

# IEEE Standard for AC High-Voltage Generator Circuit Breakers Rated on a Symmetrical Current

Sponsor

**Switchgear Committee  
of the  
IEEE Power Engineering Society**

Approved March 18, 1993

**IEEE Standards Board**

Approved August 18, 1993

**American National Standards Institute**

**Abstract:** Ratings, performance requirements, and compliance test methods are provided for ac high-voltage generator circuit breakers rated on a symmetrical current basis that are installed between the generator and the transformer terminals. Guidance for applying the circuit breakers is given. Pumped storage installations are considered a special application, and their requirements are not completely covered by this standard.

**Keywords:** AC high-voltage generator, application guidance, circuit breakers, symmetrical current-rating structure, terminals of large generators, testing procedures.

---

The Institute of Electrical and Electronics Engineers, Inc.  
345 East 47th Street, New York, NY 10017-2394, USA

Copyright © 1993 by the Institute of Electrical and Electronics Engineers, Inc.  
All rights reserved. Published 1993. Printed in the United States of America

ISBN 1-55937-320-2

*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.*

**IEEE Standards** documents are developed within the Technical Committees of 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 technical 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

IEEE Standards documents are adopted by the Institute of Electrical and Electronics Engineers without regard to whether their adoption may involve patents on articles, materials, or processes. Such adoption does not assume any liability to any patent owner, nor does it assume any obligation whatever to parties adopting the standards documents.

## Introduction

(This introduction is not a part of IEEE Std C37.013-1993, IEEE Standard for AC High-Voltage Generator Circuit Breakers Rated on a Symmetrical Current Basis.)

This standard has been revised to clarify the meaning of rated maximum voltage as used in this document and covers the requirements for ac high-voltage generator circuit breakers as applied directly to the outgoing terminals of generators. The rating, testing, and application requirements of these specialized circuit breakers are not adequately covered by the existing standards IEEE Std C37.04-1979, ANSI C37.06-1987, IEEE Std C37.09-1979, and IEEE Std C37.010-1979 series for ac high-voltage circuit breakers rated on a symmetrical current basis. In order to avoid the detailed integration and possible confusion by introducing the specialized requirements into the existing documents, it was determined that a separate standard was the most effective method for covering these devices.

A Working Group of the High-Voltage Circuit Breaker Subcommittee of the IEEE Switchgear Committee has revised this standard with input from various sources on all requirements for these specialized devices. The Working Group has developed an Application Guide contained in clause 6 of this standard, and the guide is intended to give guidance to the engineer applying a generator circuit breaker on an electric power system.

These efforts have contributed valuable standards to the industry. Further suggestions for improvement gained from the use of this standard will be welcomed.

## Participants

The Accredited Standards Committee on Power Switchgear, C37, which reviewed this standard, had the following membership at the time of approval:

**T. C. Burnett**, *Chair*

**C. H. White**, *Secretary*

**M. B. Williams**, *Program Administrator*

**A. K. McCabe**, *Executive Vice-Chair of High-Voltage Switchgear Standards*

**E. R. Byron**, *Executive Vice-Chair of Low-Voltage Switchgear Standards*

**D. L. Swindler**, *Executive Vice-Chair of IEC Activities*

### *Organization Represented*

### *Name of Representative*

|                                                        |                            |
|--------------------------------------------------------|----------------------------|
| Association of Iron and Steel Engineers.....           | (vacant)                   |
| Electric Light and Power Group.....                    | R. L. Capra                |
|                                                        | G. R. Brandenberger (Alt.) |
|                                                        | T. E. Bruck (Alt.)         |
|                                                        | M. J. Eckelkamp            |
|                                                        | K. D. Hendrix              |
|                                                        | A. K. McCabe (Alt.)        |
|                                                        | M. C. Mingoia (Alt.)       |
|                                                        | J. H. Provanzana           |
|                                                        | J. D. Stewart              |
| Institute of Electrical and Electronics Engineers..... | W. E. Laubach              |
|                                                        | S. Atkinson (Alt.)         |
|                                                        | R. W. Haas (Alt.)          |
|                                                        | W. F. Hoenigmann           |
|                                                        | D. G. Kumbera (Alt.)       |
|                                                        | D. M. Larson               |
|                                                        | R. Matulic (Alt.)          |
|                                                        | E. W. Schmunk              |
|                                                        | C. A. Schwalbe             |
| National Electrical Manufacturers Association .....    | T. C. Burnett              |
|                                                        | E. Byron                   |
|                                                        | G. T. Jones                |
|                                                        | H. L. Miller (Alt.)        |
|                                                        | R. H. Miller               |
|                                                        | R. O. D. Whitt             |

*Organization Represented**Name of Representative*

|                                                                        |                |
|------------------------------------------------------------------------|----------------|
| Tennessee Valley Authority .....                                       | D. N. Reynolds |
| Testing Laboratory Group .....                                         | L. Frier       |
|                                                                        | W. T. O'Grady  |
| U.S. Department of the Agriculture, REA .....                          | H. L. Bowles   |
| Western Area Power Administration .....                                | G. D. Birney   |
| U.S. Department of the Army, Office of the Chief of Engineers .....    | J. A. Gilson   |
| U.S. Department of the Interior, Bureau of Reclamation .....           | R. Arnold      |
| U.S. Department of the Navy, Naval Construction Battalion Center ..... | R. L. Clark    |

The Working Group of the High-Voltage Circuit Breaker Subcommittee of the IEEE Switchgear Committee that prepared IEEE Std C37.013-1989, had the following membership:

**P. L. Kolarik, Chair**

**C. J. Truax, Secretary**

|                 |                    |                      |
|-----------------|--------------------|----------------------|
| H. W. Anderl    | W. C. Huening, Jr. | E. M. Ruoss          |
| J. E. Beehler   | D. M. Larson       | M. J. Sulkowski      |
| E. W. Boehne    | A. A. Leibold      | J. S. Tannery        |
| R. D. Carson    | A. K. McCabe       | E. E. Thuries        |
| R. L. Clark     | G. F. Montillet    | W. A. van der Linden |
| R. D. Garzon    | R. A. Pace         | G. A. Votta          |
| J. K. Greene    | J. G. Reckleff     | C. L. Wagner         |
| G. T. Hall      | H. K. Reid         | D. A. Weber          |
| G. E. Heberlein | A. B. Rishworth    | B. F. Wirtz          |
|                 | W. N. Rothenbuhler |                      |

The Working Group of the High-Voltage Circuit Breaker Subcommittee of the IEEE Switchgear Committee that revised IEEE Std C37.013-1989 and prepared the Application Guide contained in clause 6, had the following membership:

**P. L. Kolarik, Chair**

|               |                 |                |
|---------------|-----------------|----------------|
| J. E. Beehler | G. F. Montillet | G. E. Seyrling |
| R. L. Clark   | A. B. Rishworth | J. S. Tannery  |
| R. D. Garzon  | E. M. Ruoss     | E. E. Thuries  |
| D. M. Larson  | M. H. Sanders   | C. L. Wagner   |
| A. K. McCabe  |                 | B. F. Wirtz    |

