

An American National Standard
IEEE Application Guide for
Transient Recovery Voltage for
AC High-Voltage Circuit Breakers
Rated on a Symmetrical Current Basis

Sponsor

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Foreword

(This Foreword is not a part of ANSI/IEEE C37.011-1979, American National Standard Application Guide for Transient Recovery Voltage for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.)

The development of standards for the rating, testing, and manufacture of high-voltage circuit breakers began almost simultaneously with the application of the first circuit breakers in early power supply systems.

A number of engineering and manufacturers trade organizations were interested in standards for high-voltage circuit breakers as well as other types of electrical equipment and worked to develop standard requirements for capabilities, sizes, and testing procedures. Among these groups were the AIEE¹, the National Electric Light Association (NELA), the Electric Power Club (a predecessor of NEMA — the National Electrical Manufacturers Association), the Association of Edison Illuminating Companies (AEIC), and the Edison Electric Institute (EEI).

During the years up to 1940, these organizations adopted and published a number of standardization proposals concerning rating, testing, and other requirements for high-voltage circuit breakers.

In 1941, a unified series of standards for circuit breakers, based on those of AIEE, AEIC, and NEMA, were published for trial use by the American Standards Association (ASA). This comprised the first American Standard for high-voltage circuit breakers. In 1945, this series was issued as an approved American Standard with the familiar C37 number identification. This series included sections on rating, preferred sizes, testing, and application of circuit breakers. In 1952 and 1953, this series of standards was revised and supplemented by additional sections, forming the complete, basic group of American Standards for high-voltage circuit breakers. At the time of publication this group of standards included:

ANSI C37.4-1953	AC Power Circuit Breakers (included definitions, rating basis, and some test requirements)
ANSI C37.5-1953	Methods for Determining the RMS Value of a Sinusoidal Current Wave and Normal-Frequency Recovery Voltage, and for Simplified Calculation of Fault Currents
ANSI C37.6-1953	Schedules of Preferred Ratings for Power Circuit Breakers
ANSI C37.7-1952	Interrupting Rating Factors for Reclosing Service
ANSI C37.8-1952	Rated Control Voltages and their Ranges
ANSI C37.9-1953	Test Code for Power Circuit Breakers
ANSI C37.12-1952	Guide Specifications for Alternating Current Power Circuit Breakers

Under these original standards, the basis of the interrupting rating was established by 6.11 of ANSI C37.4-1953 as the highest current to be interrupted at the specified operating voltage and was the "... rms value including the dc component at the instant of contact separation as determined from the envelope of the current wave." Since this standard based the interrupting rating on the total current including dc component at the instant of contact separation, it has become known as the "Total Current Basis of Rating."

For circuit breaker application, a simplified method was available in ANSI C37.5-1953, which listed multiplying factors for use with the system symmetrical fault current to derive a maximum possible total rms current which could be present at contact separation. This current was used to choose the required circuit breaker rating from those listed in ANSI C37.6-1953, or subsequent revisions. The factors recognized typical system characteristics and circuit breaker operating times.

¹AIEE (American Institute of Electrical Engineers) merged with IRE (Institute of Radio Engineers) January 1, 1963 to form the joint organization IEEE (Institute of Electrical and Electronics Engineers).

In 1951, the AIEE Switchgear Committee began to give consideration to the development of a circuit breaker rating method based on symmetrical interrupting currents. This work was initiated with the goal of:

- (1) Simplifying application where high-speed relaying and fast clearing circuit breakers are used
- (2) Bringing American standards into closer agreement with accepted international standards (IEC-International Electrotechnical Commission) to avoid confusion on rating differences
- (3) Requiring that circuit breakers are proven to demonstrate a definite relationship between asymmetrical interrupting capability and symmetrical ratings

