indicates the operational condition of an SPD, or a part of an SPD.

Surge Protective Device (SPD): A device that contains at least one nonlinear component and is intended to limit surge voltages and divert surge currents.

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

Type 1 Component Assembly: Consists of a Type 4 Component Assembly with internal short-circuit protection or [safety] disconnector that is intended for use as a Type 1 SPD. (ANSI/UL 1449)

Note: Type 1 Component Assemblies are recognized components rather than listed/certified. These components assemblies have conditions of acceptability that are usually related to having exposed terminals or the requirement to be installed within another enclosure.

Type 2 SPD: A permanently connected SPD intended for installation on the load side of the service disconnect overcurrent device, including SPDs located at the branch panel and Molded Case SPDs. (ANSI/UL 1449)

Type 2 Component Assembly: Consists of a Type 4 Component Assembly with internal or external short-circuit protection or [safety] disconnector that is intended for use as a Type 2 SPD. (ANSI/UL 1449)

Note: Type 2 Component Assemblies are recognized components rather than listed/certified. These components assemblies have conditions of acceptability that are usually related to having exposed terminals, the requirement to be installed within another enclosure or a requirement for external/supplemental overcurrent protection.

Type 3 SPD: Point of utilization SPDs, installed at a minimum conductor length of 10 m (30 ft) from the electrical service panel (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. (ANSI/UL 1449)

Note: 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.

Type 3 Component Assembly: Consists of a Type 4 Component Assembly with internal or external short-circuit protection or [safety] disconnector that is intended for use as a Type 3 SPD. (ANSI/UL 1449)

Note: Type 3 Component Assemblies are recognized components rather than listed/certified. These components assemblies have conditions of acceptability that are usually related to having exposed terminals, the requirement to be installed within another enclosure or a requirement for external/supplemental overcurrent protection.

Type 4 Component Assembly: Component assembly consisting of one or more Type 5 components together with a [safety] disconnector (integral or external) or a means of complying with the limited current abnormal overvoltage tests. (ANSI/UL 1449)

Type 5 Component: Discrete component surge protective components, (such as MOVs, gas [discharge] tubes, ABDs, etc.) that may be mounted on a printed wiring board, connected by its leads or provided within an enclosure with mounting means and wiring terminations. (ANSI/UL 1449)

Two-port SPD: SPD with two sets of terminals, input, and output. A specific series impedance is inserted between these terminals. (ANSI/IEEE C62.62-2010)

Voltage Protection Rating (VPR): A rating per ANSI/UL 1449, signifying the average Measured Limiting Voltages of a mode of protection within an SPD when the SPD is subjected to the surge produced by a 6 kV, 3 kA Combination Waveform generator.

Note: The VPR is determined by averaging the Measured Limiting Voltages of a particular mode and selecting the next highest rating from a list of preferred values. The VPR is evaluated by the certifier and is published as part of the product certification.

Voltage Regulation (V_L): A variation in the output voltage of a two-port or in-line SPD when subjected to maximum rated load condition, measured in percent of the source voltage applied to the input terminals of the SPD.

1.4 Acronyms

ABD	Avalanche Breakdown Diode
AC	Alternating Current
ANSI	American National Standards Institute
GDT	Gas Discharge Tube
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
MCOV	Maximum Continuous Operating Voltage
MLV	Measured Limiting Voltage
MOV	Metal Oxide Varistor
NEC®	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NRTL	Nationally Recognized Testing Laboratory
OSHA	Occupational Safety and Health Administration
PDS	Power Distribution System
RMS	Root Mean Square
SCCR	Short-Circuit Current Rating
SP	Standards Publication
SPC	Surge Protective Component
SPD	Surge Protective Device
SSA	Secondary Surge Arrester
TVSS	Transient Voltage Surge Suppressor
UL	Underwriters Laboratories
VPR	Voltage Protection Rating

Section 2
SPD Specification Documentation

For each SPD specified, documentation of the product's performance and safety are to be provided. The system compatibility and product performance characteristics of an SPD are:

a. Nominal system voltage (V_O)
b. Power distribution system configuration of the SPD
c. SPD Type
d. SPD Location
e. Rated load current (I_L) (two-port and In-line SPDs only)
f. Voltage regulation (V_L) (two-port and In-line SPDs only)
g. Maximum Continuous Operating Voltage (MCOV)
h. Short Circuit Current Rating (SCCR)
i. Voltage Protection Rating (VPR)
j. Measured Limiting Voltage(s) and the description of the test(s) used
k. Modes of protection
l. SPD enclosure rating
m. SPD Safety Agency Certifications
n. Nominal Discharge Current (I_N)
o. Description of external SPD safety disconnector (if required)
p. Surge Current Rating
q. Leakage Current
r. Status Indicator

For each SPD performance characteristic specified, the following information should be included if requested:

a. The test procedures used
b. A checklist detailing the features of the SPD that were installed during the testing of the device, e.g., fuses, circuit breakers, capacitors, status circuitry, etc.
c. The test results that show compliance to the published specifications
d. Agency Approvals

Note: Although this NEMA Guide does not require independent third-party testing, a list of nationally recognized testing laboratories (NRTL's) are identified by OSHA at http://www.osha.gov/dts/otpca/nrtl/

Documentation that provides evidence of the SPD performance characteristics should include relevant test procedures, atmospheric conditions, test equipment, measurement methods, calibration data, performance data, summary results, and any additional support information required to analyze the performance of the SPD under specific conditions.

Section 3
SPD Ratings

3.1 Introduction

There are two sets of ratings for an SPD. Some ratings relate to the operating system (Section 3.2) in which the SPD is to be installed and are used to coordinate the SPD with the power distribution system at the point of application. Others relate to SPD performance (Section 3.3). These characteristics include features of the SPD and its ability to limit specific transients. It is highly recommended that the grounding and bonding system be verified.

3.2 SPD Ratings Related to the Operating System

System-related operating ratings are required to ensure that the SPD specified or chosen is appropriate for the installation location in the power distribution system within a facility. The system related operating ratings for the SPD include:

a. Power distribution system configuration of the SPD and Nominal system voltage (V_O)
b. SPD Location and Type
c. Maximum Continuous Operating Voltage (MCOV)
d. Short Circuit Current Rating (SCCR)
e. Rated load current (I_L), (two port and in-line SPDs only)
f. Voltage regulation (V_L), (two port and in-line SPDs only)

It is important to note that the correct selection of the ratings for the SPD depends on the configuration of the power distribution system to which it is connected.

3.2.1 Power Distribution System Configuration and Nominal System Voltage

The power system configuration of the SPD dictates what type of power distribution system to which it can be applied. This configuration is commonly part of the nomenclature or description of the SPD itself. When specifying an SPD, the configuration of the SPD should match the configuration of the power distribution system. Further, in some cases such as the ungrounded delta system, the SPD must be specifically listed for this power system configuration as noted in NFPA 70 Article 285.3(2). Examples of power distribution system and SPD configurations are given below. Often these are referred to more generically as a “single phase,” “wye” or “delta” connected SPD.

Nominal System Voltage (V_O) is a value assigned to designate a system of a given voltage class in accordance with ANSI C84.1, Table 1.

A non-exhaustive list of example power distribution system configurations and nominal system voltages is provided in Table 3-1.

