

IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

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of the
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Abstract: This standard covers enclosed low-voltage dc power circuit breakers of the stationary or draw-out type of single- or two-pole construction with one or more rated maximum voltages of 300 V, 325 V, 800 V, 1000 V, 1600 V, or 3200 V for applications on dc systems having nominal voltages of 250 V, 275 V, 750 V, 850 V, 1500 V, or 3000 V, with general-purpose, high-speed, semi-high-speed and rectifier circuit breakers; manually or power-operated; and with or without electro-mechanical or solid-state trip devices. It deals with service conditions, ratings, functional components, temperature limitations and classification of insulating materials, insulation (dielectric) withstand voltage requirements, test procedures, and application.
Keywords: general purpose, high-speed, semi-high-speed or rectifier circuit breaker, current-limiting, impulse trip device, reverse-current trip device

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Introduction

(This introduction is not a part of IEEE C37.14-1993, IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures.)

IEEE Std C37.14-1979, a needed revision to IEEE Std C37.14-1969, properly recognized the widespread use of solid-state rectifiers in industry, particularly for the traction power systems that evolved in the 1970s. The basic material for the standard was developed by the IEEE Working Group of the Low-Voltage Switchgear Devices Subcommittee and approved by the IEEE Switchgear Committee. It was based on known applications as well as considerations for future system development, with basic ratings and tests evolving from the classic mathematical solutions available at the time.

The revision working groups for this new edition, in reviewing the status of industry applications, laboratory and on-site short-circuit testing, and new technical analyses, have concluded that certain major changes were necessary.

While it previously appeared that future transit systems would require a 1200 V maximum design rating, this voltage level never materialized, and it has become obvious that new systems would be best served by dc circuit breakers rated at 1000 V, but with a higher dielectric withstand level to accommodate certain over-voltage conditions such as regeneration. Accordingly, an equivalent 1000 V dielectric test voltage level has been assigned to the 800 V rated circuit breaker and an equivalent 1200 V dielectric test voltage level has been assigned to the re-established 1000 V rated circuit breaker.

The peak-current multiplier of 1.65 times the sustained current has been maintained in this revision even though it can be shown that a multiplier of 1.42 can be utilized for the 12-pulse rectifier designs. However, since the 6-pulse rectifier designs can produce the 1.65 peak and because of unknown future applications with additional and/or replacement circuit breakers, it was deemed necessary to maintain the 1.65 value.

It is specifically noted, however, that depending on the transformer/rectifier-design impedance coupled with the primary short-circuit current capacity and a lower dc inductance, it may be possible to obtain a higher peak current and/or sustained current depending on conditions. This design combination needs to be properly investigated and applied to prevent overrating of all circuit breakers that cannot be rated higher than the rated peak and sustained currents listed in the preferred rating tables in ANSI C37.16a.

A new facet of transit application is the need for lower rated circuit breakers for the light-duty transit systems, which are generally 800 V catenary surface systems. The power requirements are approximately one-half of those of the heavy-duty transit system, with the rectifier circuit breakers requiring maximum continuous current ratings of 4000 A and feeder circuit breakers with proportionately lower ratings. Tables 12 and 12A have been replaced with a new table in ANSI C37.16a that has been revised to reflect a reduced base rating of 4000 kW, lumped, to provide a lower level design rated circuit breakers, therefore, allowing the use of designs different from those utilized for the heavy-duty systems.

Additionally, the question of rectifier and feeder circuit breakers being rated identically was addressed in the IEEE C37.14-1979 appendix, but has now been recognized and addressed in the body of the standard. Specific installation applications normally differentiate in rating requirements between rectifier and feeder breakers in the reverse/forward-current tripping modes, as well as in the short-time/momentary rating modes. Therefore, it is important to recognize this difference in rating structures to provide for realistic design ratings and testing.

The designs of high-speed and semi-high-speed circuit breakers with two different rating/test tables were conceptually reviewed, and recognition of actual field application conditions forced a concept change. A given track system will produce given short-circuit currents and circuit stored energy at various locations regardless of circuit breaker type applied. Thus, there is a need for only two tables—one for low frequency and one for high frequency impedance bonds. Actually, the high-speed type circuit breaker is truly current-limiting by limiting let-through current to less than the available (prospective) peak in all cases. The semi-high-speed type is “semi-current limiting,” limiting let-through current to less than the sustained in all cases except in allowing the maximum peak current available to flow on low

inductance (close-in) faults, and have been so redefined. In addition, any dc circuit breaker must be capable of handling all short-circuit conditions based on its speed, current interrupted, and circuit energy interrupted as verified by the short-circuit tests a, b, c, and d of tables 11, 11A, and 12 in the latest version of ANSI C37.16a.

