



IEEE Guide for the Application of Surge Protectors Used in Low-Voltage (Equal to or Less than 1000 V, rms, or 1200 V, dc) Data, Communications, and Signaling Circuits

IEEE Power Engineering Society

Sponsored by the
Surge Protective Devices Committee

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Surge Protective Devices Committee
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IEEE Power Engineering Society

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Abstract: This guide provides assistance in selecting the most appropriate type of surge protector for a particular data, communication, and/or signaling circuit application. The purpose of this guide is to enable an understanding and an evaluation of the functions of the various types of multiple-component data, communications, and signaling circuit protectors in terms of particular applications.

Keywords: current-limiting device, dc-limiting voltage test, impulse-limiting voltage test, multiple-component protector, multiport coupling test, signaling circuit, surge protector

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Introduction

This introduction is not part of IEEE Std C62.43-2005, IEEE Guide for the Application of Surge Protectors Used in Low-Voltage (Equal to or Less than 1000 V, rms, or 1200 V, dc) Data, Communications, and Signaling Circuits.

This application guide was developed to assist the users of IEEE Std C62.36™-2000. The surge protectors covered are multiple-component series or parallel combinations of linear or nonlinear elements packaged for the purpose of limiting surge voltages, currents, or both.

Some tests are not suitable for all surge protectors as the test methods and criteria given apply to surge protectors with different functions and environmental performance. This guide will help manufacturers and users to decide which tests apply to a surge protector intended for a specific application and how to set up and run those tests.

The need for this application guide originated because of the following industry trends:

- A loss of expertise in protection of equipment connected to data, communications, or signaling circuits
- Decreasing awareness of the historical data and rationale on which standards have been based
- Increased use of sensitive electronic circuits that require surge protection

This substantially revised edition of the application guide now includes informative annexes covering applications as well as updated descriptions of protective devices. In addition, this revision comprehends the changes made to C62.36 in the 2000 edition. These changes include

- Tests for insertion loss and return loss, which were changed to use network analyzers in high-frequency applications
- A new test for measuring the degree of coupling between ports of a multiport surge protector
- A pulse mask test

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Contents

1.	Overview.....	1
1.1	Scope.....	1
1.2	Purpose.....	2
1.3	Electrical environment	2
2.	Normative references	2
3.	General theory of operation	3
3.1	General description	3
3.2	General theory of operation	4
3.3	Two-terminal basic configuration.....	5
3.4	Three-terminal basic configuration.....	5
3.5	Three-terminal theory of operation.....	6
3.6	Four-terminal basic configuration	7
3.7	Four-terminal theory of operation.....	7
3.8	Five-terminal basic configuration	8
3.9	Five-terminal theory of operation	9
4.	Protector characteristics: nonsurge performance tests	10
4.1	Rated voltage test.....	10
4.2	Rated current test	10
4.3	DC series resistance test	11
4.4	Standby current and insulation resistance test	11
4.5	Capacitance test	12
4.6	Inductance test	12
4.7	Insertion loss test	13
4.8	Phase shift test	13
4.9	Return loss test.....	14
4.10	Longitudinal balance test	14
4.11	Pulse mask test.....	15
4.12	Rise and decay time test.....	15
4.13	Bit-error rate test	15
5.	Protector characteristics: active performance tests	16
5.1	DC-limiting voltage test.....	16
5.2	Impulse-limiting voltage test	16
5.3	Transition current test	17
5.4	Current response time test.....	18
5.5	Impulse reset test	19
5.6	Current reset test	20
5.7	AC life test	21
5.8	Impulse life test.....	21
5.9	Maximum single-impulse discharge test	22
5.10	Multiport coupling test.....	23

6.	Application of surge protectors used in low-voltage data, communications, and signaling circuits	23
6.1	Operational compatibility	24
6.2	Voltage limiting	24
6.3	Grounding and bonding	25
6.4	Location of protectors	25
6.5	Codes and standards.....	27
	Annex A (normative) Description and theory of operation of certain current-limiting devices	28
	Annex B (informative) Examples of applications of surge protectors used in low-voltage data, communications, and signaling circuits.....	37
	Annex C (informative) Surge protection for paired-conductor telecom cables serving antenna towers.....	45
	Annex D (informative) Surge protection for DSL systems	48
	Annex E (informative) Protection coordination between primary and secondary surge protectors.....	51
	Annex F (informative) Antenna feeds protection and RF surge suppression technology overview for communication sites	52
	Annex G (informative) Bibliography	56

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1. Overview

1.1 Scope

This guide provides assistance in selecting the most appropriate type of surge protector for a particular data, communication, and/or signaling circuit application.

