

# IEEE Recommended Practice for Preferred Ratings for High-Voltage (> 1000 volts) AC Circuit Breakers Designated Definite Purpose for Fast Transient Recovery Voltage Rise Times

IEEE Power and Energy Society

Sponsored by the  
Switchgear Committee

# **IEEE Recommended Practice for Preferred Ratings for High-Voltage (>1000 volts) AC Circuit Breakers Designated Definite Purpose for Fast Transient Recovery Voltage Rise Times**

Sponsored by the

**Switchgear Committee**  
of the  
**IEEE Power and Energy Society**

Approved 6 December 2017

**IEEE-SA Standards Board**

**Abstract:** The preferred ratings of transformer-limited fault duty (fast transient recovery voltage rise times) of indoor and outdoor high-voltage circuit breakers rated above 1000 V for use in commercial, industrial, and utility installations are described.

**Keywords:** fast transient recovery voltage rise times, high-voltage circuit breakers, IEEE C37.06.1™, transformer-limited fault, transient recovery voltage, TRV

---

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

Copyright © 2018 by The Institute of Electrical and Electronics Engineers, Inc.  
All rights reserved. Published 6 February 2018. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-1-5044-4581-8 STD22933  
Print: ISBN 978-1-5044-4582-5 STDPD22933

*IEEE prohibits discrimination, harassment, and bullying.*

For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.

*No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.*

## Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

## Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (“IEEE-SA”) Standards Board. IEEE (“the Institute”) develops its standards through a consensus development process, approved by the American National Standards Institute (“ANSI”), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

## Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

## Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

## Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board  
445 Hoes Lane  
Piscataway, NJ 08854 USA

## Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

## Copyrights

IEEE draft and approved standards are copyrighted by IEEE under U.S. and international copyright laws. They are made available to IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

## Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

## Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE-SA Website at <http://ieeexplore.ieee.org/xpl/standards.jsp> or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at <http://standards.ieee.org>.

## Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

## Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

## Participants

At the time this recommended practice was submitted to the IEEE-SA Board for approval, the Revision of C37.06.1 Working Group had the following membership:

**Sushil Shinde, *Chair***  
**Carl Schuetz, *Vice Chair***

Roy Alexander  
Mauricio Aristizabal  
Stan Billings  
Anne Bosma  
Arben Bufi  
Chih Chow

Lucas Collette  
Patrick Di Lillo  
Denis Dufournet  
Helmut Heiermeier  
Victor Hermosillo  
Hua Ying Liu

Daniel Schiffbauer  
Harish Sharma  
Michael Skidmore  
Jan Veisker  
Richard York  
Xi Zhu

The following members of the individual balloting committee voted on this recommended practice. Balloters may have voted for approval, disapproval, or abstention.

Roy Alexander  
Ficheux Arnaud  
Roy Ayers  
Thomas Barnes  
Robert Behl  
W.J. (Bill) Bergman  
Jean-Marc Biasse  
William Bloethe  
Anne Bosma  
Jeffrey Bragg  
Jeffrey Brogdon  
Steven Brown  
Ted Burse  
Eldridge Byron  
Paul Cardinal  
Chih Chow  
Lucas Collette  
Michael Crawford  
Gary Donner  
Denis Dufournet  
Kenneth Edwards  
Sergio Flores  
Paul Forquer  
Marcel Fortin  
Mietek Glinkowski  
Edwin Goodwin  
Randall Grove  
Paul Hamer  
John Harley  
Timothy Hayden  
Marc Hues

Werner Hoelzl  
William Hurst  
Todd Irwin  
Richard Jackson  
Andrew Jones  
Yuri Khersonsky  
James Kinney  
Boris Kogan  
Jim Kulchisky  
Carl Kurinko  
Chung-Yiu Lam  
Benjamin Lanz  
Hua Liu  
Albert L. Lutz  
R. Long  
Frank Mayle  
Victoria McBride  
John Mc Cord  
Peter Meyer  
Charles Morse  
Thomas Mulcahy  
Jeffrey Nelson  
Arthur Neubauer  
Michael Newman  
Nick S. A. Nikjoo  
T. W. Olsen  
Lorraine Padden  
Shawn Patterson  
Jim Phillips  
Iulian Profir  
Moises Ramos

Moises Ramos  
Anthony Ricciuti  
Thomas Rozek  
Roderick Sauls  
Bartien Sayogo  
Daniel Schiffbauer  
Nikunj Shah  
Hamid Sharifnia  
Devki Sharma  
Harish Sharma  
Sushil Shinde  
Garett Sims  
Michael Skidmore  
Jeremy Smith  
Jerry Smith  
James Stage  
David Tepen  
James Van De Ligt  
Roger Verdolin  
John Vergis  
Mark Waldron  
Keith Wallace  
Paul Wasacz  
John Webb  
Jan Weisker  
Kenneth White  
Matthew Williford  
Larry Yonce  
Richard York  
Jian Yu  
Xi Zhu

When the IEEE-SA Standards Board approved this recommended practice on 6 December 2017, it had the following membership:

**Jean-Philippe Faure**, *Chair*  
**Gary Hoffman**, *Vice Chair*  
**John D. Kulick**, *Past Chair*  
**Konstantinos Karachalios**, *Secretary*

Chuck Adams  
Masayuki Ariyoshi  
Ted Burse  
Stephen Dukes  
Doug Edwards  
J. Travis Griffith  
Michael Janezic

Thomas Koshy  
Joseph L. Koepfinger\*  
Kevin Lu  
Daleep Mohla  
Damir Novosel  
Ronald Petersen  
Annette D. Reilly

Robby Robson  
Dorothy Stanley  
Adrian Stephens  
Mehmet Ulema  
Phil Wennblom  
Howard Wolfman  
Yu Yuan

\*Member Emeritus

## Introduction

This introduction is not part of IEEE Std C37.06.1-2017, IEEE Recommended Practice for High-Voltage (>1000 volts) AC Circuit Breakers Designated Definite Purpose for Fast Transient Recovery Voltage Rise Times.

