Recognized as an American National Standard (ANSI) **IEEE C62.41-1991**
(Revision of IEEE C62.41-1980)

IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits

Sponsor
Surge-Protective Devices Committee
of the
IEEE Power Engineering Society

Approved February 25, 1991
IEEE Standards Board

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American National Standards Institute

Abstract: A practical basis is provided for the selection of voltage and current tests to be applied in evaluating the surge withstand capability of equipment connected to utility power circuits, primarily in residential, commercial, and light industrial applications. The recommended practice covers the origin of surge voltages, rate of occurrence and voltage levels in unprotected circuits, waveshapes of representative surge voltages, energy, and source and impedance. Three locations categories are defined according to their relative position from the building service entrance. For each category, representative waveforms of surge voltages and surge currents are described, organized in two recommended “standard waveforms” and three suggested “additional waveforms.”
Keywords: ac power circuits, current tests, surge monitoring, surge test waveforms, surge voltages, surges, test waveforms, voltage tests, wave shape

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Foreword

(This Foreword is not a part of IEEE C62.41-1991, IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.)

Transient surge voltages occurring in ac power circuits can be the cause of operational upset or product failure in industrial and residential systems and equipment. These problems have received increased attention in recent years because of the widespread application of complex semiconductor devices that are more sensitive to voltage surges than vacuum tubes, relays, and earlier generations of semiconductor devices.

Logical and economical design of circuits to protect vulnerable electronic systems from upset or failure requires knowledge of or an estimate of:

1) Transient voltage and current waveforms,
2) Frequency of occurrence of transients with various energy levels,
3) Particular environmental variations such as amplitudes, and
4) Upset or failure threshold of the particular equipment to be protected.

The previous edition of this document, IEEE C62.41-1980, “IEEE Guide for Surge Voltages in Low-Voltages AC Power Circuits” (also known as IEEE Std 587-1980), contained similar information about the surge environment. Most of the voltage surge recordings for the 1980 edition were made prior to 1975, when electronic instrumentation for surge monitoring was not readily available. Instrumentation and data-base information, while still limited in some parameters such as very short rise time and frequencies, have vastly improved, as reflected in this edition.

This document provides updated and expanded information relevant to a typical surge environment based upon location within the building, power-line impedance to the surge, and total wire length. Other parameters often adding to the surge environment include proximity and type of other electrical loads, type of electrical service, wiring quality, and geographic location.

New information on probability of surges has been added. A new waveform incorporating a shorter front and two new waveforms incorporating longer durations supplement the two standard waveforms. A new section consisting of a “how-to-use” guide has also been added to allow the reader to develop a rational approach to equipment protection by following the recommendations of this document.

It must be noted that a recommendation of test waveforms alone is not an equipment performance specification. Other documents based on the waveforms recommended herein have been or will be developed to describe the performance of equipment or protective devices in low-voltage ac power circuits.

Some manufacturers have advertised that their protective device “meets the requirements” of IEEE Std 587-1980 or IEEE C62.41-1980. Such a statement is a misuse of the document, since the document only describes surges and does not specify any specific safe level or performance of equipment during application of a test waveform. The levels given in this document reflect typical environment conditions and provide a menu from which equipment designers and users can select the values appropriate to a specific application. Any statement that a protector “meets the requirements of” or “is certified to” this document is inappropriate and misleading.

The Summary given after this Foreword is intended only for a rapid overview and therefore is not included as part of the recommended practice.

Suggestions for improvements of this recommended practice will be welcomed. They should be sent to the Secretary, IEEE Standards Board, Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

At the time this recommended practice was completed, the membership of the Working Group on Surge Characterization in Low-Voltage Circuits of the Power Engineering Society consisted of:

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**Contributions to the data base from many researchers, as indicated by the source references, are also gratefully acknowledged by the working group.

When the Balloting Committee of the Surge-Protective Devices Committee reviewed and approved this document, it had the following membership:

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The Accredited Standards Committee on Surge Arresters, C62, that reviewed and approved this document, had the following members when at the time this document was sent to letter ballot:

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The final conditions for approval of this recommended practice were met on February 25, 1991. This recommended practice was conditionally approved by the IEEE Standards Board on December 6, 1990, with the following membership:

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Summary

(This Summary is not a part of IEEE C62.41-1991, IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.)

This document describes the occurrence of surges in low-voltage ac power circuits and provides guidance on the simplification of a complex data base into a limited set of representative surges. This simplification will assist designers of equipment in providing the appropriate degree of withstand capability in their designs, allow users of equipment to specify appropriate levels of withstand requirements, and provide test equipment suppliers and test laboratories with a recommended practice for a limited number of well-defined test waveforms.