The High-Voltage Circuit Breaker Subcommittee of the IEEE Switchgear Committee that reviewed and approved this revised document had the following membership:

|                 |                 |                |
|-----------------|-----------------|----------------|
| S. Berneryd     | D. M. Larson    | H. C. Ross     |
| J. H. Brunke    | G. N. Lester    | E. M. Ruoss    |
| D. R. Crawford  | R. W. Long      | L. R. Saavedra |
| C. J. Dvorak    | A. K. McCabe    | R. A. Sarkinen |
| P. W. Dwyer     | G. J. Meinders  | G. E. Seyrling |
| M. J. Eckelkamp | G. F. Montillet | D. N. Sharma   |
| R. D. Garzon    | J. F. O'Donnell | H. M. Smith    |
| K. I. Gray      | D. E. Parr      | G. St. Jean    |
| H. L. Hess      | B. Patel        | D. L. Swindler |
| P. L. Kolarik   | D. F. Pello     | T. J. Tobin    |
| S. Kuznetsov    | G. O. Perkins   | E. F. Veverka  |
| G. C. Laguens   | J. E. Reed      | C. L. Wagner   |
| S. R. Lambert   | A. B. Rishworth | B. F. Wirtz    |

The following persons were on the balloting committee:

|                  |                 |                 |
|------------------|-----------------|-----------------|
| R. J. Alton      | P. L. Kolarik   | R. Ranjan       |
| J. G. Angelis    | D. G. Kumbera   | J. C. W. Ransom |
| R. H. Arndt      | S. R. Lambert   | J. E. Reed      |
| S. C. Atkinson   | D. M. Larson    | D. N. Reynolds  |
| L. R. Beard      | W. E. Laubach   | A. B. Rishworth |
| H. L. Bowles     | J. G. Leach     | H. C. Ross      |
| M. T. Brown      | G. N. Lester    | T. E. Royster   |
| J. H. Brunke     | D. L. Lott      | L. R. Saavadra  |
| C. G. Burland    | E. L. Luehring  | L. H. Schmidt   |
| R. L. Capra      | P. C. Mayo      | E. W. Schmunk   |
| G. A. Clary      | A. K. McCabe    | C. A. Schwalbe  |
| A. Dixon         | L. V. McCall    | D. N. Sharma    |
| J. J. Dravis     | M. S. McGuire   | H. M. Smith     |
| C. J. Dvorak     | W. C. McKay     | G. St. Jean     |
| P. W. Dwyer      | H. W. Mikulecky | D. L. Swindler  |
| R. D. Garzon     | D. C. Mills     | J. S. Tannery   |
| L. W. Gaussa     | G. F. Montillet | S. H. Telander  |
| K. I. Gray       | F. Muench       | F. C. Teufel    |
| K. D. Hendrix    | J. F. O'Donnell | T. J. Tobin     |
| H. L. Hess       | A. F. Parks     | E. F. Veverka   |
| W. F. Hoenigmann | D. F. Peelo     | C. L. Wagner    |
| J. M. Jerabek    | G. O. Perkins   | B. F. Wirtz     |

When the IEEE Standards Board approved this standard on March 18, 1993, it had the following membership:

**Wallace S. Read, Chair**

**Donald C. Loughry, Vice Chair**

**Andrew G. Salem, Secretary**

|                           |                        |                   |
|---------------------------|------------------------|-------------------|
| Gilles A. Baril           | Jim Isaak              | Don T. Michael*   |
| José A. Berrios de la Paz | Ben C. Johnson         | Marco W. Migliaro |
| Clyde R. Camp             | Walter J. Karplus      | L. John Rankine   |
| Donald C. Fleckenstein    | Lorraine C. Kevra      | Arthur K. Reilly  |
| Jay Forster*              | E. G. "Al" Kiener      | Ronald H. Reimer  |
| David F. Franklin         | Ivor N. Knight         | Gary S. Robinson  |
| Ramiro Garcia             | Joseph L. Koepfinger*  | Leonard L. Tripp  |
| Donald N. Heirman         | D. N. "Jim" Logothetis | Donald W. Zipse   |

\*Member Emeritus

Also included are the following nonvoting IEEE Standards Board liaisons:

Satish K. Aggarwal  
James Beall  
Richard B. Engelman  
David E. Soffrin  
Stanley I. Warshaw  
  
Rochelle L. Stern  
*IEEE Standards Project Editor*

THIS PAGE WAS  
BLANK IN THE ORIGINAL

# Contents

| CLAUSE                                               | PAGE |
|------------------------------------------------------|------|
| 1. Scope and references.....                         | 1    |
| 1.1 Scope.....                                       | 1    |
| 1.2 References.....                                  | 1    |
| 2. Definitions.....                                  | 2    |
| 3. Service conditions.....                           | 3    |
| 3.1 Usual service conditions.....                    | 3    |
| 3.2 Unusual service conditions.....                  | 4    |
| 3.3 Impact on environment.....                       | 4    |
| 4. Ratings and required capabilities.....            | 5    |
| 4.1 Rated maximum voltage.....                       | 5    |
| 4.2 Normal frequency.....                            | 5    |
| 4.3 Rated continuous current.....                    | 6    |
| 4.4 Rated dielectric strength.....                   | 9    |
| 4.5 Rated short-circuit duty cycle.....              | 10   |
| 4.6 Rated interrupting time.....                     | 10   |
| 4.7 Rated permissible tripping delay, <i>Y</i> ..... | 10   |
| 4.8 Rated closing time.....                          | 10   |
| 4.9 Short-circuit current rating.....                | 10   |
| 4.10 Transient recovery voltage (TRV) rating.....    | 15   |
| 4.11 Rated load current switching capability.....    | 17   |
| 4.12 Capacitance current switching capability.....   | 18   |
| 4.13 Out-of-phase current switching capability.....  | 18   |
| 4.14 Excitation current switching capability.....    | 19   |
| 4.15 Rated control voltage.....                      | 19   |
| 4.16 Rated mechanism fluid operating pressure.....   | 20   |
| 4.17 Nameplate markings.....                         | 20   |
| 5. Tests.....                                        | 22   |
| 5.1 General.....                                     | 22   |
| 5.2 Design tests.....                                | 22   |
| 5.3 Production tests.....                            | 42   |
| 5.4 Tests after delivery.....                        | 45   |

| CLAUSE                                   | PAGE |
|------------------------------------------|------|
| 6. Application guide.....                | 47   |
| 6.1 General.....                         | 47   |
| 6.2 General application conditions ..... | 47   |
| 6.3 Application considerations.....      | 49   |
| 6.4 Guide to specification .....         | 72   |
| 7. Bibliography .....                    | 73   |

#### ANNEX

##### Example of the application of a generator circuit breaker

|                                                               |    |
|---------------------------------------------------------------|----|
| A.1 System characteristics.....                               | 75 |
| A.2 System source short-circuit current .....                 | 76 |
| A.3 Generator source short-circuit current .....              | 79 |
| A.4 Transient recovery voltage.....                           | 82 |
| A.5 Out-of-phase conditions.....                              | 82 |
| A.6 Continuous current application.....                       | 84 |
| A.7 Generator circuit breaker electrical characteristics..... | 85 |

# IEEE Standard for AC High-Voltage Generator Circuit Breakers Rated on a Symmetrical Current Basis

## 1. Scope and references

### 1.1 Scope

This standard applies to all ac high-voltage generator circuit breakers rated on a symmetrical current basis that are installed between the generator and the transformer terminals. Pumped storage installations are considered a special application, and their requirements are not completely covered by this standard.

### 1.2 References

1992 ANSI/ASME Boiler and Pressure Vessel Code.<sup>1</sup>

ANSI C37.06-1987, Preferred Ratings and Related Required Capabilities for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

ANSI C37.11-1979 (R1988), Requirements for Electrical Control for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis or a Total Current Basis.

IEEE Std 1-1986 (Reaff 1992), IEEE Standard General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation (ANSI).<sup>2</sup>

IEEE Std 4-1978, IEEE Standard Techniques for High Voltage Testing (ANSI).