During the course of this work, principally in a working group of the AIEE Power Circuit Breaker Subcommittee, numerous reports of the proposals on the new rating, testing, and application methods were made to the industry as a whole through committee sponsored papers at AIEE meetings in 1954, 1959, and 1960. Suggestions made in discussions were considered by the working group and incorporated where practicable. The principal change from the 1953 "Total Current" standard was in the basis of rating. 4.5.1 of ANSI C37.04 established the Rated Short Circuit Current as "the highest value of the symmetrical component of the... short-circuit current in rms amperes, measured from the envelope of the current wave at contact separation, which the circuit breaker is required to interrupt at rated maximum voltage...". Certain related capabilities were also required, including operation under specified conditions of asymmetry based on typical circuit characteristics and circuit breaker timing. This rating structure became known as the *Symmetrical Current Basis of Rating* as compared to the previous *Total Current Basis of Rating*. However, as the new ratings were developed, it became apparent that changes from the older to the newer standard could not occur overnight due to requirements for rerating and retesting of many PCBs. It was, therefore, decided to retain both rating structures, with the understanding that all new circuit breaker developments would be directed toward the *symmetrical* standards. The circuit breakers based on the *total current* standards would be transferred to the new standards as work progressed in rerating programs. This transfer is being carried out and ANSI C37.6 and ANSI C37.06 have been revised accordingly a number of times.

The *symmetrical current* group of standard sections was published in 1964 and was given ANSI C37.04, C37.05, C37.06, etc, designations. These sections and the corresponding 1953 sections were:

Total Current Standard	Symmetrical Current Standard	Subject
ANSI C37.4	ANSI C37.03	Definitions
	ANSI C37.04	Rating Structure
	ANSI C37.04a	
ANSI C37.5	ANSI C37.05	Measurement of Voltage and Current Waves
ANSI C37.6	ANSI C37.06	Preferred Ratings
	ANSI C37.06a	
ANSI C37.7	ANSI C37.07	Reclosing Factors
ANSI C37.8	(included in ANSI C37.06)	Control Voltages
ANSI C37.9	ANSI C37.09	Test Code
	ANSI C37.09a	
ANSI C37.5 (Section 3)	ANSI C37.010	Application Guide (expansion of material previously in C37.5)

Sections .04a, .06a, and .09a, also issued in 1964, were addenda concerned with supplemental dielectric capability requirements.

In ANSI C37.06-1964 and subsequent revisions prior to 1971, circuit breaker symmetrical current interrupting ratings were derived from ratings in ANSI C37.6-1961 by a relationship following a middle ground position between the total (asymmetrical) current of the former rating method and the full range of related requirements of the new rating method. For a given breaker this derivation was expressed by the formula:

$$\text{rated short circuit current} = I_{1961} \left(\frac{\text{nominal voltage}}{\text{rated maximum voltage}} \right) F$$

where

I_{1961} = interrupting rating in amperes appearing in ANSI C37.6-1961

F = 0.915 for 3 cycle breakers

0.955 for 5 cycle breakers

1.0 for 8 cycle breakers

Rated short circuit current was tabulated for rated maximum voltage rather than for nominal voltage as had been the case under the total current basis of rating.

It was stressed that this derivation was for the numerical conversion only and that a given circuit breaker, designed and tested under the total current basis of rating, could not be assumed to have these capabilities under the symmetrical current basis of rating without approval of the manufacturer.

In the revision of ANSI C37.06 published in 1971, several simplifications were introduced, including the use of a new method for selection of interrupting current ratings for outdoor circuit breakers 121 kV and above. Values for rated short circuit current were chosen from the R-10 preferred number series, and the use of a reference nominal 3-phase MVA identification was discontinued. Also the rated voltage range factor K was changed to unity, 1.0, to simplify rating and testing procedures.

In the intervening years since the official publication of the primary sections of the symmetrical basis of rating standard for high-voltage circuit breakers, a number of revisions, additions, and improvements have been developed and published. Many of these additions were in subject areas of major importance in the rating, testing, and application of circuit breakers and were published as complete standards containing appropriate definitions, rating performance criteria, rating numbers, test procedures, and application considerations. This was done to avoid delay in publication and the necessity of reprinting other existing standards as each of these was completed. The result has been the publication of a substantial number of individual supplementary standards. The basic subject areas considered in these supplementary standards, and their initial publication dates, are shown below:

ANSI C37.071-1969	Requirements for Line Closing Switching Surge Control
ANSI C37.072-1971	Requirements for Transient Recovery Voltage
ANSI C37.0721-1971	Application Guide for Transient Recovery Voltage
ANSI C37.0722-1971	Transient Recovery Voltage Ratings
ANSI C37.073-1972	Requirements for Capacitance Current Switching
ANSI C37.0731-1973	Application Guide for Capacitance Current Switching
ANSI C37.0732-1972	Preferred Ratings for Capacitance Current Switching
ANSI C37.074-1972	Requirements for Switching Impulse Voltage Insulation Strength
ANSI C37.076-1972	Requirements for Pressurized Components
ANSI C37.078-1972	Requirements for External Insulating

