Supplement to IEEE Guide for Synthetic Fault Testing of AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

8.3.2: Recovery Voltage for Terminal Faults; Asymmetrical Short-Circuit Current

Sponsor
Switchgear Committee
of the
IEEE Power Engineering Society

Approved 9 December 1997
IEEE Standards Board

Abstract: The transient recovery voltage needs to be modified when interrupting asymmetrical currents. The voltage rate R, the peak voltage E2 and the rate of change of current di/dt all change with the asymmetrical current zero. Guidance is provided on how to make these corrections when compared to the symmetrical case.
Keywords: asymmetrical current, correction factors, major current zeros, minor current zeros, X/R ratio

The Institute of Electrical and Electronics Engineers, Inc.

345 East 47th Street, New York, NY 10017-2394, USA

ISBN 1-55937-994-4

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE that have expressed an interest in participating in the development of the standard.

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. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, 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.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received 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 interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE Standards Board
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
USA

Note: 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 with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents for which a license may be required by an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Introduction

(This introduction is not part of IEEE Std C37.081a-1997, Supplement to IEEE Guide for Synthetic Fault Testing of AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis—8.3.2: Recovery Voltage for Terminal Faults; Asymmetrical Short-Circuit Current.)

This supplement was prepared by the Working Group on Synthetic Testing of The High Voltage Circuit Breaker Subcommittee. At the time this guide was approved the working group had the following membership:

H. Melvin Smith, *Chair*

Anne Bosma
Denis Dufournet
Charles Hand
Harold Hess
Robert JeanJean
George Montillet
Yasin Musa
Eric Ruoss
James Sailors
Roger Sarkinen
Kirk Smith
Guy St. Jean
Wim van der Linden

The following persons were on the balloting committee:

Roy W. Alexander
J. G. Angelis
Richard H. Arndt
Steve Atkinson
L. Ronald Beard
Harvey L. Bowles
Matthew Brown
John H. Brunke
Raymond L. Capra
Alexander Dixon
J. J. Dravis
C. J. Dvorak
Peter W. Dwyer
Ruben D. Garzon
Louis W. Gaussa
Keith I. Gray
Kenneth Hendrix
Harold L. Hess
Jerry M. Jerabek
P. L. Kolarik
David G. Kumbera
Stephen R. Lambert
Ward E. Laubach
John G. Leach
George N. Lester
Don Lott
E. L. Luehring
P. C. Mayo
Andrew K. McCabe
Lawrence V. McCall
William C. McKay
Don C. Mills
Alec C. Monroe
Georges F. Montillet
F. J. Muench
James F. O’Donnell
Raymond P. O’Leary
A. F. Parks
David F. Peelo
Gordon O. Perkins
R. Kris Ranjan
James C. Ransom
David N. Reynolds
Hugh C. Ross
Tim E. Royster
Larry H. Schmidt
E. W. Schmunk
Curt A. Schwalbe
Devki N. Sharma
Guy St. Jean
David L. Swindler
John S. Tannery
Stan H. Telander
Frederick C. Teufel
Thomas J. Tobin
Edward F. Veverka
Charles L. Wagner

CLAUSE PAGE

Supplement to IEEE Guide for Synthetic Fault Testing of AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

8.3.2: Recovery Voltage for Terminal Faults; Asymmetrical Short-Circuit Current

Revisions to IEEE Std C37.081-1981

The contents of this supplement will be incorporated into IEEE Std C37.081 in a future edition. At that time figures and tables will be labeled sequentially. This supplement is intended to be used in conjunction with IEEE Std C37.081-1981. Editing instructions necessary to incorporate this supplement into IEEE Std C37.081 are provided in ***bold italics.***

8.3.2 Recovery voltage for terminal faults; asymmetrical short-circuit current

Replace subclause 8.3.2 with the following:

The transient recovery voltage rate R and peak E_2, together with the *di/dt* of the current at current zero for asymmetrical faults needs to be modified in accordance with the degree of asymmetry of the fault current. The normal power frequency recovery voltage is sinusoidal with a value equal to that of the symmetrical fault current case.

The basis of rating for asymmetrical faults is a fully offset current with a decrement based on an X/R of 17. The total current dc component and voltage are shown in Figure 8.3.2-1 for this condition. From this it can be seen that current zeros occur at the times shown in Table 8.3.2-1 with the corresponding degree of asymmetry D.

For circuit breakers with rated maximum voltages of 121 kV to 242 kV and for 362 kV test duties 1 to 3 as listed in C37.09-1979 Table 2, the *di/dt* rated rate R and E_2 values are adjusted using the correction factor F_1 in Table 8.3.2-1 for the current zero at which interruption is attempted. For TRVs with T_2 not exceeding 500 µs, the reduction of *di/dt* for current injection methods may be obtained by reducing the charging voltage of the voltage circuit.

For the other rated maximum design voltages listed, the *di/dt* and the rated rate *R* are also adjusted by the same factor F_1. During the relatively long T_2 times for these ratings there is a significant change in the power frequency voltage, and the peak E_2 needs to be further modified because of this. The correction factor F_E for the adjustment of the peak voltage E_2 is listed in Table 8.3.2-1. The correction factor F_E is calculated using the equations of Annex B.

When the test is made for clearance at the end of a major loop, the dc form of the recovery voltage will adequately cover the first quarter loop of the recovery voltage (of an equivalent direct test). For clearance at the end of a minor loop of current, the dc form of the reduced recovery voltage will not cover the basis of rating condition since, in this case, the power-frequency recovery voltage continues to rise after the onset of the TRV.