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).

IEEE Std 119-1974, IEEE Recommended Practice for General Principles of Temperature Measurement as Applied to Electrical Apparatus.<sup>3</sup>

<sup>1</sup>ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036-8002, USA.

<sup>2</sup>IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

<sup>3</sup>IEEE Std 119-1974 has been withdrawn; however, copies can be obtained from the IEEE Standards Department, IEEE Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

IEEE Std C37.04-1979 (Reaff 1988), IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI).

IEEE Std C37.09-1979 (Reaff 1988), IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI).

IEEE Std C37.011-1979 (Reaff 1988), IEEE Application Guide for Transient Recovery Voltage for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI).

IEEE Std C37.081-1981 (Reaff 1988), IEEE Guide for Synthetic Fault Testing of AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI).

IEEE Std C37.082-1982 (Reaff 1988), IEEE Standard Methods for the Measurement of Sound Pressure Levels of AC Power Circuit Breakers (ANSI).

IEEE Std C37.23-1987 (Reaff 1991), IEEE Standard for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus (ANSI).

IEEE Std C37.100-1992, IEEE Standard Definitions for Power Switchgear.

IEEE Std C57.13-1978 (Reaff 1986), IEEE Standard Requirements for Instrument Transformers (ANSI).

NEMA MG-1-1989, Motors and Generators.

NEMA SG-4-1990, Alternating Current High-Voltage Circuit Breakers.<sup>4</sup>

## 2. Definitions

The definitions of terms contained in this document, or in other standards referred to in this document, are not intended to embrace all legitimate meanings of the terms. They are applicable only to the subject treated in this standard. For additional definitions, see IEEE Std C37.100-1992<sup>5</sup>.

An asterisk (\*) indicates that at the time this standard was approved, there was no corresponding definition in IEEE Std C37.100-1992. A dagger (†) following the definition indicates that the definition in this standard differs from that appearing in IEEE Std C37.100-1992.

**2.1 design tests:** Those tests made to determine the adequacy of the design of a particular type, style, or model generator circuit breaker to meet its assigned ratings and to operate satisfactorily under usual service conditions or under unusual conditions, if specified. Design tests are made only on representative circuit breakers of basically the same design, i.e., the same interrupters operating at the same contact speeds, and having at least the same dielectric strength. These tests are not intended to be used as a part of normal production. The applicable portions of these design tests may also be used to evaluate modifications of a previous design and to assure that performance has not been adversely affected. Test data from previous similar designs may be used for current designs, where appropriate.†

<sup>4</sup>NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street NW, Washington, DC 20037, USA.

<sup>5</sup>Information on references can be found in clause 1.2.

**2.2 excitation current switching capability (of a generator circuit breaker):** The highest magnetizing current that a generator circuit breaker shall be required to switch at any voltage up to rated maximum voltage at normal frequency without causing an overvoltage exceeding the levels agreed upon between the user and the manufacturer.\*

**2.3 production tests:** Those tests made to check the quality and uniformity of workmanship and materials used in the manufacturing of generator circuit breakers.†

**2.4 rated closing time (of a generator circuit breaker):** The interval between energizing of the close circuit at rated control voltage and rated fluid pressure of the operating mechanism and the closing of the main circuit.\*

**2.5 rated continuous current (of a generator circuit breaker):** The designated limit of current in rms amperes at normal frequency that a generator circuit breaker shall be required to carry continuously without exceeding any of its designated limitations.\*

**2.6 rated interrupting time (of a generator circuit breaker):** The maximum permissible interval between the energizing of the trip circuit at rated control voltage and rated fluid pressure of the operating mechanism and the interruption of the main circuit in all poles on an opening operation.\*

**2.7 rated maximum voltage (of a generator circuit breaker):** The highest rms voltage for which the circuit breaker is designed, and the upper limit for operation. The rated maximum voltage is equal to the maximum operating voltage of the generator to which the circuit breaker is applied.†

**2.8 rated mechanism fluid operating pressure (of a generator circuit breaker):** The pressure at which a gas- or liquid-operated mechanism is designed to operate.\*

**2.9 rated permissible tripping delay Y (of a generator circuit breaker):** The maximum time the circuit breaker is required to carry rated short-circuit current after closing on this current and before interrupting.\*

**2.10 tests after delivery:** Those tests made by the purchaser after delivery of the circuit breaker, which supplement inspection, to determine whether the circuit breaker has arrived in good condition. These tests may consist of timing tests on closing, opening, close-open no-load operations, and normal-frequency voltage withstand tests at 75% of the rated normal-frequency withstand voltage.\*

### 3. Service conditions

#### 3.1 Usual service conditions

Generator circuit breakers conforming to this standard shall be suitable for operating at their standard ratings under the following usual service conditions:

- a) The ambient temperature for outdoor generator circuit breakers is not above 40 °C or below – 30 °C; and ambient temperature for indoor generator circuit breakers is not above 40 °C or below + 5 °C.
- b) Altitude is not above 3300 ft (1000 m).
- c) For installations at nuclear power stations, static forces applied to the generator circuit breaker do not exceed the equivalent force of a 0.5 g acceleration applied horizontally at the center of gravity of the circuit breaker.

## 3.2 Unusual service conditions

### 3.2.1 Abnormal temperatures

The use of apparatus in ambient temperatures outside the limits of those specified in item a of 3.1 shall be considered as special.

### 3.2.2 Altitudes above 3300 ft (1000 m)

For applications at altitudes higher than 3300 ft (1000 m), the basic impulse insulation level and rated continuous current shall be multiplied individually by correction factors in table 1 to obtain appropriate values.

The rated short-circuit current, related required capabilities, and the rated interrupting time are not affected by altitude.

### 3.2.3 Conditions affecting construction or protecting features

There are conditions that should receive special consideration.

Such conditions should be brought to the attention of those responsible for the application, manufacture, and operation of the equipment.

Apparatus for use in such cases may require special construction or protection. Among such conditions are

- a) Exposure to damaging fumes or vapors, excessive or abrasive dust, explosive mixtures of dust or gases, steam, salt spray, oil spray, excessive moisture, dripping water, and other similar conditions
- b) Exposure to abnormal vibration, shock, tilting, or seismic forces
- c) Exposure during transportation or storage to conditions beyond temperatures listed in item a of 3.1
- d) Unusual space limitations
- e) Unusual operating duty, frequency of operation, and difficulty of maintenance
- f) Condensation on dielectric surfaces, produced by the generator circuit breaker cooling medium

**Table 1—Altitude correction factors**

| Altitude |      | Insulation level | Rated continuous current |
|----------|------|------------------|--------------------------|
| ft       | m    |                  |                          |
| 3300     | 1000 | 1.00             | 1.00                     |
| 5000     | 1500 | 0.95             | Refer to manufacturer    |
| 10 000   | 3000 | 0.80             | Refer to manufacturer    |

NOTE—Intermediate values can be obtained by interpolation.

## 3.3 Impact on environment

Generator circuit breakers conforming to this standard shall have limited impact on the environment as follows:

- a) When operated under standard conditions, with all three poles operating simultaneously, the peak instantaneous sound pressure level of the generator circuit breaker shall be less than 140 dB (unweighted) (see IEEE Std C37.082-1982).
- b) The effects of circulating currents induced by magnetic fields produced by continuous currents in the generator circuit breaker are addressed in clause 6.