This IEEE recommended practice is a revision of ANSI C37.06.1-2000 (Guide for High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis Designated “Definite Purpose for Fast Transient Recovery Voltage Rise Times”) and deals with special applications with fast TRV requirements calling for definite purpose circuit breakers with special TRV requirements and for circuit breakers in transformer-limited fault applications. This document provides preferred values of standard ratings of fast transient recovery voltage rise times. This recommended practice provides (1) preferred interrupting current and TRV values for manufacturers to test their circuit breakers against, and (2) recommended TRV values for users from which to choose when selecting circuit breakers for these applications. This document takes into account the fact that the highest TRV rates of rise are obtained in TLF (transformer-limited fault) conditions. There might be some cases of TRVs associated with faults near series reactors with a rate of rise greater than TLF. In such cases the manufacturer should be consulted for circuit breaker suitability.

This document also introduces a transformer-limited fault (TLF) current breaking capability, as the current specified would correspond to the actual need in service instead of a fixed percentage (10% or 30%) of the rated short circuit current that is in many cases far from the real need. As per CIGRE Technical Brochure 362 [B1],<sup>1</sup> in the majority of cases it has been found that the TLF current is less than 11 kA and it is not relevant to link the TLF current to 30% of the rated short-circuit current (3 kA).

The revision also includes a change from the 1-cosine to a two-parameter TRV envelope. A range of transformer impedance data (600 examples) ranging from 125 kV to 765 kV was analyzed. The data (expressed as current from infinite source) was spread over large spectrum.

ANSI C37.06.1-2000 was initially approved as a “trial-use” guide in 1997, and then approved for more general use as a guide in 2000.

The rated transformer-limited fault breaking current is the highest transformer-limited fault current required to be interrupted under the conditions of use and behavior prescribed in this recommended practice in a circuit having a power-frequency recovery voltage corresponding to the rated maximum voltage of the circuit breaker and having a transient recovery voltage equal to the value specified in Table 2 or Table 3.

Table 1 gives the standard rated transformer-limited fault breaking current selected from the R10 series. The current specified would correspond to the actual need in service instead of a fixed percentage (10% or 30%) of the rated short-circuit current that is in many cases far from the real need. The values of time  $t_3$  corresponding to these TLF currents are recalculated, and are represented as function of  $U_r$  and transformer-limited fault current in Table 2 and Table 3.

Table 2 gives the corresponding TRVs for circuit breakers with rated voltages higher than 1 kV and less than 100 kV.

Table 3 gives the corresponding TRV parameters for circuit breakers rated 100 kV and above. The other related parameters [time to peak  $t_3$ , time delay  $t_d$ , and rate-of-rise of recovery voltage (RRRV)] can be deduced per Annex A.

Annex A shows the determination of the equation that gives  $t_3$  as function of  $U_r$  and the rated short-circuit current for circuit breakers rated 1 kV and above.

<sup>1</sup>The numbers in brackets correspond to those of the bibliography in Annex C.

[Annex B](#) shows the transformer-fed fault current data for voltage ranges 115–765 kV collected through survey.

Tables are consistent as they are all based on the same relation between  $t_3$ ,  $U_r$  and the fault current. The ratings were suggested by the working group and are purely based on the transformer impedance data collected for voltages 115 kV to 765 kV from different utilities. The TRVs for currents more than or equal to 60% of rated short-circuit current remain the same as for general purpose circuit breakers. Circuit breakers not identified by the manufacturer as “definite purpose for fast transient recovery voltage rise times” shall be understood to be “general purpose circuit breakers,” meeting the IEEE C37.06 standard TRV requirements.

## Contents

1. Overview .....	11
1.1 Scope .....	11
1.2 Purpose .....	11
2. Normative references.....	11
3. Definitions .....	12
4. Rated TLF breaking currents for circuit breakers.....	12
5. Transformer limited fault TRV.....	13
6. TLF breaking current testing .....	18
Annex A (informative) Calculation of TRV parameters as a function of rated maximum voltage ( $U_t$ ) and transformer-limited fault (TLF) test breaking current for circuit breakers of rated voltages higher than 1 kV .....	19
Annex B (informative) Transformer-fed fault current ranges collected through survey based on transformer size, transformer impedance, circuit breaker rated voltage, and rated current .....	21
Annex C (informative) Bibliography.....	24

# IEEE Recommended Practice for Preferred Ratings for High-Voltage (>1000 volts) AC Circuit Breakers Designated Definite Purpose for Fast Transient Recovery Voltage Rise Times

## 1. Overview

### 1.1 Scope

This recommended practice is issued as a supplement to IEEE Std C37.06 for high-voltage circuit breaker applications where the transient recovery voltage (TRV) peak is higher and/or its rise to the crest value occurs more rapidly than those specified in IEEE Std C37.06.

### 1.2 Purpose

The purpose of this document is to introduce transformer-limited faults, similar to that established by IEEE Std C37.016 [B5], and specifically to provide preferred values for standard ratings of fast transient referred to as transformer-limited fault recovery voltage rise times and to introduce a transformer-limited fault (TLF) breaking current.<sup>2</sup>

## 2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

---

<sup>2</sup>The numbers in brackets correspond to those of the bibliography in [Annex C](#).