This guide is divided into six clauses. Clause 1 provides an overview and the scope of this guide. Clause 2 lists references to other standards. Clause 3 gives a description and the theory of the operation of surge protectors used in data, communications, and signaling circuit applications. Clause 4 and Clause 5 describe and interpret non-surge and active performance tests, respectively. Clause 6 discusses some general application principles.

This guide also contains normative Annex A, which provides a description and theory of operation of certain current-limiting devices that may be used in multiple-component surge protectors. Informative Annex B and Annex C supply examples of applications of surge protectors used in low-voltage data, communications, and signaling circuits. Informative Annex D provides guidance on the protection of digital subscriber line (DSL) systems. Informative Annex E supplies guidance on coordinating telecommunications primary and secondary protectors. Informative Annex F provides an overview of antenna feeds protection and radio-frequency (RF) surge suppression technology for communications sites. Informative Annex G contains a bibliography of the references used in developing this guide. The informative annexes provide additional information for understanding and using this guide, but they are not an essential part of the guide. This guide applies to surge protectors used in balanced or unbalanced data, communications, and signaling circuits with equal to or less than 1000 V, rms (V_{rms}), or 1200 V, dc (V_{dc}). The surge protectors covered are multiple-component series or parallel combinations of linear or nonlinear elements, packaged for the purpose of limiting voltage, current, or both.

This guide is intended to complement IEEE Std C62.36™-2000.¹ The definitions used in this application guide and the test methods standard are the same. For terms not defined in the guide or the standard, see *The Authoritative Dictionary of IEEE Standards Terms* [B12].²

This guide is not intended to apply to a packaged single-component gas discharge tube (GDT) or air gap arresters/protectors, which are covered by IEEE Std C62.42™-1992 nor to packaged single component thyristor surge protective devices, which are covered by IEEE Std C62.37™-1997.

1.2 Purpose

The purpose of this guide is to enable an understanding and an evaluation of the functions of the various types of multiple-component data, communications, and signaling circuit protectors in terms of particular applications. Consideration is given to the characteristics of multiple-component protectors and the concepts necessary to choose the appropriate product and to interpret its specifications.

1.3 Electrical environment

For a description of the electrical environment in which these protectors are intended to be used, refer to IEEE Std C62.42-1992, Clause 3.

2. Normative references

The following referenced documents are indispensable for the application of this guide. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std C62.36™-2000, IEEE Standard Test Methods for Surge Protectors Used in Low-Voltage Data, Communications, and Signaling Circuits.^{3, 4}

IEEE Std C62.37™-1997, IEEE Standard Test Specification for Thyristor Diode Surge Protective Devices.

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 1000 Vrms or 1200 Vdc) Surge Protective Devices.

IEEE Std C62.64™-1997, IEEE Standard Specifications for Surge Protectors Used in Low-Voltage Data, Communications, and Signaling Circuits.

NFPA 70, National Electric Code® (NEC®).⁵

¹Information on references can be found in Clause 2.

²The numbers in brackets correspond to those of the bibliography in Annex G.

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3. General theory of operation

This clause provides the description and theory of operation of surge protectors (also called surge-protective devices) used in low-voltage data, communications, and signaling circuits. These protectors comprise one or more series or parallel elements that limit excessive voltages, currents, or both, while maintaining the system operation to a given performance level.

These devices are used on electronic equipment where voltage and current surges on the signal line can cause system malfunction or failure. The devices have two distinct states: In the quiescent state, they are essentially transparent to the system; in the operated state, they provide voltage limiting, current limiting, or both. The devices are operated or self-triggered by the voltage or current surge and may also self-reset to their quiescent state.