## 4. Ratings and required capabilities

The ratings and required capabilities of a generator circuit breaker are the designated limits of operating characteristics based on definite conditions and shall include the following items where applicable:

- a) Rated maximum voltage (see 4.1)
- b) Normal frequency (see 4.2)
- c) Rated continuous current (see 4.3)
- d) Rated dielectric strength (see 4.4)
- e) Rated short-circuit duty cycle (see 4.5)
- f) Rated interrupting time (see 4.6)
- g) Rated permissible tripping delay,  $Y$  (see 4.7)
- h) Rated closing time (see 4.8)
- i) Rated short-circuit current (see 4.9)
- j) Transient recovery voltage (TRV) rating (see 4.10)
- k) Rated load current switching capability (see 4.11)
- l) Capacitance current switching capability (see 4.12)
- m) Out-of-phase current switching capability (see 4.13)
- n) Excitation current switching capability (see 4.14)
- o) Rated control voltage (see 4.15)
- p) Rated mechanism fluid operating pressure (see 4.16)
- q) Nameplate markings (see 4.17)

The establishment of the ratings and required capabilities and the assignment of them to a generator circuit breaker in accordance with these standards implies performance characteristics at least equal to those set forth in the following subclauses. The ratings and required capabilities assigned to a generator circuit breaker are based on test data in accordance with clause 5, but other equivalent or more effective methods of testing are not precluded.

Alternatively, for designs existing prior to the adoption of these standards, the ratings and required capabilities can be based on other tests that are judged to be equally effective on the basis of the experience gained from previous design or development tests or by service performance experience.

### 4.1 Rated maximum voltage

The rated maximum voltage of a generator circuit breaker is the highest root-mean-square (rms) voltage for which the circuit breaker is designed and is the upper limit for operation. The rated maximum voltage is equal to the maximum operating voltage of the generator (usually equal to 1.05 times the rated voltage of the generator) to which the circuit breaker is applied.

### 4.2 Normal frequency

The normal frequency of a generator circuit breaker is the frequency at which it is designed to operate, with the frequency being 60 Hz. Applications at other frequencies should receive special consideration.

### 4.3 Rated continuous current

The rated continuous current of a generator circuit breaker is the designated limit of current in rms amperes at normal frequency, which it shall be required to carry continuously without exceeding any of the limitations designated in 4.3.1 and 4.3.2. Typical values are 6.3 kA, 8.0 kA, 10.0 kA, 12.0 kA, 16.0 kA, 20.0 kA, etc.

#### 4.3.1 Conditions of continuous current rating

The conditions on which continuous current ratings are based are as follows:

- a) Circuit breakers are used under usual service conditions defined in 3.1.
- b) Current ratings shall be based on the total temperature limits of the materials used for circuit breaker parts. A temperature rise reference is given to permit testing at reduced ambient temperature.
- c) Circuit breakers designed for installation in enclosures shall have their ratings based on the ventilation of such enclosures and on a 40 °C ambient temperature outside the enclosure (see item b in 5.2.1.1).
- d) Circuit breakers designed for operation with forced air cooling assistance shall have the ratings based on a 40 °C ambient temperature with the forced air cooling system operating.

#### 4.3.2 Temperature limitations for continuous current ratings

##### 4.3.2.1 Limitations on insulating materials

The temperatures of materials used to insulate main power circuit-conducting parts from phase-to-ground or from terminal-to-terminal of an open circuit breaker shall be limited to the values listed in table 2. It is recognized that these limits are generally less than those associated with the insulating class in IEEE Std 1-1986, since such insulation may be subject to severe mechanical stress when used in a generator circuit breaker.

**Table 2—Temperature limitations on insulating materials for continuous current ratings**

| Insulating class of material (°C) | Main power circuit limits<br>Hottest spot total temperature (°C) |
|-----------------------------------|------------------------------------------------------------------|
| O                                 | 90                                                               |
| A                                 | 105                                                              |
| B                                 | 130                                                              |
| F                                 | 155                                                              |
| H                                 | 180                                                              |
| C                                 | 220                                                              |

**NOTES**

1—See IEEE Std 1-1986 for explanation of insulating classes.

2—If gaseous insulating material is used as conforming to one of the above classes, the manufacturer shall establish that it will not cause accelerated deterioration of other parts.

##### 4.3.2.2 Limitations of main contacts

The temperatures of main contacts used in generator circuit breakers shall not exceed the values listed in table 3.

Contacts may be operated at other temperatures providing it can be shown by experience or tests acceptable to the user, that accelerated deterioration will not occur.

**Table 3—Temperature limitations on main contacts for continuous current ratings**

| Contact surfaces                   | Limit of hottest spot temperature rise (°C) | Limit of hottest spot total temperature (°C) |
|------------------------------------|---------------------------------------------|----------------------------------------------|
| Copper                             | 30                                          | 70                                           |
| Silver, silver alloy or equivalent | 65                                          | 105                                          |

#### 4.3.2.3 Limitations on conducting joints

The temperature of conducting joints in the main power circuit of a generator circuit breaker shall not exceed the values listed in table 4.

Conducting joints may be operated at other temperatures providing it can be shown by experience or tests, acceptable to the user, that accelerated deterioration will not occur.

**Table 4—Temperature limitations on conducting joints for continuous current ratings**

| Conducting joint surface           | Limit of hottest spot temperature rise (°C) | Limit of hottest spot total temperature (°C) |
|------------------------------------|---------------------------------------------|----------------------------------------------|
| Copper                             | 30                                          | 70                                           |
| Silver, silver alloy or equivalent | 65                                          | 105                                          |

#### 4.3.2.4 Limitations for parts subject to contact by personnel

Circuit breaker parts handled by the operator in the normal course of work duties shall have no higher total temperature than 50 °C.

Circuit breakers having external surfaces accessible to an operator in the normal course of work duties shall have no higher total temperature on the surfaces than 70 °C. If the bus duct connected to the circuit breaker is designed for a total temperature of 80 °C on the surfaces, then the circuit breaker surface temperature can be 80 °C.

Circuit breakers having external surfaces not accessible to an operator in the normal course of work duties shall have no higher total temperature on the surfaces than 110 °C.

#### 4.3.2.5 Limitations on other materials

Other materials shall be chosen so that the maximum temperature to which they may be subjected shall not cause accelerated deterioration.

### 4.3.3 Emergency current ratings during loss of cooling

The operating considerations for generator circuit breakers require that emergency ratings are established to enable the circuit breaker to remain in service following loss of normally required auxiliary forced cooling systems.

- It is possible to operate the circuit breaker for limited time periods with circuit breaker parts at a higher total temperature than the limits specified for the continuous current rating.
- The difference between the emergency temperature limits and the normal operating temperatures provide a definite allowable time period during which full load may be carried before the reduction in load current must be accomplished.
- The circuit breaker may remain in service at a reduced load current, the value of which will depend on the type of emergency condition prevailing.
- Where the circuit breaker continuous current rating is affected by several independent systems (e.g., interrupting medium, cooling medium, forced air cooling of isolated phase bus, etc.), the effect of losing each system individually and in combination should be established.
- In addition to the above, certain generating station designs (e.g., single generator output connected by two generator circuit breakers to two unit step-up transformers) may also require special emergency operating conditions and ratings.

All of the above factors are illustrated in figure 1.