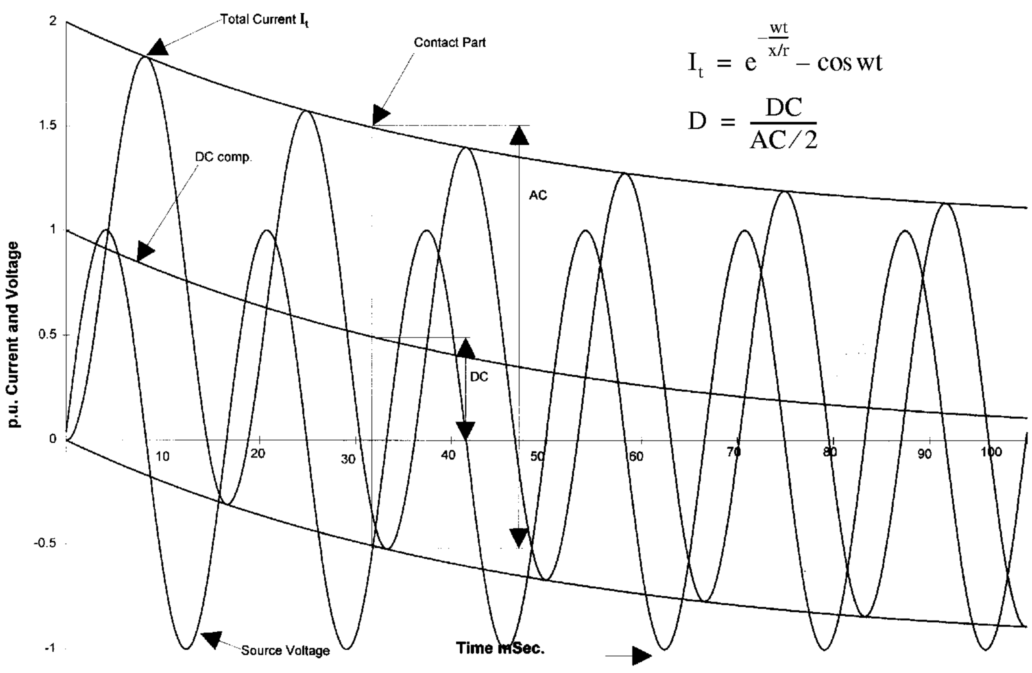

Figure 8.3.2-1 —Total current dc component and voltage

Circuit interruption after a minor loop with reduced *di/dt* and resulting TRV is assumed to be less severe than the equivalent symmetrical test. If it is required to prove this condition, there are three possibilities:

a) The test is performed with asymmetrical current conditions with the voltage source charged as for the symmetrical test. It must be recognized that this represents a considerable increase in severity above that of an equivalent direct test since both *di/dt* and the TRV are higher.
b) The test is performed as under a) except that the inductance of the injection circuit is increased in inverse proportion to *di/dt*. In this case, the *di/dt* value is correct but the TRV is higher.
c) The test is performed with an ac recovery voltage.

Table 8.3.2-1 —Correction factors for adjustment of peak voltage

Current zero no.	Loop type	Time of zero µs	Asymmetry factor *D*	Correction factor F_1	Correction factor F_E				
					362 kV	550 kV		800 kV	
					100%	40–60%	100%	40–60%	100%
1	Major	14.64	0.723	0.733	0.573	0.594	0.475	0.575	0.442
2	Minor	18.93	0.657	0.716	0.854	0.836	0.940	0.853	0.970
3	Major	30.58	0.508	0.890	0.784	0.799	0.715	0.785	0.692
4	Minor	36.27	0.447	0.869	0.959	0.947	1.018	0.958	1.038
5	Major	46.79	0.354	0.956	0.883	0.893	0.835	0.884	0.819
6	Minor	53.34	0.306	0.934	0.995	0.987	1.036	0.995	1.049
7	Major	63.16	0.246	0.983	0.933	0.940	0.900	0.934	0.889
8	Minor	70.27	0.210	0.966	1.007	1.001	1.035	1.007	1.044

Annex B

(Informative)

Add Appendix B as follows:

Correction factor calculation

The correction factors may be determined using the following equations:

Correction factor $F_1 = \sqrt{(1 - D^2)} - \left(\frac{D}{(X)/R}\right)$

where:

–D	is current with major loop
+D	is current with minor loop
D	is the per unit asymmetric factor
X/R	is 17
NAF	is Natural Amplitude Factor for the dependent time coordinate of the transient recovery voltage

For voltage ratings with T_2 times greater than 500 µs, the following equations were used:

$$\omega = 2 \text{ x } \pi \text{ x } f$$

$$NAF = AF + \left\{1 - \sin\left(\arctan\frac{X}{R} + T_2 \times \omega\right)\right\}$$

$$CF = (NAF - 1)\sin a_0 + \sin(a_0 \times T_2 + \omega)$$

$$a_0 = \arccos D - \arctan\frac{\sqrt{1 - D^2}}{X/R}$$

Where D is the per unit asymmetric factor, all angles are in radians, amplitude factor (AF) for E_2 is 1.44; assumes first pole to clear factor of 1.5.

Correction factor F_E = crest factor (CF)/AF

Substituting NAF in CF:

$$F_E = \frac{1}{AF}\left\{\left[AF - \sin\left(\arctan\frac{X}{R} + T_2 \times \omega\right)\right]\sin a_0 + \sin(a_0 + T_2 \times \omega)\right\} \text{ t}$$