Multiple-component surge protectors may contain voltage-limiting devices, which are connected in parallel with the terminals to be protected. They may also contain current-limiting devices in series with the terminals to be protected. Descriptions and theory of operation of certain voltage-limiting devices that may be used in multiple-component surge protectors can be found in IEEE Std C62.42-1992 and in IEEE Std C62.37-1997. Descriptions and theory of operation of certain current-limiting devices that may be used in multiple-component surge protectors are provided in Annex A. Multiple-component protectors may use voltage limiters that are not covered in IEEE Std C62.42-1992 and IEEE Std C62.37-1997, they may use current limiters that are not covered in Annex A, or both.

Numerous combinations of series and parallel components can be contained in surge protectors, and a comprehensive characterization is too complex to describe completely in this guide. Therefore, several examples of these combinations are given in 3.1 – 3.9 to describe these protectors and to illustrate how internal component interactions occur. This information is organized according to the six basic configurations defined in IEEE Std C62.36-2000. These configurations are illustrated in Figure 1.

Some of the description and theory of operation discussed in Clause 4 is common to many or all of the various configurations to follow.

3.1 General description

Each overvoltage (V) or overcurrent (I) protection element contained in the basic protector configurations may be a single component, or it may be a pair of parallel or series components for redundant, additive, or backup protection features.

Examples of the overvoltage protection elements are as follows:

- An air gap
- A GDT
- A solid state device
- A combination of these elements

Currently, three types of solid state components are used in surge protective devices that can also be used as stand-alone protection components. These are avalanche breakdown diodes (ABDs), metal oxide varistors (MOVs), and thyristor surge suppressors (TSSs). ABD and TSS components are manufactured with a silicon-based semiconductor technology. ABD components are two terminal devices that can be either unidirectional (one P/N junction) or bidirectional (two P/N junctions). They are nonlinear devices with a continuous voltage/current (V/I) characteristic curve in both positive and negative directions. TSS components are two- or three-terminal devices that can be either unidirectional, bidirectional, symmetrical, or asymmetrical. Their voltage/current (V/I) characteristic curve is defined by their ability to switch from a high-impedance (OFF-state) to a low-impedance (ON-state). Three-terminal TSSs are known as

programmable devices connected to an external voltage source. MOV components are two-terminal devices that are symmetrical and nonlinear with a continuous voltage/current (V/I) characteristic curve. As a variation of a single-layer junction, MOVs are manufactured with a ceramic-based metal oxide material to form multiple junctions between the two terminals. These are known as multiple layer varistors (MLV).

Examples of the overcurrent protection element are as follows:

- A fuse
- A positive temperature-coefficient (PTC) thermistor
- A circuit breaker
- A heat coil
- A semiconductor
- A combination of these elements

The voltage-limiting device, in its quiescent state, should present a high resistance across the protected elements. The rated voltage should be greater than any voltages on the line during normal operation. Examples of such voltages are the dc supply voltage plus the peak of any superimposed signaling or ringing voltage. The current-limiting device should present a low resistance. The surge protector, in its quiescent state, should present low loss at transmission frequencies.

Selection of the voltage-limiting component with regard to current handling is determined by the nature of the surges likely to be encountered. If application of the protector is in a high lightning area, impulse life is an important factor. For exposure to contacts with ac power lines, or induction from nearby ac power lines, the alternating current life is important.

The protector elements and their interconnections are usually contained in a plastic or metallic housing, although they may also be openly mounted on a circuit board or other substrate. Electrical connections to the network and equipment to be protected may include screw terminals, lugs, pins, card-edge connectors, spring-loaded leaf or button contacts, insulation displacement terminals, or other means.