Table 3-1
Common Power Distribution System Voltages

Nominal System Voltage	Power Distribution System Configuration	Number of Conductors
120	Single phase	2W+G
120D	3-phase ungrounded delta	3W+G
127	Single phase	2W+G
120/240	Single (split) phase	3W+G
208Y/120	3-phase wye	4W+G
208D	3-phase ungrounded delta	3W+G
220Y/127	3-phase wye	4W+G
220	Single phase	2W+G

Nominal System Voltage	Power Distribution System Configuration	Number of Conductors
230	Single phase	2W+G
240	Single phase	2W+G
240D/120	3-phase high-leg delta	4W+G
240D	3-phase ungrounded delta	3W+G
240D	3-phase corner grounded delta	3W+G
380Y/220	3-phase wye	3W+G
400Y/230	3-phase wye	4W+G
480Y/277	3-phase wye	4W+G
480D	3-phase ungrounded delta	3W+G
480D	3-phase corner grounded delta	3W+G
600Y/347	3-phase wye	4W+G
600D	3-phase ungrounded delta	3W+G

All points within the power distribution system, including the SPD, are to be installed and maintained in accordance with the local code and/or appropriate national electrical code.

3.2.2 SPD Locations and Types

SPDs (including Open-Type SPDs) can be located throughout the power distribution system. They can be connected upstream (on the line or utility side) of the service equipment or downstream (on the load side) of the service equipment for the facility. In either case, the local code and/or appropriate national electrical code govern the applications of SPDs in these locations.

SPD installation locations are referred to by SPD Type in ANSI/UL 1449. SPDs permitted to be installed on the line side of the service equipment are denoted as Type 1 SPDs and Open-Type 1 SPDs. Type 1 SPDs are also permitted to be installed on the load side of the service equipment. Type 2 SPDs and Open-Type 2 SPDs are only permitted to be installed on the load side of service equipment and might require an external safety disconnector. Type 3 SPDs and Open-Type 3 SPDs are installed on the load side of the service equipment. Type 1, 2 and 3 SPDs, Open-Type 1, 2, and 3 SPDs, and Component Assemblies are marked with Voltage Protection Ratings (VPRs) when listed/certified to ANSI/UL 1449.

> Note: The terms “service equipment” and “service disconnect” are used interchangeably in Clause 285 of the NEC (2017 revision). Therefore, references in this standard to the “service equipment” are to be understood to include what is referred to as the “service disconnect.”

Another recent addition to the UL SPD types are the Open-Type SPDs. For example, an Open-Type 1 SPD is similar to a Type 1 SPD except that it does not have a complete enclosure. The SPD must meet the full requirements like that of a complete SPD, but it is intended to be installed into an existing enclosure. The Open-Type 1 SPD must have suitable field or factory wiring terminations included on the device.

> Note: Although outside the scope of this standard, Type 4 Component Assemblies and Type 5 Components are defined as partial assemblies or surge protective components that require additional packaging and testing in order to be installed on the electrical distribution system. Type 4 and 5 SPDs have Measured Limiting Voltage (MLV) ratings determined at various surge levels only and not VPRs when listed/certified to ANSI/UL 1449. These ratings might be determined at different levels than those reported in Section 5.

SPDs can be installed either internal or external to switchgear, panelboards, end-use equipment, etc. Some SPDs (component assemblies and recognized components) have conditions of acceptability that must be met to permit their use in particular applications. Consult the SPD manufacturer regarding how to address conditions of acceptability for SPD component assemblies. Further, consult with the manufacturer when installing SPDs internal to end-use equipment. See Section 2 for the definitions of SPD Types.

Note: Procuring SPDs and SPD installation may be simplified by appreciating that the term “single phase” may have colloquial meanings of ‘true single phase’ or ‘split phase.’ Also, be aware that many SPDs are voltage specific and may have specific wiring instructions for Corner Grounded Delta’s (Phase B is normally grounded) and Hi-Leg Delta’s (Phase B is normally the Hi-Leg).

3.2.3 Maximum Continuous Operating Voltage (MCOV)

The SPD has a characteristic of being able to withstand a continuous voltage that is greater than the nominal system voltage of the power distribution system. It is recommended that the Maximum Continuous Operating Voltage be greater than or equal to 115 percent of the nominal system voltage to accommodate normal fluctuations within a power system.

The Maximum Continuous Operating Voltage is required to be on the product data label of the SPD and in the installation instructions and/or operation manual.

Maximum Continuous Operating Voltage is a parameter declared by the manufacturer on the basis of several considerations, e.g., ambient temperature, exposure to surges, actual system voltage, definition of an end of life criteria, SPD topology.

For SPDs listed/certified to ANSI/UL 1449 (and/or tested in accordance with ANSI/IEEE Std. C62.62), the MCOV is a required marking, and the declared value is verified during the Nominal Discharge Current Test.

3.2.4 Short Circuit Current Rating (SCCR)

The SPD is required to be marked with a Short Circuit Current Rating (SCCR). As per NFPA 70, Article 285, the SCCR of the SPD shall be equal to or greater than the available short-circuit current of the system at the point of installation. The Short Circuit Current Ratings detailed in ANSI/UL 1449 for SPDs (in thousands of amperes, kA) include:

5, 10, 14, 18, 22, 25, 30, 42, 50, 65, 85, 100, 125, 150, 200

The testing methodology is specified in ANSI/UL 1449, Standard for Safety for Surge Protective Devices.

3.2.5 Rated Load Current (Two-Port and In-Line SPDs Only)

The rated load current of the SPD applies to two-port SPDs (which have an intended series impedance) and In-line SPDs (which have separate input and output terminals but no intended series impedance). The rated load current is the amount of steady-state current that the SPD can conduct through to the load without causing damage to the SPD due to excess heat buildup or mechanical stress. It is important to ensure that for a two-port or in-line SPD operating at rated load current, that the series voltage drop or voltage regulation is acceptable to the load. Common rated load currents, in amps, of two-port or in-line SPDs include:

5, 10, 15, 20, 30, 50, 75, 100, 200, 225, 250, 400, 600, 800, 1,000, 1,200, 1,600, 2,000, 3,000, 4,000

3.2.6 Voltage Regulation (Two-Port and In-Line SPDs Only)

Voltage regulation (V_L) is calculated by the equation:

$$\%V_L = \left[\frac{|V_{IN} - V_{OUT}|}{V_{IN}} \right] * 100$$

Where V_{IN} is the voltage across the input terminals, and V_{OUT} is the voltage across the output terminals.

Common voltage regulation values of two-port and in-line SPDs includes: 1%, 3%, and 5%

3.3 SPD RATINGS RELATED TO PERFORMANCE

These ratings and characteristics provide data to help quantify an SPD's ability to divert or attenuate and mitigate the effects of transients under parameters given by specific industry standards or items that are relevant to the SPD's application and for comparison purposes. The electrical industry has used these specific parameters for many years. The common parameters include:

a. Measured Limiting Voltage(s) (MLVs)
b. Voltage Protection Rating (VPR)
c. Nominal Discharge Current (I_N)
d. Modes of protection
e. Enclosure rating
f. Safety agency certifications
g. Safety disconnector description
h. Surge current rating

3.3.1 Measured Limiting Voltage(s)

Measured Limiting Voltage (MLV) is defined as 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. MLVs are peak voltages, not rms voltages. The Measured Limiting Voltages can be used to analyze the capability of an SPD to limit transients (test wave shapes and amplitudes) defined in ANSI/IEEE Std. C62.41.2 and ANSI/IEEE Std. C62.62. The standard test waveforms are the:

a. Category A 100 kHz Ring Wave
b. Category B 100 kHz Ring Wave
c. Category A Combination Wave
d. Category B Combination Wave
e. Category C Low Combination Wave
f. Category C High Current Driven Test

Further, the tests listed above are the "standard" tests from ANSI/IEEE Std. C62.41.2 and ANSI/IEEE Std. C62.62. These standards also contain "additional" and "optional" tests that might be selected by mutual agreement. In these cases, these tests can be added to the specification checklist (Section 5) as needed. The additional waveforms identified are the:

a. EFT Burst
b. Unidirectional 10/1000 μs Long Wave

Testing of the SPD is conducted using all overcurrent components, over-temperature components, EMI capacitors, status indication, disconnects, SPD safety disconnectors, etc.