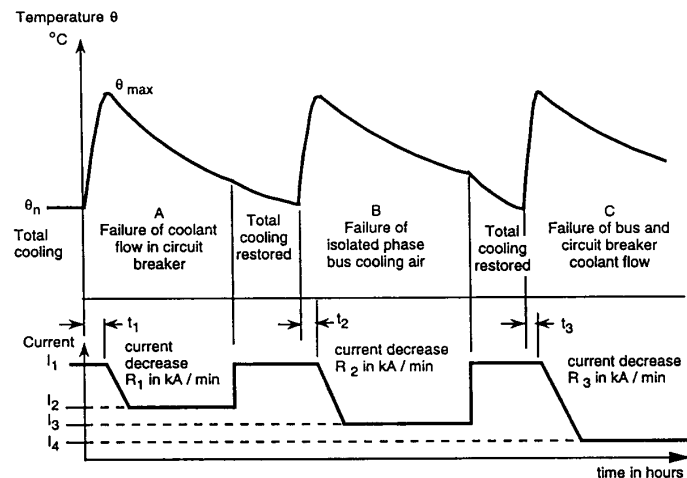


**Figure 1—Effect of various cooling failures and subsequent load reductions on circuit breaker temperature**

- $I_1$  is rated current with all cooling systems in operation
- $I_2$  is allowable load current if failure (A) of coolant in circuit breaker occurs
- $I_3$  is allowable load current if failure (B) of isolated phase bus cooling air occurs
- $I_4$  is allowable load current if failure (C) of bus and circuit breaker coolant flow occurs
- $\theta_{max}$  is allowable hottest spot total temperature in °C
- $\theta_n$  is hottest spot total temperature at rated continuous current in °C
- $t_1, t_2, t_3$  are allowable times without a reduction in rated continuous current and without exceeding  $\theta_{max}$

Figure 1 illustrates typical emergency conditions in which the loss of two cooling systems, that of the circuit breaker and that of the bus duct, have been studied separately and simultaneously.

The following are the parameters that are required for correct operation under each type of emergency condition and for which values must be determined by the manufacturer:

$t_1, t_2, t_3$  The time available at rated current before the load must be reduced.

$R_1, R_2, R_3$  The rate at which the load current must be reduced in kA/min.

$I_2, I_3, I_4$  The emergency current assigned to circuit breaker for operating under each emergency condition for a specified maximum period of time.

#### 4.4 Rated dielectric strength

The rated dielectric strength of a circuit breaker is its voltage withstand capability with specified magnitudes and waveshapes. In the event of loss of insulating medium pressure, the circuit breaker shall be able to withstand 1.5 times the following voltages:

- In the open position, the phase opposition voltage across the contacts, the phase-to-ground, and the line-to-line voltage between phases
- In the closed position, phase-to-ground, and line-to-line voltage between phases. (For applications requiring full dielectric withstand upon loss of insulating medium, agreement should be reached between the user and the manufacturer.)

**Table 5—Schedule of dielectric strength for  
ac generator circuit breakers and external insulation**

| Line | Circuit breaker rated<br>maximum voltage kV, rms | Insulation withstand voltages        |                                          |
|------|--------------------------------------------------|--------------------------------------|------------------------------------------|
|      |                                                  | Normal frequency<br>60 Hz $\pm$ 20 % | Impulse $1.2 \times 50 \mu\text{s}$ wave |
|      |                                                  | 1 min dry kV, rms                    | Full wave withstand kV, crest            |
|      | Column 1                                         | Column 2                             | Column 3                                 |
| 1    | 15.8 and below                                   | 50                                   | 110                                      |
| 2    | 15.9 to 27.5                                     | 60                                   | 125                                      |
| 3    | 27.6 to 38.0                                     | 80                                   | 150                                      |

##### 4.4.1 Dielectric strength of external insulation

External insulation shall conform to the performance requirements of this standard. Requirements for the rated dielectric strength of the external insulation of generator circuit breakers are given in table 5.

##### 4.4.2 Rated normal-frequency withstand voltage (dry)

The rated normal-frequency withstand voltage (dry) is the voltage that a new generator circuit breaker must be capable of withstanding for one min (see column 2 of table 5 and also 5.2.2).

#### **4.4.3 Rated full wave impulse withstand voltage**

The rated full wave impulse withstand voltage is the crest value of a standard  $1.2 \times 50 \mu\text{s}$  impulse voltage wave that a new generator circuit breaker must be capable of withstanding (see column 3 of table 5 and also 5.2.2).

#### **4.4.4 Rated switching impulse withstand voltage**

For generator circuit breakers, the requirements for switching impulse withstand voltage are satisfied by the normal-frequency withstand voltage.

#### **4.5 Rated short-circuit duty cycle**

The rated short-circuit duty cycle of a generator circuit breaker shall be two unit operations with a 30 min interval between operations (CO—30 min—CO).

#### **4.6 Rated interrupting time**

The rated interrupting time of the generator circuit breaker is the maximum permissible interval between the energizing of the trip circuit at rated control voltage and rated fluid pressure of the operating mechanism and the interruption of the main circuit in all poles on an opening operation. Typical values are 4, 5, and 6 cycles with the actual time being dependent on the rated short-circuit current. For generator circuit breakers equipped with resistors, the interrupting time for the resistor current may be longer.

#### **4.7 Rated permissible tripping delay, $T$**

The rated permissible tripping delay of a generator circuit breaker is 0.25 s. This is the maximum time the circuit breaker is required to carry rated short-circuit current after closing on this current and before interrupting.

#### **4.8 Rated closing time**

The rated closing time of a generator circuit breaker is the interval between energizing of the close circuit at rated control voltage and rated fluid pressure of the operating mechanism, and the closing of the main circuit.

#### **4.9 Short-circuit current rating**

The short-circuit current rating of a generator circuit breaker is the rms symmetrical component of short-circuit current to which all required short-circuit capabilities are related. Procedures for determining the symmetrical short-circuit current duties that compare with ratings and related required capabilities are found in clause 6.

#### 4.9.1 Rated short-circuit current

The rated short-circuit current of a generator circuit breaker is the highest rms value of the symmetrical component of the polyphase short-circuit current. It is measured from the envelope of the current wave at the instant of primary arcing contact separation, and is the current that the generator circuit breaker shall be required to interrupt at the rated maximum voltage and rated duty cycle when the source of the short-circuit current is from the power system through at least one transformation. It establishes also, by ratios as defined in 4.9.2, the highest current that the generator circuit breaker shall be required to close and latch against, to carry, and to interrupt. Typical values are 63 kA, 80 kA, 100 kA, 120 kA, 160 kA, etc.

#### 4.9.2 Related required capabilities

The generator circuit breaker shall have the following related required capabilities, which are based on the minimum time to primary arcing contact separation including a relay time of 1/2 cycle, but may be used with any relay time.

##### 4.9.2.1 Required symmetrical interrupting capability for polyphase faults

For polyphase faults, the required symmetrical interrupting capability of a generator circuit breaker at the instant of primary arcing contact separation for operating voltages equal to rated maximum voltage shall not exceed the rated short-circuit current for the rated duty cycle irrespective of the direct current component of the total short-circuit current.

##### 4.9.2.2 Required asymmetrical interrupting capability for polyphase faults

For polyphase faults, the required asymmetrical interrupting capability of a generator circuit breaker is the highest rms value of the short-circuit current at the instant of primary arcing contact separation that the generator circuit breaker shall be required to interrupt at rated maximum voltage and for the rated duty cycle. The numerical value shall be equal to the product of ratio  $S_g$  (specified below and illustrated in figure 2) times the rated short-circuit current of the generator circuit breaker.  $S_g$  is the ratio of the required asymmetrical-to-symmetrical interrupting capability of the generator circuit breaker. Based on an X/R ratio of 50, which is considered to be conservative, the values of  $S_g$  are 1.6, 1.54, 1.49, 1.39, 1.32, or 1.25 for circuit breakers having primary arcing contact parting times of 1, 1.5, 2, 3, 4, or 5 cycles, respectively. The values of  $S_g$  for primary arcing contact parting times between those given above shall be determined from figure 2. For X/R values greater than 50, use the formula for calculating  $S_g$  given in 6.3.6.3.2.