3.2 General theory of operation

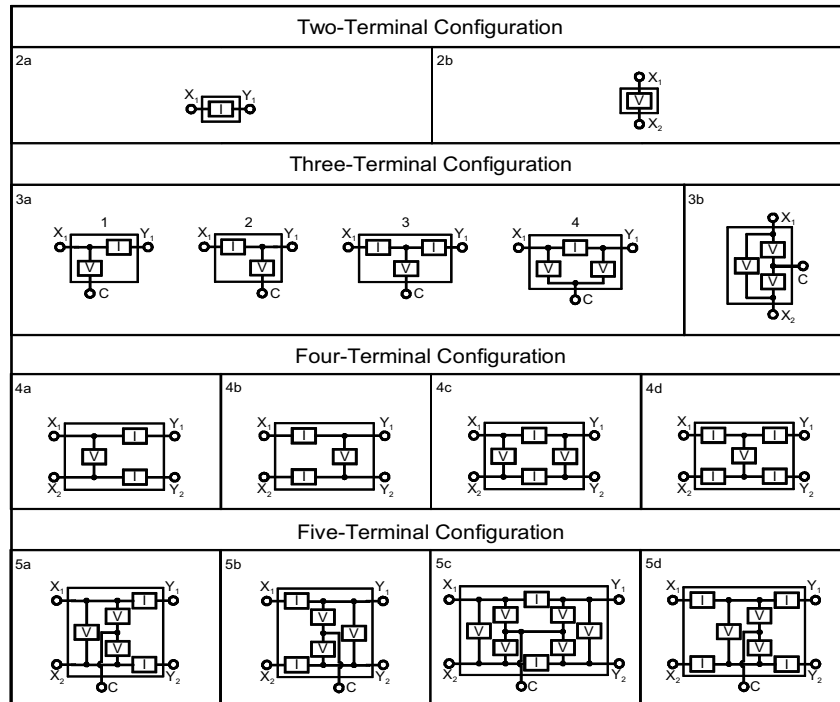
The overvoltage device may consist of two separate or integral components in parallel to provide redundant, additive, or backup protection. Although two or more overcurrent devices may be safely employed in series to provide coordination, they are not intended to be placed in parallel.

For redundant protection, both components may be expected to be equally capable of performing the primary protection function. For example, GDTs placed in parallel should have approximately the same breakdown and energy-handling characteristics, such that if one failed to operate because of high-breakdown voltage, the other would take over the protective function completely. On the other hand, if one degrades into a low breakdown voltage mode, it would very likely continue to handle the overvoltage surges, and the other redundant GDT may not operate.

For additive protection, both devices are needed to meet the total protection requirement. Each device may be addressing a different function or fault.

For backup protection, the two devices are designed to operate at different overcurrent or overvoltage levels. The normal operating function for the primary device is to suppress an overcurrent or overvoltage condition at a predetermined level below the operating range of the secondary device. In the event of a malfunction (high-breakdown voltage or high-current interrupt level) of the primary device, the secondary device is intended to operate at a coordinated higher current or voltage. The secondary device is deliberately set to a higher level so that it does not interfere with the operation of the lower current or voltage primary device.

Figure 1⁶ depicts various arrangements of voltage- and current-limiting components having two, three, four, and five terminals. The depicted arrangements and configurations are examples for discussion, and they are not intended to represent all possible arrangements or configurations of voltage- and current-limiting components.



NOTE—I and V current- and voltage-limiting components, respectively.

Figure 1—Possible internal arrangement of protector components

3.3 Two-terminal basic configuration

A two-terminal multiple component overcurrent protector, such as depicted by configuration 2a (Figure 1), may include one or more overcurrent components arranged in series within a common enclosure.

A two-terminal multiple component overvoltage protector, such as depicted by configuration 2b (Figure 1), may include of one or more overvoltage components arranged in parallel within a common enclosure.

3.4 Three-terminal basic configuration

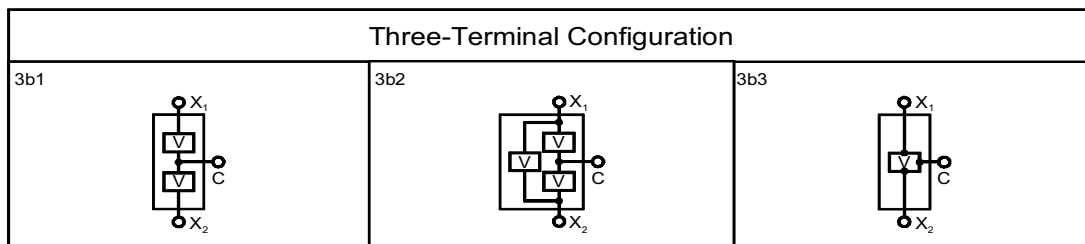
Configurations 3a1, 3a2, 3a3, or 3a4 of Figure 1 show arrangements of overvoltage and overcurrent protection components for single-conductor signal lines that have a *common ground*. The protector may consist of two or more overvoltage protection components connected in parallel with one other, as well as the overcurrent-protection components as shown, within a common enclosure.