The testing methodology used is defined in ANSI/IEEE Std. C62.45 (testing of equipment) and ANSI/IEEE Std. C62.62 (testing of SPDs). The point of application of the surge voltage and the resultant Measured Limiting Voltages are defined in UL 1449 and ANSI/IEEE Std. C62.62. In particular, the Measured Limiting Voltages for a parallel (one-port) connected SPD are measured at a point of 150 mm (6 inches) from where the conductors exit the enclosure of the SPD. The Measured Limiting Voltages of a series (two-port) connected SPD are measured at the output terminals of the SPD. See ANSI/IEEE Std. C62.62 for specific details, illustrations, and examples. Further, ANSI/IEEE Std. C62.62 provides specific requirements on the measurement equipment, measurement methods, and methods of reporting the results of surge testing SPDs.

By mutual agreement between end-user and manufacturer, the appropriate wave shapes and amplitudes for the specific application are to be selected from ANSI/IEEE Std. C62.41.2 and/or ANSI/IEEE Std. 62.62. Not all the test waveforms are appropriate for every application. For example, a Type 3 SPD might not need to be tested to the Category C Current Driven Test.

3.3.2 Voltage Protection Rating (VPR)

The VPR utilizes MLVs from a sampling of SPDs when subjected to a specific set of transient wave shapes and (e.g., voltage and current). Once the MLVs are obtained, then the VPR can be determined from a list of values and assigned by an NRTL.

The VPR is to be determined using the procedure in ANSI/UL 1449. A brief outline of the procedure is listed here. The same samples used to determine the VPR are used for the Nominal Discharge Current Test as described in ANSI/UL 1449 and in Section 3.3.3 of this Guide.

Testing, using a 6 kV, 3 kA Combination Wave generator, is conducted on three SPD samples for each mode of protection (see Section 3.3.4) declared by the manufacturer. The MLVs of the tests are recorded and averaged. The averaged value of the MLVs for a particular mode of protection is then utilized to determine the VPR for that mode of protection—which is equal to or lower than a selected value from a list of values in ANSI/UL 1449. VPRs are marked on the product. The VPR indicated in volts (V) are as shown in Table 3-2. For example, if the average MLV of three impulses is 598 V, the NRTL would assign a VPR of 600. If the average MLV of three impulses is 602 V, the NRTL would assign a VPR of 700 (because it is over 600 V).

Table 3-2
VOLTAGE PROTECTION RATINGS

330	400	500	600	700	800	900	1000	1200
1500	1800	2000	2500	3000	4000	5000	6000	--

3.3.3 Nominal Discharge Current (I_n)

The following is an excerpt from ANSI/IEEE Std. C62.62 describing the purpose and rationale for the Nominal Discharge Current Test:

> *The Nominal Discharge Current Test exercises an SPD's ability to be subjected to repetitive current surges of a selected value without degradation in performance by comparing a pre-test and post-test baseline averaged Measured Limiting Voltages per mode of a mode of protection (e.g., A-N pre-test versus A-N post-test).*
>
> *The purpose of these tests is to demonstrate the performance (repetitive surges, energy handling capability, and absence of undesirable side effects) of an SPD in response to surges that can be expected at the service equipment and/or within a building.*
>
> Note: ANSI/IEEE C62.62-2010. Reprinted with permission from IEEE. Copyright IEEE 2010 - All Rights Reserved.

The manufacturer declared Nominal Discharge Current is verified by a listing agency using the procedure in ANSI/UL 1449 in conjunction with the determination of the VPR. (The same test is included in ANSI/IEEE Std. C62.62.) The test amplitudes from ANSI/UL 1449 are listed below. Other standards may have additional values. The test short-circuit current wave shape is 8/20 μs.

10 kA or 20 kA for Type 1 SPDs, and
3 kA, 5 kA, 10 kA or 20 kA for Type 2 SPDs
3 kA for Type 3 SPDs (optional)

Some Type 3 SPDs are tested to the 3 kA test value for Nominal Discharge Current. This is an optional test from ANSI/UL 1449. Other Type 3 SPDs listed/certified to ANSI/UL 1449 are subjected to the Duty Cycle Test as defined in ANSI/UL 1449 which uses a 6 kV, 3 kA Combination Wave test rather than a 3 kA Current Driven Test.

3.3.4 Modes of Protection

The modes of protection for the SPD shall be appropriate for the installation. In most North American grounded power systems, the line-to-neutral (L-N), line-to-line (L-L), and line-to-ground (L-G) modes of protection are all that are available for an SPD applied at the service equipment. The neutral-to-ground (N-G) bond in grounded wye systems (208Y/120, 3Φ, 4w) ensures that the neutral (grounded) conductor and the grounding conductor are at the same potential (bonded) at this point in the power system. Therefore, the existence of the N-G mode at the service equipment is not required but does not need to be specifically excluded.

When the distance of the SPD from the neutral-ground bond exceeds two meters, additional modes of protection should be considered. This includes common modes of protection, e.g., line-to-ground (L-G), and neutral-to-ground (N-G).

There are also cases where the power system is ungrounded. In these cases, line-to-line (L-L) protection and line-to-ground (L-G) protection are the available modes of protection.

Further, it is important to understand how test results are reported with regard to the modes of protection. For additional detail on this topic, see Appendix A.2 and A.3.

The modes of protection are declared by the manufacturer. The existence or effectiveness of the modes of protection can be verified through Measured Limiting Voltages and the Nominal Discharge Current Test results.

3.3.5 SPD Enclosure Protection Rating

The SPD enclosure protection rating is very similar to the NEMA 250 enclosure ratings used for electrical enclosures and determines if it is appropriate to apply the SPD at specific locations within the power distribution system. The SPD enclosure protection rating is not the same as the NEMA enclosure rating but differs only because the rating is obtained after the SPD manufacturer has installed all components and status features that make up the entire SPD package. Some common SPD enclosure ratings are shown in Table 3-3.

Table 3-3
Common SPD Enclosure Protection Ratings

SPD Enclosure Protection Rating (NEMA)	Location for Use
1	General Purpose - Indoor
3R	Rainproof, Sleet Resistant - Outdoor
4	Watertight, Dust-tight, Sleet Resistant - Indoor & Outdoor
4X	Watertight, Dust-tight, Sleet Resistant, Corrosion Resistant – Indoor & Outdoor
12, 13	Industrial Use, Dust-tight & Drip-tight - Indoor

There is no direct equivalency between NEMA and IEC IP ratings. See Table A-1 of https://www.nema.org/Products/Documents/nema-enclosure-types.pdf.

The SPD enclosure protection rating should be detailed on the product and documentation provided with all submittal packages. To determine the actual details of the appropriate NEMA ratings, consult NEMA 250.

3.3.6 SPD Safety Agency Certifications

SPDs undergo safety agency certifications for application and installation in various locations. The applicable national safety standards, unlike this guide, dictate requirements for the safety of the SPD including acceptable end-of-service or failure conditions. The certifications carried by a product are to be provided.

