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IEEE Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits

IEEE Power Engineering Society

Sponsored by the
Surge Protective Devices Committee

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Abstract: This is a guide describing the surge voltage, surge current, and temporary overvoltages (TOV) environment in low-voltage [up to 1000 V root mean square (rms)] ac power circuits. This scope does not include other power disturbances, such as notches, sags, and noise.
Keywords: lightning surges, low-voltage ac power circuit, surge environment, surge testing, surge withstand level, switching surges

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Introduction

[This introduction is not part of IEEE Std C62.41.1-2002, IEEE Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits.]

This guide is the result of 20 years of evolution from the initial 1980 document, IEEE Std 587™, IEEE Guide for Surge Voltages in Low-Voltage AC Power Circuits, which promptly became IEEE Std C62.41™ with the same title. The guide was updated in 1991 as IEEE Std C62.41-1991, IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits, reflecting new data on the surge environment and experience in the use (and misuse) of the original guide. The purpose of the document was and still is to provide information on the surge environment and offer recommendations to interested parties involved in developing application standards related to surge protective devices (SPDs) as well as recommendations to product designers and users.

The 1980 version, based on data available up to 1979, proposed two novel concepts:

1) The reduction of a complex database to two representative surges: a new "Ring Wave" featuring a decaying 100 kHz oscillation, and the combination of the classical, well-accepted 1.2/50 μs voltage waveform and 8/20 μs current waveform into a "Combination Wave" to be delivered by a surge generator having well-defined open-circuit voltage and short-circuit current.
2) The concept that location categories could be defined within an installation where surge voltages impinging upon the service entrance of an installation or generated within an installation would propagate, unabated, in the branch circuits, while the associated currents, impeded by (mostly) the inductance of the conductors, would be reduced from the values observed in circuits located close to the service entrance to lower values observed in circuits located at the end of long branch circuits.

The 1991 version, based on additional data as well as experience in the use of the 1980 guide, maintained the concepts of the location categories and the recommendation of representative surge waveforms.

The two seminal surges, Ring Wave and Combination Wave, were designated as "standard surge-testing waveforms," and three new "additional surge-testing waveforms" were added to the "menu." Meanwhile, a companion document, IEEE Std C62.45™-1992, IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits, was developed, outlining procedures for error-free application of the waveforms defined by IEEE Std C62.41™-1991 while enhancing operator safety.

The perceived need to justify the expansion of the two-only waveforms to a menu of five led to the growth in the document volume, from the 25-page IEEE Std 587-1980 to the 111-page IEEE Std C62.41-1991.

Additional data collected toward an update of the 1991 version (which was reaffirmed in 1996) would have increased further the volume of the document. Instead, a new approach was selected: to create a "Trilogy" by separating the information into three distinct documents, making their use more reader-friendly while maintaining the credibility of the recommendations:

— A guide on the surge environment in low-voltage ac power circuits (the present document)
— A recommended practice on characterization of surges in low-voltage ac power circuits (IEEE Std C62.41.2™-2002)
— A recommended practice on surge testing for equipment connected to low-voltage ac power circuits (IEEE Std C62.45™-2002)

In this manner, interested parties will have a faster, simpler access to the recommendations for selecting representative surges relevant to their needs. A comprehensive database will be available for parties desiring to gain a deeper understanding of the surge environment and an up-to-date set of recommendations on surge testing procedures.

Participants

At the time this recommended practice was completed, the Working Group on Surge Characterization on Low-Voltage Circuits had the following membership:

Hans Steinhoff, *Chair*
James Funke, *Co-Chair*
Raymond Hill, *Secretary*
François D. Martzloff, *Technical Editor*

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William Bush
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Joesph L. Koepfinger
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Don Worden

Other individuals who contributed review and comments in developing this recommended practice are

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J. Birkl
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C. Dhooge
D. Dorr
H. E. Foelker
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The following members of the balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

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Rural Electrication Administration (REA)	E. Cameron
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	S. G. Whisenant
	H. J. Steinhoff

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Also included is the following nonvoting IEEE-SA Standards Board liaison:

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Contents

IEEE Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits

1. Overview

This guide is divided into eight clauses. Clause 1 provides the scope of this guide and its context with respect to other IEEE standards directly related to the subject. Clause 2 lists references to other standards that are useful in assessing the surge environment described in this guide. Clause 3 states that no new definitions have been generated for this guide; however, for the convenience of the reader, important definitions already in existence are cited in the glossary (Informative Annex C). Clause 4 provides a tutorial description of the origins of surge voltages and surge currents. Clause 5 provides information on the propagation of surges. Clause 6 provides a summary of the database, drawn from the comprehensive data listed in Informative Annex A. Clause 7 provides basic information on the occurrence of temporary overvoltages (TOVs). Clause 8 suggests how this complex database can be simplified toward selecting a few representative surge waveforms that will be more specifically defined in the recommended practice IEEE Std C62.41.2™-2002,[1] which is a companion to this guide within the Trilogy.