Configurations 3a1 and 3a2 depict asymmetrical protector component arrangements, wherein the applied surge encounters the overvoltage component either before or after the overcurrent component. Applications define which side of the protector is to receive surges and which side of the protector is to be connected to protected equipment.

⁶Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the guide.

Configurations 3a3 and 3a4 depict symmetrical protector component arrangements, wherein a protector is designed to handle surges entering from either X or Y terminals. If the 3a3 and 3a4 configuration protectors are intended to have fully symmetrical capabilities (i.e., if they are designed to handle the same surge energy at each terminal irrespective of how they are connected to the system or equipment to be protected), then all protection components may be of the same type and have the same energy ratings. If, on the other hand, the protector is to be applied in an asymmetrical situation in which expected surges imposed on the Y terminal are of much lower energy content than those expected at the X terminal, then the corresponding protection components are generally of much different types and energy ratings. In this latter case, the overcurrent components should include an impedance to ensure that the primary or higher energy overvoltage component operates on surges having more current flowing through the overcurrent component than the secondary overvoltage component can handle (configuration 3a4).

For two-conductor signal lines that have a *common terminal*, the configuration of overvoltage protectors are as shown in configurations 3b1, 3b2, and 3b3 of Figure 2. The protector may contain two or more overvoltage components connected in parallel, and arranged within a common enclosure. In configuration 3b1, the components are connected between each signal line and common. In configuration 3b2, the components are connected between each signal line and common and another component is connected between the two signal lines. In configuration 3b3, a single three-terminal component is shown.



NOTE 1—I and V current- and voltage-limiting components, respectively.

NOTE 2—V multiterminal voltage-limiting component.

Figure 2—Variations of configuration 3b

The arrangements depicted serve only as examples for discussion and are not intended to represent all possible arrangements or inclusion of voltage and current-limiting components in any given configuration.

The configurations of 3b2 and 3b3 may be used to minimize the differential voltages caused by operation of the protection component. The components may be three-element GDTs or three-terminal solid-state components. Circuits that include GDTs may include shunt overvoltage air gaps for backup protection in case of venting of the hermetic seal of the GDT. When three-terminal solid-state components are used, these may contain either two or three solid-state chips that may be selected for matched conditions and molded in one package. Because solid-state components normally fail short-circuit, the backup-type components used with GDTs are generally not needed.

3.5 Three-terminal theory of operation

Configuration 3a protectors of Figure 1 limit either common mode overvoltage or overcurrent surges or both dependent on their intended design and use.

Configuration 3a1 opens the line to surge currents conducted by the protector, but it will maintain overvoltage protection at the X terminal. Configuration 3a2 opens the line to surge currents conducted by the protector and isolates the overvoltage component from further surge activity at the X terminal. In either case, the overcurrent component can be designed to limit surge currents driven by voltages too low in magnitude to operate the overvoltage component.

Configuration 3a3 requires that a surge be conducted by an overcurrent protective component before it appears at the overvoltage component, regardless of which terminal is surged. The overcurrent components may be selected so that the protector opens the line being surged and the overvoltage component is isolated from further surges on that line. The other overcurrent component may or may not isolate the overvoltage component from the opposite line.

In configuration 3a4, if the overcurrent protector components open the line, any high voltage present on either side of the protector is shunted to ground by the overvoltage protector component. The overvoltage components may have equal performance ratings for fully symmetrical applications, or they may be different components selected for additive or backup protection features in asymmetrical applications.

The overvoltage protectors of configuration 3b1 (Figure 2) limit the common-mode voltage (longitudinal voltage) to a low level and limit the normal mode (differential mode) voltage. However, the maximum differential voltage could be as large as twice the common mode, which would occur when the two-conductor signal lines carry transient voltages of opposing polarity. If the components used have breakdown values that are nearly equal, for coincidental voltage surges on both signal lines, the differential voltage generated at the output terminals is minimal. If large differences exist in breakdown levels, the resulting overvoltage imposed on the load may be a problem.