> Note: In the US, the United States Department of Labor through the Occupational Safety and Health Administration (OSHA) oversees safety agency certifications through its Nationally Recognized Testing Laboratory (NRTL) program. An NRTL is by its definition a third party, independent organization as defined below by OSHA:

A Nationally Recognized Testing Laboratory (NRTL) is a private-sector organization that OSHA has recognized as meeting the legal requirements in 29 CFR 1910.7 to perform testing and certification of products using consensus-based test standards. These requirements are:

a. The capability to test and evaluate equipment for conformance with appropriate test standards;
b. Adequate controls for the identification of certified products, conducting follow-up inspections of actual production;
c. Complete independence from users (e.g., employers subject to the tested equipment requirements) and from any manufacturers or vendors of the certified products; and
d. Effective procedures for producing its findings and for handling complaints and disputes.

An organization must have the necessary capability both as a product safety testing laboratory and as a product certification body to receive OSHA recognition as an NRTL.

See https://www.osha.gov/dts/otpca/nrtl/nrtl_faq.html for additional details.

3.3.7 SPD Safety Disconnector Description

Some SPDs require an external safety disconnector (usually an external circuit breaker or fuse). This requirement is part of the SPDs certification, and the safety disconnector is required to maintain the listing of the SPD in end use applications. If applicable, the external safety disconnector is to be specified or supplied by the SPD manufacturer.

3.3.8 Surge Current Ratings

The following is an excerpt from ANSI/IEEE Std. C62.72-2016 (Clause 13.2):

When an SPD operates to limit a transient overvoltage, the SPD mitigates the impact of the overvoltage surge by conducting current. It is important for specifiers and users of SPDs to understand the term surge current. Surge current ratings, or the surge current capability of an SPD is one of the most common specification parameters of an SPD. At the release date of this publication, there is no standardized test for determining maximum or peak surge current ratings of SPDs within IEEE standards that apply to SPDs within the scope of this guide. However, the Nominal Discharge Current Rating is well defined (see ANSI/IEEE Std. C62.62™). Users and specifiers should consult the SPD manufacturer to determine how this rating [surge current rating] is determined for a particular SPD. The surge current rating of an SPD can refer to the amount of current that the SPD can divert resulting in the following conditions or based upon:

- *No damage or degradation to the SPD without the operation of an internal or external SPD [safety] disconnector*
- *No damage or degradation to the surge protective components within an SPD but with the operation of an internal or external SPD [safety] disconnector not resulting in an undesirable end of service condition*
- *Damage or degradation of the SPD, surge protective components within the SPD, and/or internal or external SPD [safety] disconnector not resulting in an undesirable end of service condition*
- *The sum of the component manufacturer's surge current ratings of the individual surge protective components within the SPD with or without consideration of an internal or external SPD [safety] disconnector surge current rating*

Note: ANSI/IEEE Std. C62.72-2016. Reprinted with permission from IEEE. Copyright IEEE 2016 - All Rights Reserved.

For additional information on per mode and per phase surge current ratings, see Annex A Section A.2.

Section 4
Specification Checklist

SPD Manufacturer ____

SPD Model Number ____

NOTE: The corresponding section numbers for each item in Table 4-1 are listed to the left of each heading.

Table 4-1
Specification Checklist

4.1 SPD Ratings Related To The Operating System	
3.2.1 Power Distribution System Configuration	

3.2.1 Nominal system voltage	

3.2.2 SPD Location/Type	

3.2.3 SPD Maximum Continuous Operating Voltage (MCOV)							
L-N		L-G		N-G		L-L	

3.2.4 SPD Short Circuit Current Rating (SCCR) - see 3.3.7 in this Table	

3.2.5 SPD Rated Load Current (I_L) (Two-Port and In-Line SPDs only)	

3.2.6 SPD Voltage Regulation (V_R) (Two-Port and In-Line SPDs only)	

4.2 SPD Ratings Related To Performance							
Measured Limiting Voltages (MLV) (add lines as necessary):							
3.3.1 IEEE Category A 100 kHz Ring Wave Measured Limiting Voltages (if applicable)							
Open Circuit Voltage				Phase Angle			
L-N		L-G		N-G		L-L	

3.3.1 IEEE Category B 100 kHz Ring Wave Measured Limiting Voltages (if applicable)							
Open Circuit Voltage				Phase Angle			
L-N		L-G		N-G		L-L	

3.3.1 IEEE Category A Combination Wave Measured Limiting Voltages (if applicable)							
Open Circuit Voltage				Short Circuit Current			
Phase Angle							
L-N		L-G		N-G		L-L	

3.3.1 IEEE Category B Combination Wave Measured Limiting Voltages (if applicable)							
Open Circuit Voltage				Short Circuit Current			
Phase Angle							
L-N		L-G		N-G		L-L	

3.3.1 IEEE Category C Low Combination Wave Measured Limiting Voltages (if applicable)							
Open Circuit Voltage				Short Circuit Current			
Phase Angle							
L-N		L-G		N-G		L-L	

3.3.1 IEEE Category C High Current Drive Test Measured Limiting Voltages (if applicable)

Voltage				Current Through SPD			
Phase Angle							
L-N		L-G		N-G		L-L	

3.3.1 Additional and Optional IEEE Tests - Measured Limiting Voltages (if applicable)							
Test Waveform/Description							
Voltage Amplitude				Short Circuit Current			
Phase Angle							
Notes:							
L-N		L-G		N-G		L-L	

3.3.2 Voltage Protection Rating (VPR) – ANSI/UL 1449							
L-N		L-G		N-G		L-L	

3.3.3 Nominal Discharge Current Rating (I_n)	

3.3.4 Modes of Protection (Check those that apply)							
L-N		L-G		N-G		L-L	

3.3.5 SPD Enclosure Rating	

3.3.6 SPD Safety Agency Listings/Certifications (list all standards the SPD is listed/certified to, file numbers, links to certification pages, etc.)	Check all that apply: ☐ NEMA 1 ☐ NEMA 3R ☐ NEMA 4 ☐ NEMA 4X ☐ NEMA 12,13 ☐ Other:____________________

3.3.7 SPD Safety Disconnector/Overcurrent Protection Device Requirements (if applicable), i.e., fuse or circuit breaker	Select/provide as applicable: ☐ No Additional Safety Disconnector Required ☐ External Fuse Required Type and Size: ______________________ Manufacturer Part Number: ____________ ☐ External Circuit Breaker Required Type and Size: ______________________ Manufacturer Part Number: ____________
4.2.8 SPD Surge Current Rating	Select/provide as applicable: ☐ Per Phase: _______kA ☐ L-N Mode: _______kA ☐ L-G Mode: _______kA ☐ N-G Mode: _______kA ☐ L-L Mode: _______kA

Annex A
Additional Information
(Informative Only)

The following annex is provided as additional information only and is not a normative part of NEMA SPD1.1, *Surge Protective Device Specification Guide for Low Voltage Power Distribution Systems–Part 1*.

A.1 Surge Current Ratings

SPD surge current ratings are subjective based on multiple factors such as surge amplitude, level of redundancy, projected life expectancy, anticipation of degradation, value of protected load, value of avoided downtime losses, etc.

Within structures, ANSI/IEEE standards defining the expected surge environment state that system inductance and impedance limit the expected surge current to levels around 10 kA. ANSI/UL 1449 includes repetitive surge current testing up to 20 kA. Surge current levels in outdoor equipment environments from direct lightning strikes are not well documented but may exceed these values. Similarly, a direct lightning stroke to earth can create momentary, localized increases in ground potential (Ground Potential Rise), which may also exceed these values.

SPDs are purposely placed in harm's way. It is generally good engineering practice to specify sufficient surge current capacity, plus margin for error and/or redundancy. Additional and/or multiple internal suppression components will share surge current, thus reducing stresses on individual components leading to longer SPD life. For similar reasons, lower measured limiting voltages are sometimes achievable. There are instances where additional and/or larger surge protective components provide safety benefit, and/or reduce degradation effects from usage.