Another consideration for this revision was that only one testing sequence was required. It is noted for comparison that ac low-voltage power circuit breakers are required by ANSI C37.50-1989 to be tested in four (4) sequences for certification/conformance. Similar analysis of required testing resulted in the assignment of two (2) sequences in this standard.

This standard represents the standard practice in the United States for low-voltage dc circuit breakers. Molded case circuit breakers are covered by other standards, but in some instances may be able to meet this standard.

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IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

1. Scope

This standard covers the following types of enclosed low-voltage dc power circuit breakers:

- a) Stationary or draw-out type of one- or two-pole construction
- b) Having one or more rated maximum voltages of 3200 V, 1600 V, 1000 V, 800 V, 325 V, or 300 V for applications on systems having nominal voltages of 3000 V, 1500 V, 850 V, 750 V, 275 V, or 250 V
- c) Manually-operated or power-operated
- d) With or without overcurrent trip devices

NOTE — In this standard, the use of the words “circuit breaker” shall be considered to mean “enclosed low-voltage dc power circuit breaker.”

2. References

This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

ANSI C37.16-1988, Preferred Ratings, Related Requirements and Application Recommendations for Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors.¹

ANSI C37.16a, Preferred Ratings, Related Requirements and Application Recommendations for Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors.²

ANSI C37.17-1979, American National Standard for Trip Devices for AC and General Purpose DC Low-Voltage Power Circuit Breakers.

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

²At the time of publication, ANSI C37.16a, which contains new rating tables critical to this standard, was in the balloting process. As a courtesy to the user, the draft rating tables are included annex B. The latest draft is available from the National Electrical Manufacturers Association (NEMA), 2101 L Street NW, Washington, DC 20037, USA.

IEEE Std 1-1986, IEEE Standard General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation (ANSI).³

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

IEEE Std C37.20.1-1987 (Reaff 1992), IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear (ANSI).

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

3. Definitions

The definitions of terms contained in this standard, or in other standards referred to in this document, are not intended to embrace all legitimate meanings of these terms. They are applicable only to the subject treated in this standard.

The definitions of most terms used in this standard are found in IEEE Std C37.100-1992.⁴

3.1 circuit breaker, general purpose low-voltage dc power: A circuit breaker that, during interruption, does not limit the current peak of the available (prospective) fault current, and may not prevent the fault current from rising to its sustained value. *Note:* This design circuit breaker requires a peak, a short-time, and a short-circuit current rating.

3.2 circuit breaker, high-speed low-voltage dc power: A circuit breaker that, during interruption, limits the current peak to a value less than the available (prospective) fault current. *Note:* This design circuit breaker requires a short-circuit current rating and may have a short-time current rating assigned.

3.3 circuit breaker, semi-high-speed low-voltage dc power: A circuit breaker that, during interruption, does not limit the current peak of the available (prospective) fault current on circuits with minimal inductance, but that does limit current to a value less than the sustained current available on higher inductance circuits. *Note:* This design circuit breaker requires a peak and a short-circuit current rating, and may have a short-time current rating assigned.

3.4 circuit breaker, rectifier low-voltage dc power: A circuit breaker that carries the normal current output of one rectifier, and, during fault conditions, functions to withstand and/or interrupt abnormal current as required. *Note:* This design circuit breaker requires a short-circuit current rating for $n-1$ rectifiers and a short-time current rating for its own rectifier.

NOTE — For total performance at other than test circuit parameter values, consult the manufacturer.

3.5 trip device (opening release), impulse: A trip device that is designed to operate only by the discharge of a capacitor into its release (trip) coil and is utilized on high-speed circuit breakers to produce the tripping times that are independent of di/dt .

4. Service conditions

A circuit breaker conforming to this standard shall be suitable for operation up to and including all of its standard ratings, providing that:

- a) The temperature of the air surrounding the circuit breaker is not below -5°C
- b) The altitude does not exceed 6600 ft (2000 m)

³IEEE 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.

⁴Information on references can be found in clause 2.

- c) The relative humidity of the air surrounding the circuit breaker is such that there will be no condensation on the circuit breaker parts at any time
- d) None of the conditions listed in 10.5.2 prevail

NOTE — When properly applied in metal-enclosed power switchgear or individual enclosures, a circuit breaker will operate within the limits of ambient temperature of the air surrounding the enclosure as specified in IEEE Std C37.20.1-1987.

Whenever the service conditions vary from those defined in this clause, consultation between the user and manufacturer is recommended. Some of the service conditions that may require additional attention are listed in 10.5.2.

5. Ratings

5.1 Rating information

The rating of low-voltage dc power circuit breakers is a designated limit of operating characteristics based upon the service conditions of clause 4. and shall include the following as applicable:

- a) Rated maximum voltage(s)
- b) Rated continuous current
- c) Rated peak current
- d) Rated short-time current
- e) Rated short-circuit current
- f) Rated control voltage(s)

The designated ratings in ANSI C37.16a⁵ are preferred, but are not to be considered restrictive.