The three-terminal protector of configuration 3b3 provides protection for both signal lines within one component. The effect of a surge on one line is to provide a low-resistance path to ground, and to enhance the breakdown of the other line almost simultaneously, thereby minimizing the differential voltage.

The functional interaction of the primary overvoltage component with a backup component is determined by the application. Some voltage limiters should never short the line for longer than the duration of the surge, because to do so would cause an unacceptable malfunction of the signaling system. For telephone network equipment, shorting of the lines is permitted because a temporary shorted condition is acceptable. The protector continues to provide protection until manual restoration is completed. The short-circuit failure mode may be inherent in the primary component or may be obtained by the mechanical action of a secondary component such as a heat coil.

3.6 Four-terminal basic configuration

The four-terminal protector configuration (Figure 1) may provide either overvoltage or overcurrent protection or both for differential fault conditions dependent on its intended design and use.

In the case of a four-terminal protector, the overvoltage or overcurrent components are designed to protect a two-wire system and the protector does not have a common connection. As shown in configurations 4a and 4b of Figure 1, a current-interrupting device or current-limiting device is connected in each conductor of a two-wire circuit, and a voltage limiter is applied either at the input or at the output terminals. Redundant, additive, or backup overcurrent components may be added in series on the output side of the overvoltage component, as shown in configurations 4c and 4d.

3.7 Four-terminal theory of operation

If required to be present, the overcurrent protector of configuration 4a of Figure 1 limits abnormal currents in a load in the event of a differential overvoltage condition that has occurred at or within the load. The level of overcurrent protection depends on coordination of a current-limiting component and the abnormal current tolerance of the load.

In the case of a differential fault, abnormal current flows through either side of the circuit, connected load, and opposite side. This condition can be controlled by one current-limiting component. In the case of a longitudinal fault seeking common through the load, the overcurrent component located in the conductor, experiencing the fault, limits the abnormal current without affecting the condition of the overcurrent component in the opposite line. A longitudinal fault has no effect on an overvoltage protector (configuration 4b) because the overvoltage protector has no connection to common.

Configuration 4b shows the addition of an overvoltage component in parallel with the load to limit overvoltage conditions.

When conduction of the overvoltage component occurs in configuration 4c, excessive current is shunted through the overvoltage component and away from the load. At the same time, the overvoltage condition is distributed along the incoming conductor impedance where the energy is dissipated. In the event of a sustained overcurrent condition, the overcurrent component either opens, diverts, or reduces current.

Configuration 4d shows two additional overcurrent components for the purpose of redundancy, additive, or backup features.

3.8 Five-terminal basic configuration

Configuration 5a of Figure 1, which is sometimes used as, but not limited to, a telephone central office or remote switch protector, has an overvoltage protection element connected between each line and common, and it may also have an overcurrent protector element connected in series with each line and placed on the protected-equipment side of the overvoltage components. A separate overvoltage protector component may also be connected between the lines for differential overvoltage protection.

Configuration 5b, which is sometimes used as, but not limited to, a telephone station secondary protector, has an overvoltage protection components connected between each line and the common terminal, and it has an overcurrent protection components connected in series with each line and placed on the surge input side of the overvoltage components. A separate overvoltage protector component may also be connected between the lines for differential overvoltage protection.

Configuration 5c is a six-component protector (or, alternatively, has eight components if X-terminal and Y-terminal line-to-line overvoltage components are included). Four overvoltage components connect between the four-line terminals and common or ground. Two overcurrent components connect between respective X-line and Y-line terminals, and they separate the overvoltage function components.

If differential overvoltage components are incorporated in the protector, they are connected line-to-line across the X-pair and the Y-pair terminals.

If the configuration 5c protector is intended to have symmetrical capabilities and handle the same surge energy, irrespective of terminal connection, then all line-to-ground overvoltage components may be of the same type and have the same energy ratings. If the protector is to be applied in asymmetrical situations because of different surge magnitudes imposed on different terminals, then the overvoltage components for the different terminals may be of different types and energy ratings.