Geographic considerations may apply. For example, the southeastern United States is prone to numerically-higher rates of lightning strokes, although most regions can expect to receive equally large lightning in terms of kA amplitude. The physical proximity of SPD and load to outdoors is also a consideration based on the likelihood of additional stresses.

The user or specifier should consult the SPD manufacturer for application guidance.

A.2 Per Mode And Per Phase Ratings

A 'Per Mode' surge current rating is the summed rating of suppression elements connected directly from one power system terminus to a second. Modes may be line-to-neutral (L-N), line-to-ground (L-G), neutral-to-ground (N-G) or line-to-line (L-L). (It is to be understood that "line" and "phase" are often used interchangeably to indicate the connection to a particular phase of the system.) For example, L-N may be specified as 100 kA, suggesting ten 10 kA MOVs, or two 50 kA MOVs, etc. connected in parallel to the specified mode.

a. 'Per Mode' ratings are not intended to include indirectly connected suppression elements. For example, the L-G per mode rating is not intended to include compound-connected suppression elements configured as L-N-G for L-G. Similarly, the L-L per mode rating is not intended to include compound-connected suppression elements such as L1-N-L2 and/or L1-G-L2 for the L-L mode.
b. In a given manufacturer declaration, no individual suppression element may be double counted to obtain 'Per Mode' ratings.
c. Determination of any L-L 'Per Mode' rating is the number of suppression elements connected directly from one energized power system terminus to a second energized power system terminus. The L-L 'Per Mode' rating is not intended to include L1-N-L2 and/or L1-G-L2, etc.

A ‘Per Phase’ surge current rating is the summed rating of suppression elements connected directly from one energized power system terminus to another terminus, which may or may not be energized. For example, Phase A might have five 10 kA MOVs connected Phase A-Neutral, and five 10 kA MOVs connected Phase A-Ground for a per phase rating of 100kA.

a. N-G suppression elements are not to be included in ‘Per Phase’ surge current ratings.
b. For ‘Per Phase’ surge current rating calculation purposes, any contribution of L-L suppression elements should be limited to one phase to a second phase, and not one phase to multiple other phases.

Calculations of surge current ratings for SPDs including derived neutral connections and/or compound-connected should clearly indicate such and identify any suppression elements that are counted more than once.

A.3 SPD Modes Of Protection

A mode of protection is defined as how an SPD’s protective components might be connected line to line, line to ground (earth), line to neutral, or neutral to ground (earth), and any combination thereof. A mode of protection can be established using directly connected surge protective components in a particular mode or through a combination of surge protective components connected between other modes that when used in a series combination also covers other modes. This is different than a “per mode” or “per phase” surge current rating. A mode of protection offers defense against surges propagating in that mode.

For example, an SPD with SPCs directly connected in ten modes provides protection for all ten modes of the wye configured PDS. Similarly, an SPD with SPCs directly connected in seven modes (i.e., each phase to neutral, each phase to ground and neutral to ground) provides protection for all ten modes for the wye configured PDS; however, the phase to phase mode of protection is accomplished through the series combination of the phase to neutral (or ground) SPCs. For example, the phase A to phase B mode of protection is completed by the series connection of the SPCs connected phase A to neutral to phase B (or via the phase to ground SPCs in a similar fashion). In this case, the phase to phase MCOV would be the MCOV of phase A to neutral (or ground) plus phase B to neutral (or ground).

Likewise, an SPD with SPCs directly connected in four modes (i.e., each phase to neutral and neutral to ground for a Wye configured SPD) also provides protection for all ten modes of the wye configured PDS. In this case, the phase to phase mode of protection is completed in the same way as the SPD with SPCs directly connected in seven modes; however, the phase to ground mode of protection is completed by the series combination of the phase to neutral and neutral to ground SPCs. The phase to ground MCOV would be the MCOV from phase to neutral plus neutral to ground. This compounding of MCOVs may increase Measured Limiting Voltages, which may or may not be desirable in some circumstances.

All three of these designs offer defense in all the modes of protection available for the PDS; however, they accomplish this through different means. The specifier or user of SPDs should understand how a particular SPD provides protection (what modes of protection exist and how they are accomplished) for the equipment connected to the PDS. There are differing philosophies as to which approach is preferred. The user or specifier should consult the SPD manufacturer to understand the design philosophy of a particular SPD.

For additional information regarding MLVs and VPRs, see Table 4-1.

Annex B
General Earthing
(Grounding) Practices
(Informative Only)

The following annex is provided as additional information only and is not a normative part of NEMA SPD1.1 *Surge Protective Device Specification Guide for Low Voltage Power Distribution Systems—Part 1*.

B.1 Description

Network systems are classified by the International Electrotechnical Commission (IEC) in IEC 60364-1 (Low-voltage electrical installations—Part 1: Fundamental principles, assessment of general characteristics, definitions) according to the type of grounding, or *earthing*, practices used in the PDS and the methods used for protection against electrical shock in the installation. Although all IEC network systems are not currently used within the United States, some classifications can be applied.

An important note is the difference in language, between IEC countries and that of North America, for terms having the same meaning. In this annex, the terms *earthed* and *unearthed* have the same meaning as *grounded* and *ungrounded*. For clarity to the readers, this guide will substitute the IEC term, *earthed*, for the common North American term, *grounded*, and the IEC term, *unearthed*, for the common North American term, *ungrounded*.

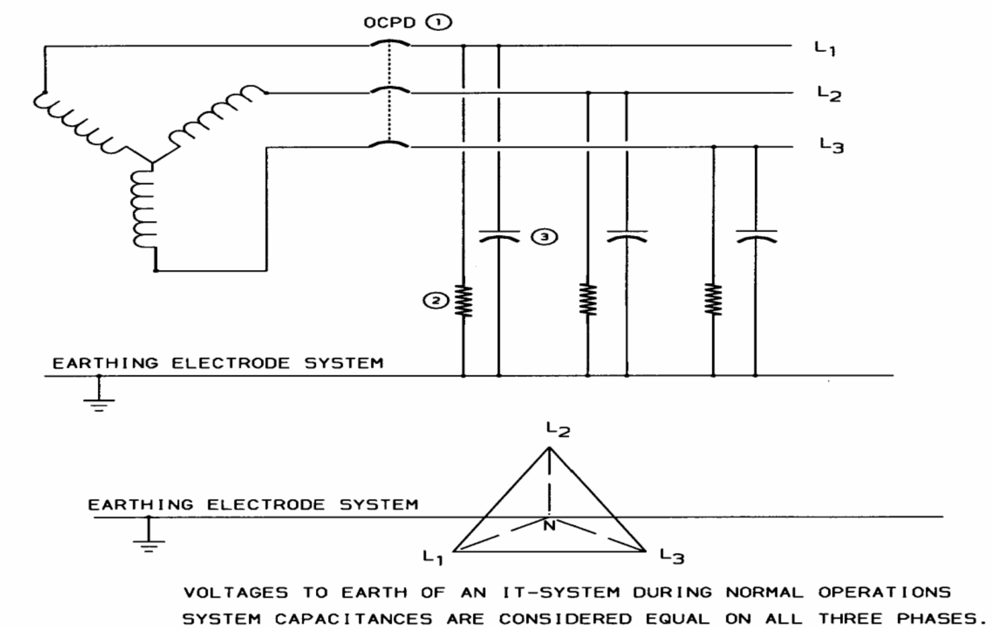
PDSs are divided into grounded and ungrounded systems. IEC 60364-1 classifies network systems according to the configuration of live conductors (including the neutral) and the type of grounding system used. As part of the classification, the following nomenclature is used. The first letter, I or T, shows the relationship between the current carrying conductors and the grounding system. The second letter, T or N, shows the relationship of the accessible conductive parts, including a metallic frame, of the component or equipment in the installation with respect to the grounding system.