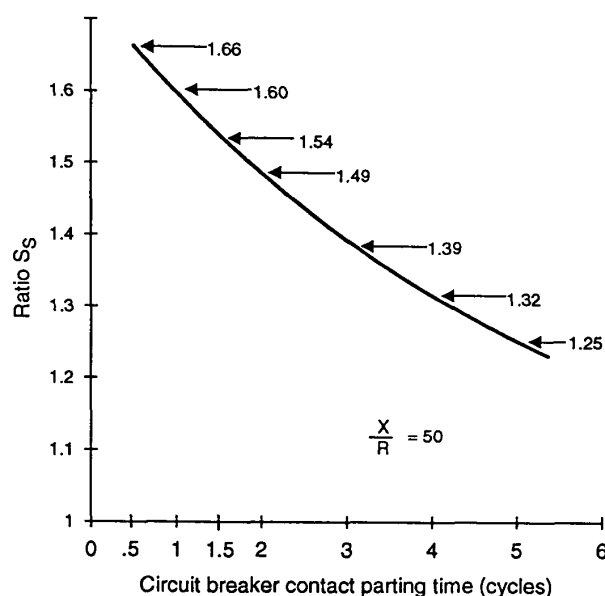


**Figure 2—Ratio of circuit breaker asymmetrical-to-symmetrical interrupting capabilities for three-phase system-source short-circuit current**

The primary arcing contact parting time shall be considered equal to the sum of 1/2 cycle (present practical minimum tripping delay) plus the minimum opening time of the particular generator circuit breaker.

NOTE—Any combination of symmetrical and direct current components of short-circuit current is permissible provided that the following conditions are met at the instant of primary arcing contact separation:

- a) The symmetrical component does not exceed the rated short-circuit current
- b) The degree of asymmetry does not exceed 100%
- c) The total short-circuit current does not exceed the required asymmetrical interrupting capability

#### 4.9.2.3 Required generator-source symmetrical interrupting capability for polyphase faults

No specific rating is assigned to cover the generator-source short-circuit current because its maximum value is significantly less than the short-circuit current from the power system. If a rating is assigned, then the generator circuit breaker shall be tested for the following related capabilities. For polyphase faults, the required generator-source symmetrical interrupting capability of a generator circuit breaker is the highest value of the symmetrical component of the short-circuit current, measured from the envelope of the current wave at the instant of primary arcing contact separation that the generator circuit breaker shall be required to interrupt, at rated maximum voltage and rated duty cycle when the source of the short-circuit current is entirely from a generator through no transformations.

#### 4.9.2.4 Required generator-source asymmetrical interrupting capability for polyphase faults

For polyphase faults, the required generator-source asymmetrical interrupting capability of a generator circuit breaker is the highest rms value of the total generator-source short-circuit current at the instant of primary arcing contact separation that the generator circuit breaker shall be required to interrupt at rated maximum voltage and for the rated duty cycle. The numerical value shall be equal to the product of a ratio  $S_g$ , specified below, times the required generator-source symmetrical interrupting capability of the generator

circuit breaker determined for rated maximum voltage. The value of  $S_g$  shall be 1.85 for all generator circuit breaker primary arcing contact parting times. (The formula for  $S_g$  is given in 6.3.6.3.4). The primary arcing contact parting time shall be considered equal to the sum of 1/2 cycle (present practical minimum tripping delay) plus the minimum opening time of the particular generator circuit breaker.

Any combination of symmetrical and direct-current components of short-circuit current is permissible provided that the following conditions are met at the instant of primary arcing contact separation:

- a) The symmetrical component does not exceed the required generator-source symmetrical interrupting capability.
- b) The degree of asymmetry from the generator-source does not exceed 110%.
- c) The total short-circuit current does not exceed the required generator-source asymmetrical interrupting capability.

#### 4.9.2.4.1 Required generator-source asymmetrical interrupting capability for maximum required degree of asymmetry

For the condition of maximum required degree of asymmetry of polyphase faults, the required generator-source asymmetrical interrupting capability of a generator circuit breaker is a value of 155% of the required generator-source symmetrical interrupting capability. The formula for this calculation is given in 6.3.6.3.5.

The maximum required degree of asymmetry of this current is 130%. Under the condition of maximum required degree of asymmetry, the symmetrical component of the short-circuit current is only 74% of the value of the required generator-source symmetrical interrupting capability.

#### 4.9.2.5 Required interrupting capability for single-phase-to-ground faults

Generator circuit breakers are designed for use on high-impedance grounded systems where the single phase-to-ground short-circuit current will not exceed 50 A.

In no case are the capabilities for single phase-to-ground faults required to exceed this value.

#### 4.9.2.6 Required closing, latching, carrying, and interrupting capabilities

The generator circuit breaker shall be capable of performing the following duties in immediate succession:

- a) Closing and, immediately thereafter, latching any normal frequency-making current whose asymmetrical rms value does not exceed  $C_g$  times the required generator-source symmetrical interrupting capability or  $C_s$  times the rated short-circuit current and whose maximum crest (peak-making current) does not exceed  $C_g'$  times the required generator-source symmetrical interrupting capability or  $C_s'$  times the rated short-circuit current, whichever is higher. The values of  $C_s$  and  $C_s'$  are 1.66 and 2.74, respectively. The values of  $C_g$  and  $C_g'$  are shown in figure 3 and the formula for  $C_s'$  is given in 6.3.6.3.6.

$C_g$  is the ratio of the generator-source asymmetrical short-circuit rms current at 1/2 cycle to the required generator-source symmetrical interrupting capability at the contact parting time of the generator circuit breaker.

$C_g'$  is the ratio of the generator-source asymmetrical short-circuit peak current at 1/2 cycle to the required generator-source symmetrical interrupting capability at the contact parting time of the generator circuit breaker.

$C_s$  is the ratio of the maximum asymmetrical short-circuit rms current at 1/2 cycle to the rated short-circuit current at the contact parting time of the generator circuit breaker.

$C_s'$  is the ratio of the maximum asymmetrical short-circuit peak current at 1/2 cycle to the rated short-circuit current at the contact parting of the generator circuit breaker.

- b) Carrying short-circuit current for any time up to the permissible tripping delay determined in accordance with 4.7
- c) Interrupting any short-circuit current which, at the instant of primary arcing contact separation, has a symmetrical value not exceeding the required symmetrical interrupting capability and an asymmetrical value not exceeding the required asymmetrical interrupting capability

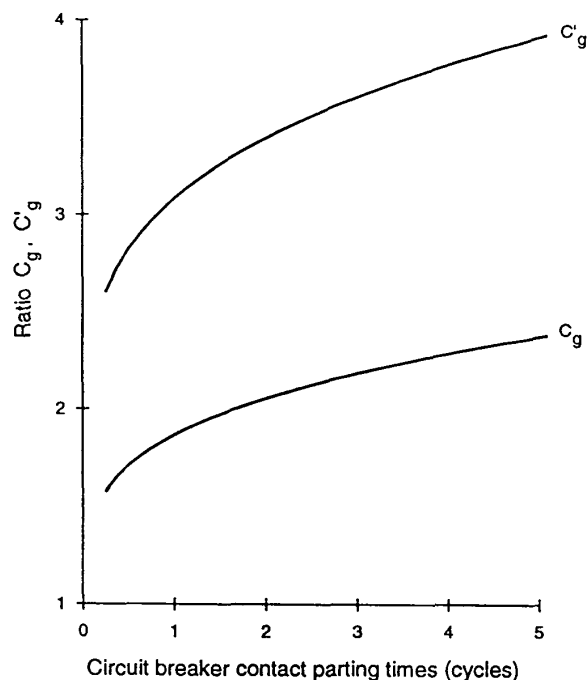


**Figure 3—Ratios of generator-source asymmetrical current at 1/2 cycle to the required generator-source symmetrical interrupting capability of generator circuit breakers at the contact parting times given**

#### 4.9.2.7 Required short-time current-carrying capability

The generator circuit breaker shall be capable of carrying for  $T_s$  equals 1 s, any short-circuit current determined from the envelope of the current wave at the time of the maximum crest, whose value does not exceed  $C_s'$  times the rated short-circuit current, and whose rms value  $I$  determined over the complete 1 s period does not exceed the rated short-circuit current considered above.