Protection from surge voltages in ac power circuits can best be achieved through the application of protective devices matched to the environment and to the operational requirements of the equipment. Environmental conditions can be represented by two selected voltage-current waveforms, described as standard waveforms, with amplitude and available energy dependent upon the pertinent location within the power system or distance from the surge source. Circumstances may be encountered where other waveforms, described as additional waveforms, may be appropriate to represent surges caused by less frequent mechanisms or by the presence of equipment recognized as the cause of longer or shorter disturbances.

Standard Waveforms

For practical purposes, locations are divided into three categories. Surge characteristics, that is, rates of occurrence, waveforms, source impedances, and amplitudes, are discussed for each category of location and exposure.

1) Locations
   Category A: Long branch circuits, receptacles (indoor)
   Category B: Major feeders, short branch circuits, service panel (indoor)
   Category C: Outdoor overhead lines, service entrance
2) Exposure
   Low Exposure: Systems in geographical areas known for low lightning activity, with little load-switching activity.
   Medium Exposure: Systems in geographical areas known for medium to high lightning activity, or with significant switching transients, or both.
   High Exposure: Those rare installations that have greater surge exposure than those defined by Low Exposure and Medium Exposure.

3) Recommended Values
Recommended values are given for the waveforms, voltage amplitude, and current amplitude of representative surges in line-to-neutral, line-to-line, and neutral-to-ground configurations.

Additional Waveforms

Special situations have been identified in which additional waveforms may be appropriate; these have been added to the standard waveforms initially defined in the 1980 version of this document. These special situations include the presence of large banks of switched capacitors or the operation of fuses at the end of long cables. These cases warrant consideration of additional waveforms that have the capability of depositing substantial energy in a surge-diverting protective device and causing failure of devices not sized for that occurrence. However, the characteristics of these phenomena are closely related to the specifics of the situation, so that it is difficult to provide generally applicable recommendations. For that reason, this document presents information on these surges as a range of values rather than specific numbers.

The presence of nearby equipment involving load switching can couple bursts of fast transients that have the capability of interfering with logic circuits and causing upsets. This situation has been recognized, and test procedures have been defined by other organizations to demonstrate immunity of equipment that may be subjected to these bursts. This document endorses the recommendations made by these organizations and includes the fast-transient burst where applicable.

Guidance Versus Specification

The recommendations given in this document are provided as the basis for selecting specifications appropriate to the needs of equipment designers and users, depending on the particulars of the situation. While recognizing the desirability of sweeping general specifications, this document cautions the reader against such practice. The specification of equipment withstand capability, and of test levels to prove this capability, remains the responsibility of equipment suppliers and equipment users, based on an understanding of the situation that this document is attempting to provide. While short-term monitoring of an individual site often gives some useful information, the environment is so dynamic that the analysis of a brief period may not give a good prediction of the future environment.

Readers are also warned on the economic fallacy of specifying unrealistic complexities of test procedures or excessive withstand capability in an attempt to obtain greater reliability. The complexity of the surge environment is such that no set of test waveforms will ever completely simulate the environment, and a slightly higher level of surges can always be proposed to boost equipment withstand. This document was prepared with the intent to avoid such unrealistic requirements.

CLAUSE PAGE

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IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits

1. Scope

The purpose of this recommended practice is to provide information on surge voltages in low-voltage[1] ac power circuits. With this information, equipment designers and users can evaluate their operating environment to determine their need for surge-protective devices. The document characterizes electrical distribution systems in which surges exist, based upon the data that have been recorded in interior locations on single-phase and three-phase residential, commercial, and industrial power distribution systems.

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

The surges considered in this document do not exceed one-half period of the normal mains waveform in duration. They may be periodic or random events and may appear in any combination of line, neutral, or grounding conductors. They include those surges with amplitudes, durations, or rates of change sufficient to cause equipment damage or operational upset (see Fig 1). While surge-protective devices acting primarily on the amplitude of the voltage are often applied to divert the damaging surges, the upsetting surges may require other remedies.

Test procedures are described in IEEE C62.45-1987 [8],[2] as a companion to the present document. Other surge-related standards are identified in Section 4; the present document is intended to complement these standards.

[1]Note that “low voltage” is defined by the IEEE and IEC as up to 1000 V rms.
[2]References in the text, shown as [x], are listed in Section 4. Citations shown as [Bx] are found in Appendix C.