> Note: “Grounded” or “ungrounded” refers to the power system’s reference to ground. This is different than an incorrect colloquial understanding where there is, or is not, a ground conductor. All equipment requires a ground conductor. Reference to ground refers to the connection of the secondary side of a transformer to ground. Among other things, this provides system voltage stability particularly for L-G and N-G modes.

For the purposes of this discussion, a “bolted” fault is a short-circuit condition. Per ANSI/NEMA FU 1-86, the definition for a bolted fault refers to a zero impedance fault considered at locations in a power system where the maximum value of available fault current is calculated.

First letter (I or T)

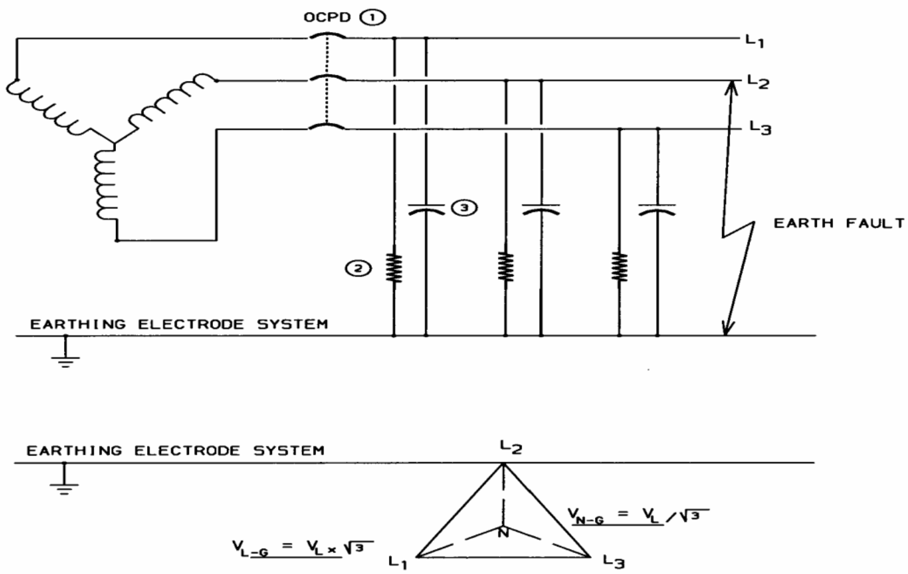
The first letter "I" represents *isolation*. The letter "I" signifies that all live parts are isolated from ground or earth, or that points of the network are connected to earth through some impedance as a surge arrester or air gap. The first letter "T" represents the Latin word, *terra*, meaning earth. The "T" signifies a direct connection of at least one point in the network to earth. Special grounding requirements or practices may be necessary depending on the type of network system used. See Figure B.1 through Figure B.3.



NOTE:

1. OVER CURRENT PROTECTIVE DEVICE
2. INSULATION RESISTANCE OF CONDUCTOR WITH RESPECT TO EARTH (TYPICAL FOR ALL PHASES)
3. CAPACITIVE REACTANCE IN SYSTEM (TYPICAL FOR ALL PHASES)

Figure B.1 - Typical IT System During Operation

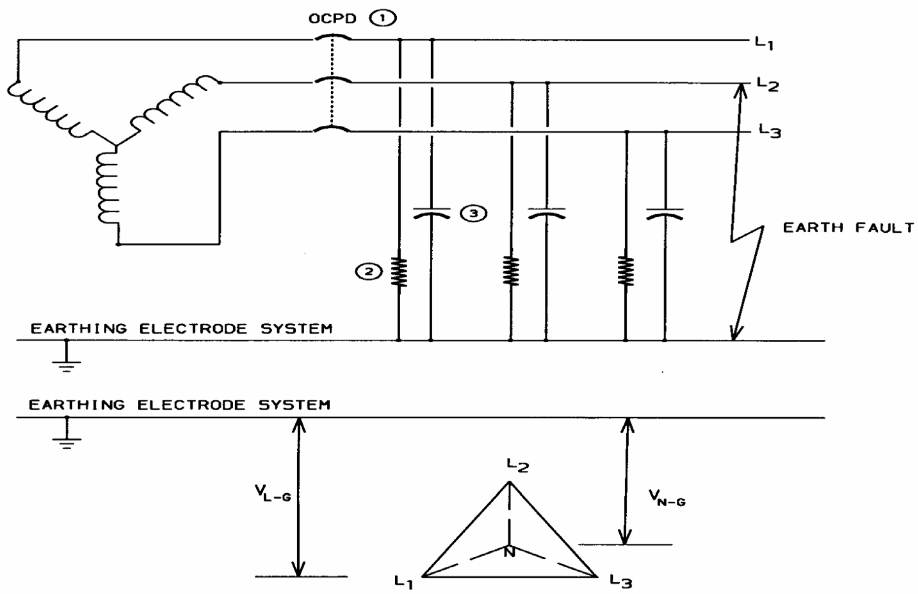


VOLTAGES TO EARTH OF AN IT-SYSTEM DURING A BOLTED FAULT TO EARTH CONDITION. WHEN A SOLID BOLTED FAULT OCCURS ON ONE PHASE THE PSEUDO NEUTRAL POINT IS DISPLACED AND THE VOLTAGE ON THE UNGROUNDED PHASES IS ELEVATED.

NOTE:

1. OVER CURRENT PROTECTIVE DEVICE
2. INSULATION RESISTANCE OF CONDUCTOR WITH RESPECT TO EARTH (TYPICAL FOR ALL PHASES)
3. CAPACITIVE REACTANCE IN SYSTEM (TYPICAL FOR ALL PHASES)

Figure B.2- IT System with a Bolted Fault



VOLTAGES TO EARTH OF AN IT-SYSTEM DURING AN ARCING FAULT TO EARTH CONDITION. AN ARCING FAULT TO EARTH IS POTENTIALLY MORE DESTRUCTIVE BECAUSE THE PSEUDO NEUTRAL POINT CAN BE OFFSET SIGNIFICANTLY FARTHER FROM THE GROUND PLAIN EACH TIME THE ARC RESTRIKES.

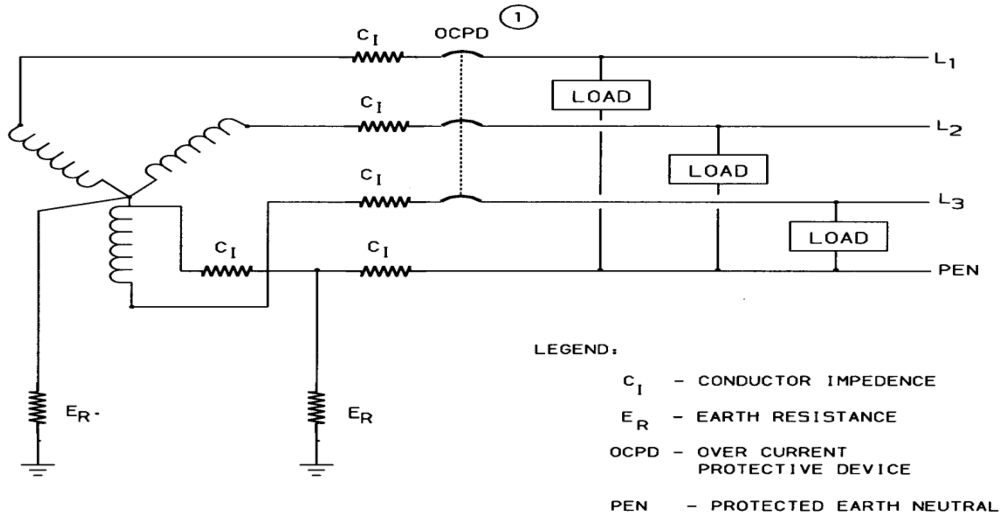
NOTE:

1. OVER CURRENT PROTECTIVE DEVICE
2. INSULATION RESISTANCE OF CONDUCTOR WITH RESPECT TO EARTH (TYPICAL FOR ALL PHASES)
3. CAPACITIVE REACTANCE IN SYSTEM (TYPICAL FOR ALL PHASES)

Figure B.3 - IT System with an Arcing Fault

Second Letter (T or N)

The second letter designates the type of connection between the protective equipment—grounding conductor used in the installation and earth. The second letter "T" signifies a direct connection between accessible conductive parts of connected equipment and ground (terra), which is independent of the grounding system that may or may not exist on current carrying conductors of the system. The second letter "N" signifies a direct connection of accessible conductive parts to the ground points of the PDS by means of a PEN (protected earth neutral) or PE (protected earth) conductor. The PDS is then connected to ground. See Figure B.4 through Figure B.7.

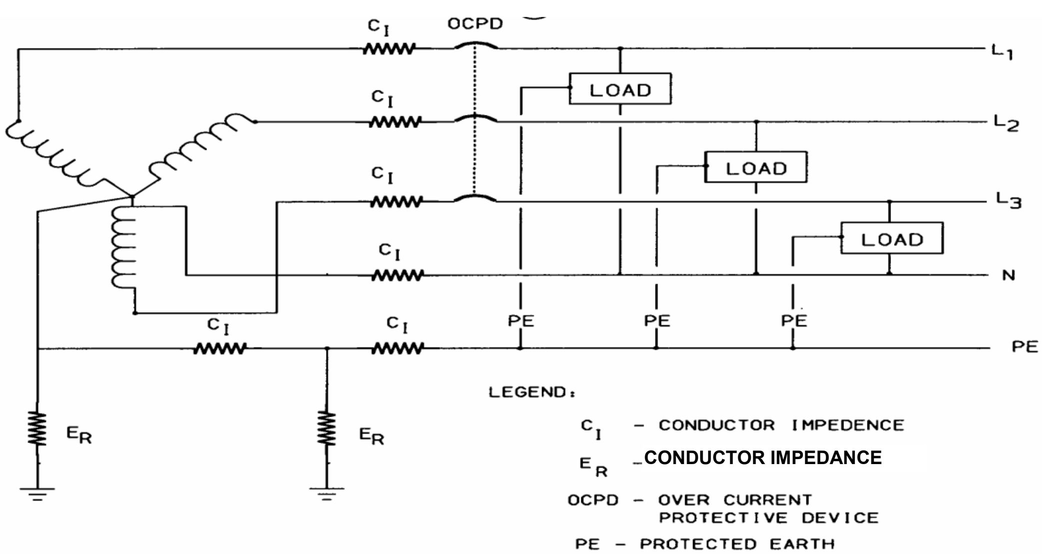


TYPICAL EXAMPLE OF A TN-C SYSTEM

NOTE:

1. MAIN OVERCURRENT PROTECTIVE DEVICE SHOULD NOT HAVE GROUND FAULT PROTECTION

Figure B.4 - Typical TN-C System

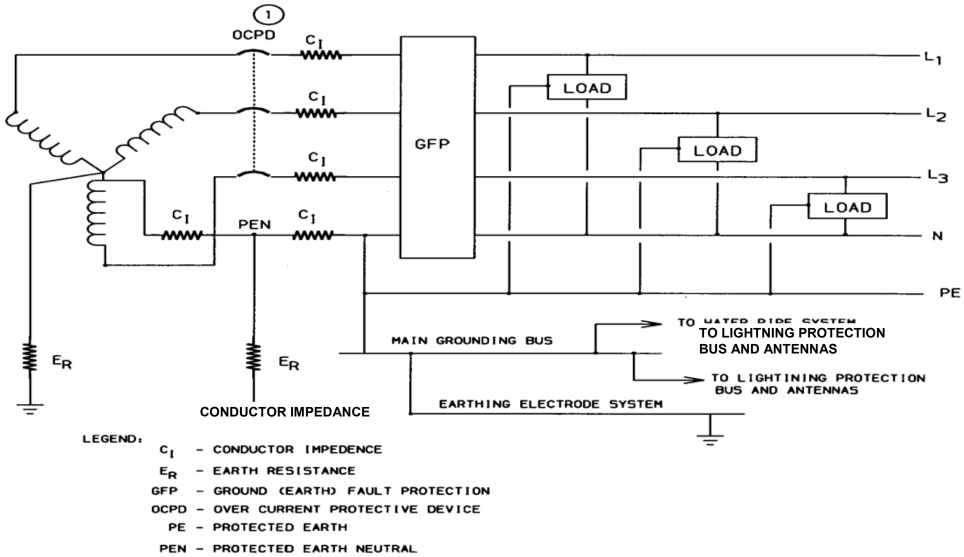


TYPICAL EXAMPLE OF A TN-S SYSTEM

NOTE:

1. OCPD CAN INCLUDE, OR NOT INCLUDE, GROUND FAULT PROTECTION

Figure B.5 - Typical TN-S system

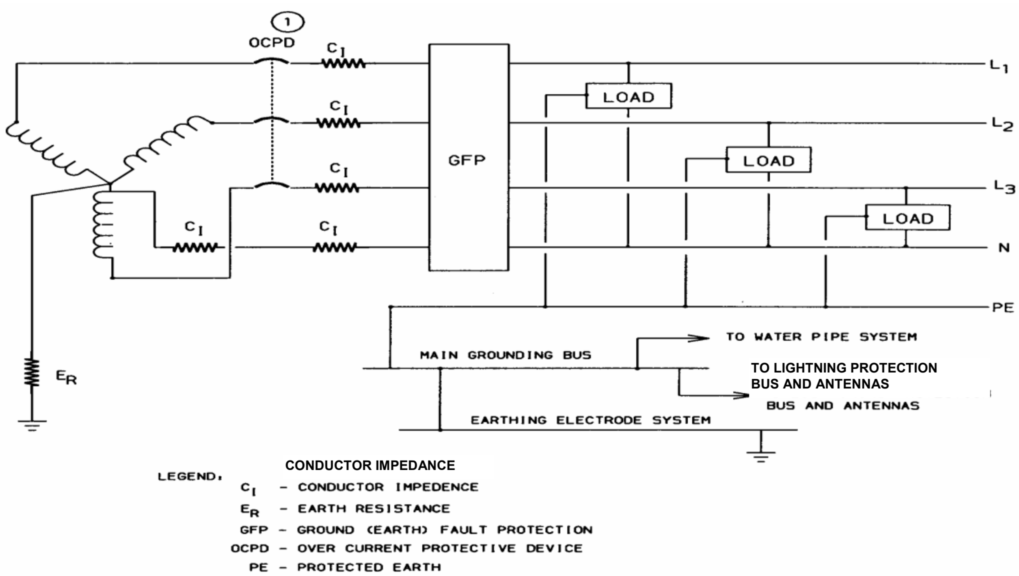


TYPICAL EXAMPLE OF A TN-C-S SYSTEM

NOTE:

1. OCPD CAN INCLUDE, OR NOT INCLUDE, GROUND FAULT PROTECTION

Figure B.6 - Typical TN-C-S system



TYPICAL EXAMPLE OF A T-T SYSTEM

NOTE:

1. OCPD CAN INCLUDE, OR NOT INCLUDE, GROUND FAULT PROTECTION

Figure B.7 - Typical T-T system

In IEC network systems, the grounding of the PDS and the means of protection against electric shock are independent considerations. Distribution systems are grounded to limit the voltage rise that can develop from lightning, transient over voltages, contact with higher voltage(s), or ground faults that may occur in a PDS. The PDS can be intentionally ungrounded to avoid service interruption when a single ground fault occurs. See Table B.1.