The mathematical expression for the rms value  $I$  of a short-circuit current over the period  $T_s$  is

$$I = \sqrt{\frac{1}{T_s} \left( \int_0^{T_s} i^2 dt \right)} = \sqrt{\int_0^1 i^2 dt}$$

where

- $i$  is the instantaneous current in amperes (see section 7 of IEEE Std C37.09-1979).
- $t$  is the time in seconds.

It is not to be inferred that the generator circuit breaker is to be capable of interrupting after the above duty until it has cooled down to normal heat run temperature.

#### 4.9.3 Interrupting performance

##### 4.9.3.1 Rated performance

A generator circuit breaker shall perform at or within its rating without producing any injurious emissions.

##### 4.9.3.2 Service capability duty requirements

Generator circuit breakers shall be capable of the following performances under short-circuit and load current interruption conditions:

- a) One short-circuit duty cycle (CO—30 min—CO)
- b) A number of load current interruptions in which the sum of the currents interrupted does not exceed 5000% of rated continuous current of the circuit breaker. The number of operations used to make up the 5000% is cumulative over a period of time and is a measure of the circuit breaker's reliability and a guide to maintenance. Thermal limitations of parts, such as opening resistors, require that the number of opening operations comprising the 5000% shall not exceed 2 in 30 min or 4 in 4 h.

#### 4.10 Transient recovery voltage (TRV) rating

At its rated maximum voltage, each circuit breaker must be capable of interrupting three-phase grounded faults at rated short-circuit current in any circuit in which the three-phase grounded circuit TRV does not exceed the rated TRV envelope.

Each TRV rating is for a three-phase circuit breaker. It is not required that a single phase of a circuit breaker interrupt a single-phase circuit that produces a circuit TRV equal to the rated TRV envelope.

However, as covered in 5.2.3.8, the single-phase test at 1.5 times phase-to-ground voltage is given as one of the basic approaches to demonstrating the rating in a design test. It is an optional design test, not a rating requirement.

#### 4.10.1 Rated inherent transient recovery voltage (TRV)

The rated inherent TRV shall be defined by an oscillatory waveshape having a TRV rate, time delay, and crest voltage ( $E_2$ ) as listed in tables 6 and 7. The formula and method for determining the time to crest ( $T_2$ ) are given in 6.3.7.3 and figure 16.

#### 4.10.2 First-pole-to-clear factor

The first-pole-to-clear factor shall be 1.5.

#### 4.10.3 Amplitude factor

The amplitude factor shall be 1.5.

**Table 6—TRV parameters for system-source faults**

| Transformer rating<br>MVA | $T_2$ in $\mu\text{s}$ | Inherent TRV         |                            |
|---------------------------|------------------------|----------------------|----------------------------|
|                           |                        | $E_2$ -crest voltage | TRV rate kV/ $\mu\text{s}$ |
| 100 or less               | 0.62 V                 | 1.84 V               | 3.5                        |
| 101 to 200                | 0.54 V                 | 1.84 V               | 4.0                        |
| 201 to 400                | 0.48 V                 | 1.84 V               | 4.5                        |
| 401 to 600                | 0.43 V                 | 1.84 V               | 5.0                        |
| 601 to 1000               | 0.39 V                 | 1.84 V               | 5.5                        |
| 1001 or more              | 0.36 V                 | 1.84 V               | 6.0                        |

**NOTES**

- 1—Time delay shall be equal to or less than 1  $\mu\text{s}$ .  
2—V is the rated maximum voltage in kV.

**Table 7—TRV parameters for generator-source faults**

| Generator rating MVA | $T_2$ in $\mu\text{s}$ | Inherent TRV         |                            |
|----------------------|------------------------|----------------------|----------------------------|
|                      |                        | $E_2$ -crest voltage | TRV rate kV/ $\mu\text{s}$ |
| 100 or less          | 1.35 V                 | 1.84 V               | 1.6                        |
| 101 to 400           | 1.20 V                 | 1.84 V               | 1.8                        |
| 401 to 800           | 1.08 V                 | 1.84 V               | 2.0                        |
| 801 or more          | 0.98 V                 | 1.84 V               | 2.2                        |

**NOTES**

- 1—Time delay shall be equal to or less than 0.5  $\mu\text{s}$ .  
2—V is the rated maximum voltage in kV.

#### 4.11 Rated load current switching capability

The operation endurance capabilities specified in table 8 are the type and number of complete closing-opening operations that the generator circuit breaker shall be capable of performing at any voltage up to the rated maximum voltage under the following conditions:

- a) The circuit breaker shall operate with rated control voltage and rated fluid (gas or liquid) pressure in the operating mechanism
- b) The frequency of operations is not to exceed 2 in 30 min and 4 in 4 h because the circuit breaker may be equipped with auxiliary devices, such as resistors, which have thermal limitations. When auxiliary devices such as resistors are not used, the manufacturer may provide alternate "frequency of operation" values.
- c) The values listed in the rating tables have been established by experience and engineering judgment. Those involving currents are derived from service capability and circuit breaker condition (see 4.9.3.2) and are not separate ratings. (See also 5.2.9.2.)

**Table 8—Operation endurance capabilities for generator circuit breakers**

| Circuit breaker ratings           | Number of operations<br>(operation = 1 closing + opening) |                                               |                                                                        |
|-----------------------------------|-----------------------------------------------------------|-----------------------------------------------|------------------------------------------------------------------------|
|                                   | Between servicing<br>(See note 2)                         | No-load mechanical<br>(See notes 2 through 8) | Continuous current<br>switching<br>(See notes<br>2, 4, 5, 7, 8, and 9) |
| Column 1                          | Column 2                                                  | Column 3                                      | Column 4                                                               |
| Up to 38 kV & 6.3 kA<br>and above | 500                                                       | 1000                                          | 50                                                                     |

**NOTES**

1—The integrated duty on the circuit breaker must be within the service capability as defined in 4.9.3. See also clause 6.

2—Maintenance consists of cleaning, tightening, adjusting, lubricating, and dressing of contacts, etc. as recommended by the manufacturer under usual service conditions. Maintenance intervals are usually based on both an elapsed time and a number of operations, whichever occurs sooner. In determining maintenance intervals for particular applications, consideration must be given to actual conditions prevailing at the installation site. Refer to clause 3 for service conditions and to clause 6 for general application conditions. The number of operations specified in column 2 are based on usual service conditions. When used as a guide for field application, they define maximum maintenance intervals.

3—When closing and opening no-load.

4—With rated control voltage applied (see table 11).

5—Frequency of operation (see 4.11).