ANSI C37.0781-1972	Test Values for External Insulation
ANSI C37.079-1973	Method of Testing Circuit Breakers When Rated for Out-of-Phase Switching

A goal of work recently completed, and represented by the 1979 publication of these standards, has been the editorial incorporation of all the supplementary standards listed above into the proper primary standards documents. For circuit breakers rated on a symmetrical current basis, the consolidated standards sections are:

ANSI/IEEE C37.04-1979	Rating Structure
ANSI C37.06-1979	Preferred Ratings and Related Required Capabilities
ANSI/IEEE C37.09-1979	Test Procedure
ANSI/IEEE C37.010-1979	Application Guide — General
ANSI/IEEE C37.011-1979	Application Guide — Transient Recovery Voltage
ANSI/IEEE C37.012-1979	Application Guide — Capacitance Current Switching

The present ANSI C37.05, Measurement of Current and Voltage Waves, is incorporated into ANSI/IEEE C37.09; ANSI C37.07, Interrupting Capability Factors for Reclosing Service, is incorporated into ANSI/IEEE C37.04, ANSI C37.06, and ANSI/IEEE C37.09. Definitions which have been in C37.03-1964 are now in ANSI C37.100-1972.

Standards are presently being developed in a number of additional subject areas, which will be initially published as supplementary standards and incorporated into the primary subject document at some future date. Included among these subjects are requirements for current transformers, a guide for synthetic testing, sound level measurements, and seismic capability requirements.

For circuit breakers still rated on a total current basis, as listed in ANSI C37.6, the existing standards ANSI C37.4, ANSI C37.6, ANSI C37.7, and ANSI C37.9 will continue to be applicable.

Documents pertaining to guide specification and control schemes, which apply to both groups of ratings, are included in the ANSI C37 series as shown below:

ANSI C37.11-1972	Requirements for Electrical Control on AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis and a Total Current Basis
ANSI C37.12-1969	Guide Specifications for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis and a Total Current Basis

Periodic review of all these standards takes place through the normal ANSI procedure that standards are reaffirmed, revised, or withdrawn within no more than five year intervals from the original publication date.

Suggestions for improvement gained in the use of this standard will be welcome. They should be sent to the

American National Standards Institute
1430 Broadway
New York, NY 10018

The basic data included in this consolidated document is the result of contributions made by many individuals over many years. At the time of approval, however, the American National

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C. L. Wagner, *Chairman*

J. P. Lucas, *Secretary*

J. E. Beehler, *Executive Vice-Chairman of High-Voltage Switchgear Standards*

W. E. Laubach, *Executive Vice-Chairman of Low-Voltage Switchgear Standards*

W. R. Wilson, *Executive Vice-Chairman of IEC Activities*

Organization Represented	Name of Representative
Association of Iron and Steel Engineers	J. M. Tillman
Electric Light & Power Group	J. E. Beehler H. G. Darron H. G. Frus K. D. Hendrix F. R. Solis K. G. Adgate (Alt) R. L. Capra (Alt) R. L. Lindsey (Alt) E. E. Ramm (Alt)
Institute of Electrical and Electronics Engineers	M. J. Maier H. H. Fahnoe R. E. Friedrich G. W. Walsh H. F. White M. J. Beachy (Alt) C. A. Mathews (Alt) R. A. McMaster (Alt) D. C. Musgrave (Alt)
National Electrical Manufacturers Association.	A. P. Colaiaco R. W. Dunham D. G. Portman G. A. Wilson W. R. Wilson
Testing Laboratory Group.	E. J. Huber R. A. Naysmith R. W. Seelbach (Alt)
Tennessee Valley Authority.	R. C. St. Clair
U.S. Department of the Army	R. H. Bruck
U.S. Department of the Interior, Bureau of Reclamation.	E. M. Tomsic
U.S. Department of the Navy, Naval Facilities Engineering Command	D. M. Hannemann