In this latter case, the overcurrent component may also include an impedance to ensure the operation of the overvoltage component. The impedance limits the current conducted by the second overvoltage component and enhances the operation of the first overvoltage component by restoring the voltage across its terminals.

In configuration 5d, overvoltage components are each connected between one line and common. Both the first and the second overcurrent components typically have a complementary component in the opposite line.

The six components may be mounted within a common enclosure, or they may be configured into modules that plug into one other to form the complete protection package.

3.9 Five-terminal theory of operation

Protectors of this type are intended to provide line-to-line and line-to-ground protection, and they may have the capability to interrupt abnormal currents through the lines, which might otherwise damage the protected equipment. The current-limiting component should be properly selected to ensure operation and prevent service wiring or equipment damage. Some protectors use a fusible link of wire of finer gauge, having faster fusing characteristics than that of the protected service wire, and the protector is thus said to be coordinated with the wiring.

Overcurrent protection components are selected such that they minimize series resistance and provide adequate overcurrent sensitivity for the application. Shunting-type overcurrent components, such as heat coils or some solid-state limiters, should have sufficient current-carrying ability to shunt the overcurrent such that the network can deliver without permanently opening the shunting device.

If the overcurrent protection component is a fuse, fusible link, or nonresettable heat coil, it or the overall protector will have to be replaced to restore service. If a resettable overcurrent element is used, the service may be restored manually or automatically reset after the overcurrent event has passed. In some cases, sufficient time should be allowed for the protector to reset.

Protectors of this type are also intended to shunt overvoltage surges appearing on lines X_1 , X_2 , Y_1 , and Y_2 to the common reference terminal.

In the event of differential overvoltages appearing at the protector terminals because of unbalanced surges or the operation of only one of the line-to-common overvoltage components, the optional line-to-line overvoltage component provides additional surge protection to the equipment connected to the Y terminals.

If the line-to-line component is designed to limit at a voltage lower than the line-to-common components, it may then operate to protect the equipment from abnormally high differential voltages before the second line-to-common component operates.

Overvoltage component operation, if sustained by a power line contact or similar event, may cause sufficient current to pass through the overcurrent component to cause it to operate. Such intercomponent coordination is designed to prevent damage to the multielement protector.

In the case of configuration 5b, and possibly 5d, it should be noted that if the overcurrent protector components open the line, any high voltage present on the X_1 and X_2 terminals of the protector will remain on the line or the energy will be dissipated by other protectors or impedances of the network. Depending on the application, this condition may or may not be desirable.

In the case of configuration 5a or 5c, if the overcurrent protector components open the line, any high voltage present on the X_1 and X_2 terminal side of the protector will be shunted to ground by the overvoltage protector component.

Some multiple-component protectors use a thermal overload feature to prevent damage or a fire hazard from excess heat. Sustained overvoltages applied to the network cause the overvoltage component (air gap, GDT, or solid-state component) to operate and heat. The excess heat is thermally coupled to a mechanical, metallic alloy, or plastic component that melts or operates and allows electrical contacts to close. These contacts then bypass the overvoltage component and connect the lines to common.

Operation of an overvoltage component, if sustained by a power line contact or similar event, may generate sufficient heat in that component to cause the overcurrent component to operate if the latter is thermally coupled to the overvoltage component. For example, if a sustained overvoltage condition is applied to the circuit, the air gap, GDT, or solid-state overvoltage component will operate and overheat, which melts the solder of the heat coil. The heat coil's spring-loaded action then closes a switch that short-circuits the overvoltage component, connecting line to common. The protector then cools to a safe temperature, which dissipates the power caused only by contact resistances.

4. Protector characteristics: nonsurge performance tests

This clause gives guidance on the applicability of the nonsurge performance tests for surge protectors used in low-voltage data, communications, and signaling circuits. A protector should not adversely affect the normal operating conditions of a system to which it is connected. The nonsurge performance tests may be used for initial characterization of protectors, and they may form the basis for assessing a surge protector for damage after the active performance tests from IEEE Std C62.36-2000 have been performed. Before using this clause, it is important to have an appreciation of the normal operating conditions of the application.