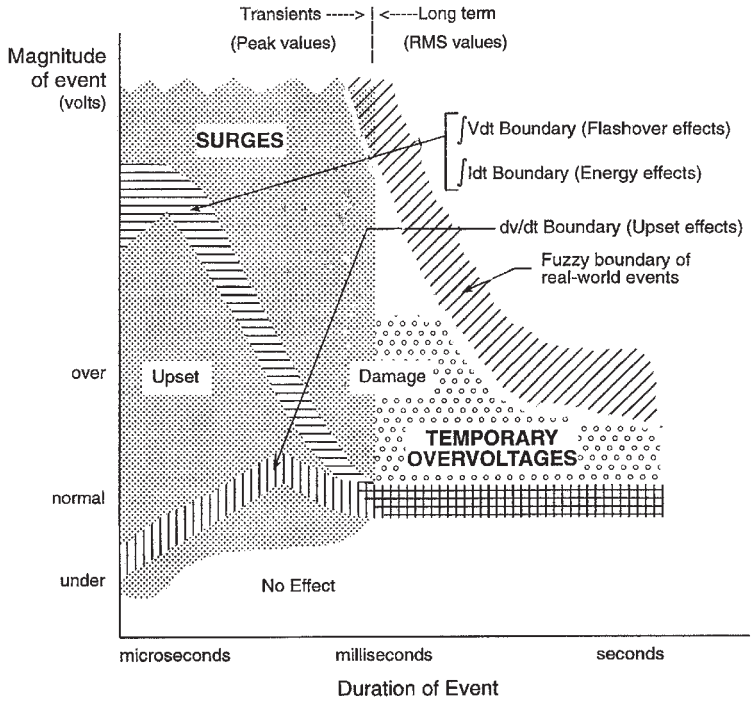
This guide also contains four informative annexes. Informative Annex A describes the results of surge measurements performed in the field, as well as the results of numerical simulations performed to supplement the recording of surge events. Useful inferences on the surge environment that can be drawn from equipment field success and failures are also discussed in this annex. Informative Annex B provides further tutorial information on the occurrence and propagation of surges. Informative Annex C lists some well-established definitions of terms used in this guide, complemented by further comments. Informative Annex D is an annotated listing of bibliographic references used to develop this guide and provides suggestions for further detailed reading on the surge environment.

1.1 Scope

This is a guide describing the surge voltage, surge current, and TOV environment in low-voltage [up to 1000 V root mean square (rms)] ac power circuits. This scope does not include other power disturbances, such as notches, sags, and noise.

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

The surges considered in this guide do not exceed one-half period of the normal mains waveform (fundamental frequency) in duration. They can be periodic or random events and can appear in any combination of line, neutral, or grounding conductors. They include surges with amplitudes, durations, or rates of change sufficient to cause equipment damage or operational upset (see Figure 1). While surge protective devices (SPDs) acting primarily on the amplitude of the voltage are often applied to divert the damaging surges, the upsetting surges may require other remedies. The rationale for including a description of TOVs in this guide on the surge environment is given in 1.2.



NOTES

1—The graph shows the relative position of effects and the order of magnitude of the amplitude and duration. Do not attempt to read numerical values from this graph.
2—The scope of the guide is shown by the two dot-pattern areas. The fine pattern relates to surges, the prime scope of this guide. The coarse pattern relates to TOVs, the secondary scope of this guide. For surges, the upper limit for the duration is one half-cycle of the applicable power frequency. Swells—overvoltage events longer in duration than a surge, but lasting only a few seconds—are considered to be a subset of TOVs.
3—The values or positions of the boundaries between "no effect" and "upset" and between "upset" and "damage" vary with the withstand characteristics of the equipment exposed to the surges.
4—The boundary between "upset" and "damage" in the microsecond range is shown as the integral of $V\mathrm{d}t$ to reflect the upturn in the volt-time characteristic of sparkover. Equipment responses that do not involve a sparkover are more likely to be influenced by the simple magnitude of voltage V.
5—This figure shows only one measure of surge severity emphasizing voltage and time relationships. Other possible measures include current peak and duration, rise time, and energy transfer.

Figure 1—Simplified relationships among voltage, duration, rate of change, and effects on equipment

1.2 Purpose

This guide, the first of a Trilogy of three IEEE standards addressing surges in low-voltage ac power circuits, focuses on the surge environment and on the TOV environment. This part provides readers with basic information on the occurrence of surges, as a database for the second document of the Trilogy, IEEE Std C62.41.2-2002 where recommendations are presented on the selection of representative surge