Table B.1

IEC Systems And Equipment Grounding

System designation	System grounding	Equipment grounding
IT	No direct system grounding. Can be connected to earth through impedance or gap.	Independently and directly connected to earth
TT	Connected to earth at one or more points in the PDS outside of the premises wiring.	Independently and directly connected to earth.
TN	Connected to earth at one or more points in the PDS and at one or more points in the premises wiring.	Connected to the PDS via a PEN or PE conductor.

Third Letter (C or S)

In TN systems, a third letter designates the possible configuration of, as well as the relationship between, the neutral conductor, the PE-conductor, and the PEN-conductor.

In a "TN-C"-type PDS, the suffix "C" represents a common function. The PEN-conductor is used to serve the common function of a grounding or protective earthing conductor as well as the neutral conductor for the PDS. In a "TN-C"-type PDS, ground-fault current and neutral current use the same return path. In such installations, the neutral conductor would be bonded to the frame of the equipment or apparatus at each utilization point. In a "TN-C"-type PDS, the application and installation of ground-fault protective devices are not indicated or recommended because such devices would never reliably function as intended. (In North America, older low-voltage appliances with metallic frames represent a single-phase circuit in a "TN-C" system and residential two-prong receptacle circuits where a separate grounding conductor is not used.)

In a "TN-S"-type PDS, the suffix "S" represents a separate grounding or protective earthing conductor. There is no PEN-conductor. The PE-conductor is only bonded once to the neutral conductor and only at the neutral terminal of the supply transformer for the PDS. In a "TN-S"-type PDS, ground-fault current and neutral current use separate conductive paths. In such installations, a separate grounding conductor would be bonded to the frame of the equipment or apparatus at each utilization point for the conduction of ground-fault current. In a "TN-S"-type PDS, the separation of the PE-conductor and the neutral conductor allows for the successful application and utilization of a ground-fault protection system.

TN-C-S Systems

A "TN-C-S"-type PDS is a combination of a "TN-C"- and a "TN-S"-type system. The "TN-C-S"-type PDS is the most commonly used earthing system. In a "TN-C-S"-type PDS, there is a PEN-conductor, a separate PE-conductor, and a separate neutral conductor. The PEN-conductor is used only between the supply transformer and the service equipment. The actual connections to earth of the PEN-conductor are commonly made at the neutral terminal of the supply transformer and on the neutral conductor in the service equipment. Beyond the service equipment, only separate neutral conductors and PE-conductors are used. In a "TN-C-S"-type PDS, the separation of the PE-conductor and the neutral conductor allows for the successful application and utilization of a ground-fault protection system as those used in a "TN-S" type system. However, a ground-fault protection system can only be used downstream or on the load side of the PEN-conductor. In addition, any electrical connections between, or bonding of, a PE-conductor and a neutral conductor downstream of the PEN-conductor could cause dysfunction in a ground-fault protection system installed in the "TN-C-S" system.

Differences Highlighted

The following illustrations serve to show the differences between some of the common systems.

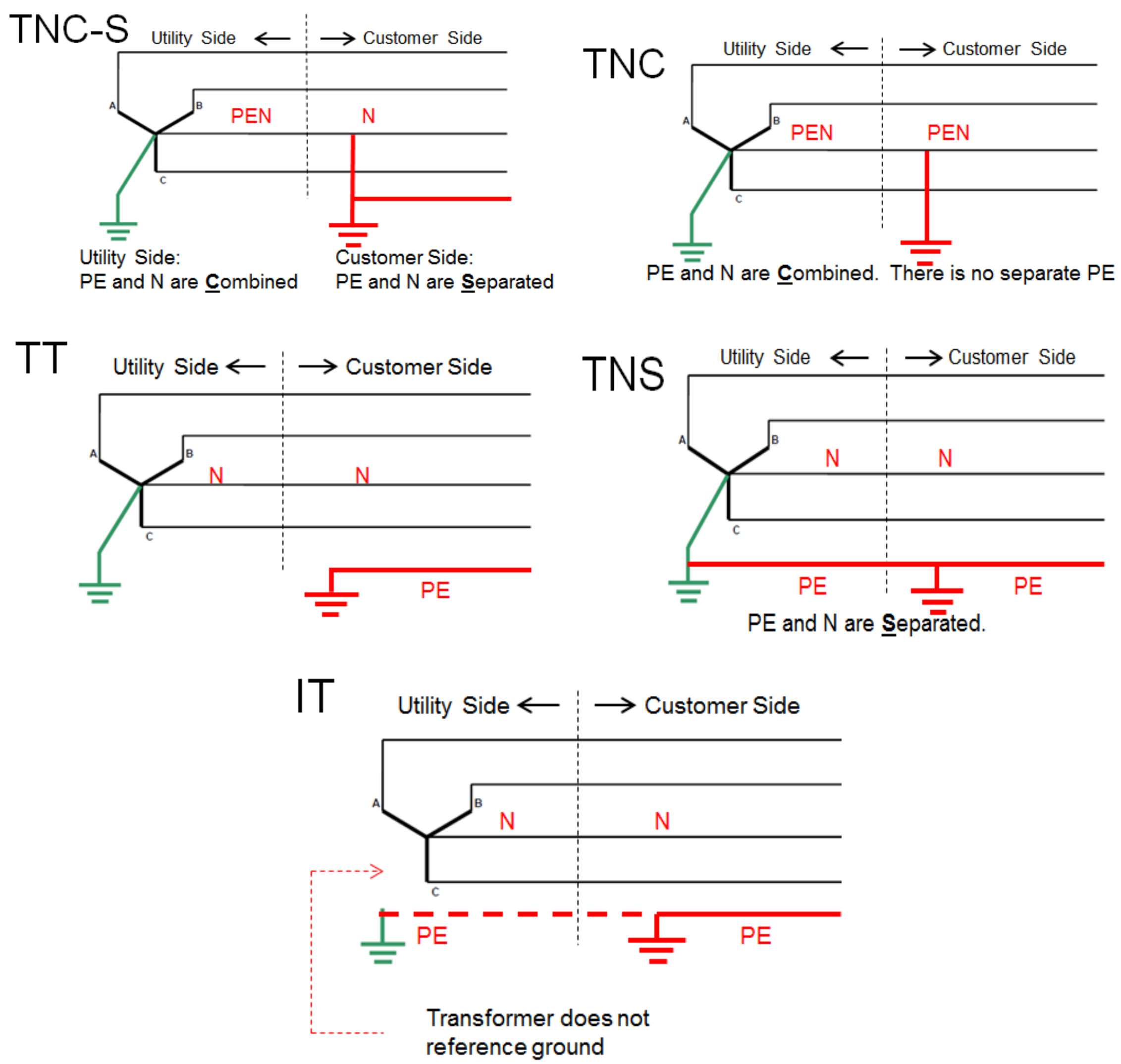


Figure B.8 - Differences in Common Systems

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