4.1 Rated voltage test

The purpose of this test is to verify that the surge protector can be used continuously at a specified maximum voltage, frequency, and temperature without undesirable signal distortion, undesirable power loss, or failure. For a given application, under normal operating conditions, the maximum operating voltage applied to a protector should be identified, and system performance should not be affected by the use of the surge protector at this maximum voltage. The rated voltage test is applicable when overvoltage (shunt) protection is employed between terminals of a signaling circuit, where excessive leakage current in the protector may affect circuit performance. An example is a telecommunication application in which the ringing voltage used for signaling exceeds the voltage used during transmission of data. A surge protector that performs satisfactorily under transmission conditions may limit or distort the higher ringing voltage. When specifying the maximum voltage across the protector during the ringing interval, any extraneous voltages (e.g., induction from power lines) should be considered.

4.2 Rated current test

This test is conducted to verify that a surge protector does not degrade normal circuit functions while carrying the rated current. The protector is tested at the specified rated current.

While carrying continuous current under normal operating conditions, a surge protector should not

- Degrade normal circuit functions
- Generate temperatures that are excessive for any component in the protector or for any materials in proximity to the protector

If used at currents that are above the rated current, series overcurrent devices may overheat under continuous current conditions causing degradation of circuit functions (e.g., high-impedance, open-fuse, tripped PTC) or excessive temperatures on insulating materials.

4.3 DC series resistance test

For an application in which the surge protector provides overcurrent protection or only provides a through-link function, this test gives a measure of its series resistance. This test is applicable if the type of protector used introduces a resistance in series with the line. The dc series resistance is measured using a continuous current having a value that is appropriate for the application. The current source is applied to the relevant terminals of the surge protector, and the voltage across the terminals is measured. The dc resistance is then calculated as the quotient of the voltage drop and specified current (e.g., 100% rated current, 80% rated current, etc.).

4.4 Standby current and insulation resistance test

Standby current is the continuous current that is conducted between specified terminals of a surge protector when applying a specified dc voltage across these terminals. The insulation resistance is the calculated result of dividing the applied voltage by the measured standby current. This test usually applies across terminals that are intended to be a high resistance such as on a voltage limiter or insulation. All protector terminals not being measured should be left completely disconnected during the measurement, so that other current leakage paths, if present, are not inserted into the measurement circuit. The standby current can also be measured between the external surface of the protector housing (sometimes wrapped in metallic foil) and the terminals. The results of this test indicate whether the protector contains an undesirable leakage current path, which would interfere with normal circuit operation or pose a safety hazard. The standby current of a surge protector may depend on the magnitude of the applied voltage, polarity of the applied voltage, ambient temperature, and humidity.

This test is meant to be a steady-state measurement, so the capacitance of the surge protector should be allowed to charge to the applied voltage before the current is measured. Any additional capacitance from the test circuit wiring and components may require even longer settling times. For some devices, such as spark-gap devices, up to 100 ms may be needed for the gap to stabilize and reach steady state.

As the applied voltage approaches the rated voltage of the device, the standby current of the device tends to increase. When measuring the standby current, the magnitude of the applied voltage should not exceed the rated voltage of the protector (4.1), because the protector may be significantly conductive at or above its rated voltage. The magnitude of any system dc bias voltage used during normal circuit operation should be considered as at least one voltage used to measure the standby current of a protector.

With some solid-state surge protective devices, the standby current is relatively constant over a large part of the applied voltage from zero to the rated voltage. Therefore, the calculated insulation resistance increases as the applied dc voltage increases, or conversely, the calculated insulation resistance decreases as the voltage decreases, even though the leakage current is not changing. The needs of the protected circuit should be considered when determining whether to specify either standby current or insulation resistance of the protector.

The standby current can also be affected by ambient temperature and humidity, and different types of protection devices react differently to these conditions. In particular, the standby current of solid-state surge protective devices increases as the device temperature increases. On the other hand, the standby current of surge protectors incorporating air gaps (carbon blocks or GDTs having backup air gaps) can increase as the relative humidity of the nearby atmosphere rises. Moisture condensation inside these types of protectors may bridge the gap, thereby providing a leakage path for current.

The standby current of a protector can also be dependent on the polarity of the applied test voltage. It can be particularly true for solid-state bidirectional thyristor surge protective devices.