The personnel of the C37 Subcommittee on High Voltage Circuit Breakers which reviewed and approved this document were as follows:

F. G. Schaufelberger, *Chairman*

J. J. Fayed, *Secretary*

J. E. Beehler
D. O. Craghead
M. A. Durso
C. J. Dvorak
R. E. Friedrich
R. D. Hambrick

D. R. Kanitz
W. E. Laubach
G. N. Lester
F. W. Smith
D. L. Swindler
W. R. Wilson

The basic source documents used in this consolidated document were prepared by various Working Groups of the Power Circuit Breaker Subcommittee of the IEEE Switchgear Committee. The personnel of the subcommittee at the time of consolidation were as follows:

G. N. Lester, *Chairman*

H. W. Anderl	G. P. Guaglione	H. K. Reid
J. E. Beehler	R. D. Hambrick	A. B. Rishworth
D. M. Benenson	G. R. Hanks	W. N. Rothenbuhler
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W. F. Giles	I. E. Olivier	B. F. Wirtz
K. I. Gray	G. O. Perkins	C. E. Zanzie
	J. G. Reckleff	

The Working Group of this subcommittee responsible for the editorial consolidation work on this standard consisted of:

N. E. Reed	W. N. Rothenbuhler	F. G. Schaufelberger
------------	--------------------	----------------------

The personnel of the Working Group of the Power Circuit Breaker Subcommittee of the IEEE Switchgear Committee and the High-Voltage Circuit Breaker Technical Committee of the NEMA Switchgear Section, which prepared the basic document, were as follows:

IEEE

F. R. Solis, <i>Chairman</i>	B. F. Wirtz, <i>Secretary</i>
J. E. Beehler	H. J. Holley
W. A. Carter	G. N. Lester
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IEEE (Advisors)

R. H. Amundson	J. M. Fleissner
R. A. Bednarik	R. D. Hambrick
E. W. Boehne	O. Naef
C. J. Essel	N. E. Reed
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An American National Standard

IEEE Application Guide for Transient Recovery Voltage for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

NOTE: Refer to ANSI/IEEE C37.04-1979, Rating Structure for AC High-Voltage Circuit Breakers, for requirements for transient recovery voltage and refer to ANSI C37.06-1979, Schedules of Preferred Ratings and Related Required Capabilities for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis, for preferred transient recovery voltage ratings and related required capabilities.

1. Scope

This standard covers the application guide for transient recovery voltage requirements for ac high-voltage circuit breakers rated above 1000 volts and on a symmetrical current basis.

The capability limits of these circuit breaker interrupting devices are determined largely by the transient recovery voltages. The guide for application is not included in other existing circuit breaker standards.

2. Purpose

The purpose of this standard is to provide an application guide on requirements for transient recovery voltage for ac high-voltage circuit breakers rated on a symmetrical current basis. Familiarity with other American National Standards¹ applying to circuit breakers is assumed, and provisions of those standards are indicated herein only when necessary for clarity in describing application requirements.

¹ American National Standards are available from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

3. Transient Recovery Voltage

3.1 General. During the interruption process the arc voltage, which occurs across the terminals of a pole of a circuit breaker prior to current zero, approaches the normal-frequency pole-unit recovery voltage occurring after current zero, in a manner called the transient recovery voltage. If the circuit breaker is able to withstand the transient recovery voltage, and also the normal-frequency pole-unit recovery voltage, the circuit interruption will be successful.

Transient recovery voltages can be oscillatory, triangular, or exponential and can occur as a combination of these forms. The most severe oscillatory or exponential recovery voltages occur across the first pole to open of a circuit breaker interrupting a three-phase ungrounded symmetrical fault at its terminal, when the system voltage is maximum. Therefore, only 3-phase ungrounded terminal faults need be considered when determining the transient recovery voltage capabilities of a circuit breaker. The triangular recovery voltages are associated with line faults. The initial rate of rise of the recovery voltages for line faults becomes greater the closer the fault is to the circuit breaker; however, the magnitude of this line side triangular wave decreases as the rate of rise increases. Generally, the source recovery voltage is much slower and only the triangular recovery voltage is effective in the early time of the transient recovery voltage. The amplitude of the recovery voltages for these line faults is determined on a single-phase basis during their early portions.