6—Requirements are based on specified maintenance intervals in accordance with column 2.

7—No functional part shall have been replaced prior to completion of the specified number of operations.

8—After completion of the specified number of operations, the circuit breaker shall withstand at least 75% of its rated normal frequency withstand voltage, and the resistance of the current carrying circuit from terminal to terminal measured with a current of at least 100 A flowing, shall not be greater than 200% of the maximum value given by the manufacturer for the circuit breaker when new. Under these conditions, the circuit breaker is considered capable of carrying rated continuous current, at normal frequency, without injurious heating until maintained and of performing one interruption at rated short-circuit current or a related capability. After completion of this series of operations, functional part replacement and general maintenance may be necessary.

9—If a short-circuit operation occurs before the completion of the listed operations, maintenance is recommended and possible functional part replacement may be necessary depending on previous duty, fault magnitude, and expected future operations.

#### 4.11.1 Inherent transient recovery voltage (TRV)

The inherent TRV for a load switching operation shall be defined by an oscillatory waveshape having a TRV rate and time delay as listed in table 9. The formula and method for determining the time to crest ( $T_2$ ) are given in 6.3.7.3 and figure 16.

#### 4.11.2 Amplitude factor

The amplitude factor shall be 1.5.

**Table 9—TRV parameters for load current switching**

| Generator rating MVA | $T_2$ in $\mu$ s | Inherent TRV         |                      |
|----------------------|------------------|----------------------|----------------------|
|                      |                  | $E_2$ -crest voltage | TRV rate kV/ $\mu$ s |
| 100 or less          | 1.08 V           | 0.92 V               | 1.0                  |
| 101 to 400           | 0.91 V           | 0.92 V               | 1.2                  |
| 401 to 800           | 0.77 V           | 0.92 V               | 1.4                  |
| 801 or more          | 0.62 V           | 0.92 V               | 1.6                  |

**NOTES**

1—Time delay shall be equal to or less than 1  $\mu$ s.

2—See 5.2.9.2 for test voltage values.

3—V is the rated maximum voltage in kV.

#### 4.12 Capacitance current switching capability

This is a special case where the line or bus capacitance is separated from the generator circuit breaker through transformation. If this capability is required, the user should consult the manufacturer.

#### 4.13 Out-of-phase current switching capability

This capability applies to a generator circuit breaker used for switching the connection between two parts of a three-phase system during out-of-phase conditions. The generator circuit breaker may be assigned an out-of-phase current switching rating when its out-of-phase current switching capability has been demonstrated by the tests specified in clause 5. However, other equivalent or more effective methods of test are not precluded.

##### 4.13.1 Assigned out-of-phase current switching rating

The assigned out-of-phase current switching rating is the maximum out-of-phase current that the generator circuit breaker shall be capable of switching at an out-of-phase recovery voltage equal to that specified in 5.2.10.2 and under prescribed conditions.

##### 4.13.2 Interrupting time for out-of-phase current switching

The interrupting time for out-of-phase current switching is equal to the rated interrupting time.

#### 4.13.3 Inherent TRV for out-of-phase current switching

The inherent TRV for out-of-phase current switching shall be defined by an oscillatory waveshape having the TRV rate, time delay, and crest voltage ( $E_2$ ) as listed in table 10 (see 6.3.10.2). The formula and method for determining the time to crest ( $T_2$ ) are given in 6.3.7.3 and figure 16.

**Table 10—TRV parameters for out-of-phase current switching**

| Generator rating MVA | $T_2$ in $\mu$ s | Inherent TRV         |                      |
|----------------------|------------------|----------------------|----------------------|
|                      |                  | $E_2$ -crest voltage | TRV rate kV/ $\mu$ s |
| 100 or less          | 0.89 V           | 2.6 V                | 3.3                  |
| 101 to 400           | 0.72 V           | 2.6 V                | 4.1                  |
| 401 to 800           | 0.63 V           | 2.6 V                | 4.7                  |
| 801 or more          | 0.57 V           | 2.6 V                | 5.2                  |

**NOTES**

1—Time delay shall be equal to or less than 1  $\mu$ s.

2—V is the rated maximum voltage in kV.

#### 4.14 Excitation current switching capability

The excitation current switching capability is the highest magnetizing current that a generator circuit breaker shall be required to switch at any voltage up to rated maximum voltage at normal frequency without causing an overvoltage exceeding the levels agreed upon between the user and the manufacturer. The test to establish the capability shall be determined between the user and the manufacturer.

#### 4.15 Rated control voltage

The rated control voltage of a generator circuit breaker is the designated voltage that is to be applied to the closing or tripping devices to close or open the generator circuit breaker (see table 11).

The transient voltage in the entire control circuit, due to interruption of control circuit current, shall be limited to 1500 V crest.

NOTE—The control voltage is allowed to vary above and below its rated value within a specified range (see table 11). The control voltage is measured at the terminals of the operating coils with the operating current flowing. The maximum voltage is measured at the control power terminals of the operating mechanism at no-load and the minimum voltage is measured with the maximum operating current flowing. Rated voltages and their permissible ranges for the control power supply of circuit breakers shall be shown as below.

**Table 11—Rated control voltages and their ranges for generator circuit breakers**

| Direct current voltage ranges <sup>1, 2, 4, 7, 8</sup><br>Closing and auxiliary functions |                            |                             |                                      | Alternating current<br>voltage ranges <sup>1, 2, 3</sup> |                                                  |
|-------------------------------------------------------------------------------------------|----------------------------|-----------------------------|--------------------------------------|----------------------------------------------------------|--------------------------------------------------|
| Rated voltage                                                                             | Indoor circuit<br>breakers | Outdoor circuit<br>breakers | Tripping<br>functions<br>(All types) | Rated voltage<br>(60 Hz)                                 | Closing, tripping,<br>and auxiliary<br>functions |
| 24 <sup>5</sup>                                                                           | —                          | —                           | 14–28                                | Single phase                                             |                                                  |
| 48 <sup>5</sup>                                                                           | 38–56                      | 36–56                       | 28–56                                | 120                                                      | 104–127 <sup>6</sup>                             |
| 125                                                                                       | 100–140                    | 90–140                      | 70–140                               | 240                                                      | 208–254 <sup>6</sup>                             |
| 250                                                                                       | 200–280                    | 180–280                     | 140–280                              | Polyphase                                                |                                                  |
|                                                                                           |                            |                             |                                      | 208 Y/120                                                | 180 Y/104–<br>220 Y/127                          |
|                                                                                           |                            |                             |                                      | 240                                                      | 208–254                                          |

**NOTES**

1— Relays, motors, or other auxiliary equipment that function as part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

2— Mechanism devices in some applications may be exposed to control voltages exceeding those specified here due to abnormal conditions, such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control exposed continuously to control voltages approaching the upper limits of ranges specified herein require specific attention, and the manufacturer should be consulted before application is made.

3— Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered in NEMA MG-1-1989.

4— It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

5— Twenty-four (24) V and 48 V tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. Twenty-four (24) V closing is not recommended.

6— Includes heater circuits.

7— Extended voltage ranges apply to all closing and auxiliary devices when cold. Mechanisms utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

8— Direct-current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges.

**4.16 Rated mechanism fluid operating pressure**

The rated mechanism fluid operating pressure of a generator circuit breaker is the pressure at which a gas- or liquid-operated mechanism is designed to operate. The pressure is allowed to vary above and below its rated value within a specified range.

**4.17 Nameplate markings**

The following minimum data, when applicable, shall appear on the nameplates of each circuit breaker and associated device.