5.2 Rated maximum voltage

The rated maximum voltage of a circuit breaker is the highest average dc voltage at which it is designed to perform with a recurring crest voltage no higher than that which occurs with a three-phase full wave bridge rectifier. The circuit breakers shall be rated at one of the maximum rated voltages as specified in ANSI C37.16a.

5.3 Rated continuous current

The rated continuous current of a circuit breaker is the designated limit of sustained current in rms amperes that it shall require to carry continuously without exceeding the temperature limitations designated in clause 7. The preferred continuous current ratings of the various frame sizes are listed in ANSI C37.16a. The rated continuous current of a circuit breaker, which is equipped with direct-acting trip devices of a smaller rating than the frame size of the circuit breaker, is determined by the rating of those devices.

5.4 Rated peak current

The rated peak current of a circuit breaker is the designated limit of non-repetitive available (prospective) peak amperes that it shall require to close into and still be able to open and then close. This rating will apply to circuit breakers having direct-acting instantaneous trip devices active in the direction of the current flow.

⁵See annex B for new rating tables that are referenced in this standard.

5.5 Rated short-time current

The rated short-time current of a circuit breaker is the designated limit of available (prospective) sustained current in rms amperes that it shall require to carry for a period of 250 ms without impairing its ability to operate and perform all other ratings. This rating will apply both without direct-acting instantaneous trip devices and with current flow in the non-active direction of polarized direct-acting instantaneous trip devices.

This rating also requires that the circuit breaker be able to withstand a peak current equal to at least 1.65 times the value of its rated short-time current occurring approximately 8 ms after the start of the current flow.

5.6 Rated short-circuit current

The rated short-circuit current of the circuit breakers is the designated limit of available (prospective) current in rms amperes they shall be required to perform their short-circuit current duty cycle (0–15 s—CO) at rated maximum voltage under the prescribed test conditions given in 9.2.7.

5.6.1 General-purpose dc circuit breakers

The preferred ratings are listed in table 8 of ANSI C37.16a.

5.6.2 General-purpose dc circuit breakers for mining operations

The preferred ratings are listed in table 10 of ANSI C37.16a.

5.6.3 Semi-high-speed dc circuit breakers

The preferred ratings are listed in tables 11 and 11A of ANSI C37.16a.

5.6.4 High-speed dc circuit breakers

The preferred ratings are listed in tables 11 and 11A of ANSI C37.16a.

5.6.5 Rectifier dc circuit breakers

The preferred ratings are listed in tables 11 and 11A of ANSI C37.16a.

NOTE — Any applicable type circuit breaker may be utilized to meet table 12 requirements.

5.7 Rated-control voltage

The rated-control voltage is the voltage at which the mechanism of the circuit breaker is designed to operate when measured at the control power terminals of the operating mechanism with operating current flowing. Rated control voltages and their ranges for low-voltage power circuit breakers are listed in table 23 of ANSI C37.16-1988.

NOTE — Mining circuit breakers may require control voltage up to 325 V.

6. Functional components

The functional components required for manually and power-operated circuit breakers are listed in table 1. Additional accessory devices may be available. The manufacturer should be consulted for specific information.

Table 1— Functional components

	General purpose dc circuit breakers* Frame size 600 to 6000 A		Rectifier or feeder Semi-high-speed and high-speed dc circuit breakers Frame size 1200 to 12 000
	Operating mechanism type		
Functional component	Manual	Power	
a) Direct-acting trip device(s) calibrated in accordance with ANSI C37.17-1979	X [†]	X [†]	—
b) Overcurrent release (trip) in response to forward or reverse current flow as necessary	—	—	X [†]
c) Manual trip device	X	X	X
d) Contact position indicator—in accordance with 6.2	X	X	X
e) Manually-operated mechanism, trip-free with standard operating handle	X [‡]	—	—
f) Power-operated mechanism, trip-free, with anti-pump feature and maintenance closing device	—	X	X
g) Shunt trip device or opening release with necessary control auxiliary switches	—	X	X
h) Stored energy indicator—in accordance with 6.3	X ^{**}	X ^{**}	X ^{**}
i) Locking—in accordance with 6.4	X	X	X
j) Nameplate(s), with markings, in accordance with 6.1	X	X	X

*General-purpose dc circuit breakers for mining applications are not covered in this table; the manufacturer should be consulted for functional components.

†As required by the application.

‡Manually-operated circuit breakers 3000 A and above shall be furnished with closing mechanisms that provide for only independent manual operation.

**Required only on closing mechanisms that provide for stored energy operation when the mechanism can be left in the charged position.

6.1 Nameplate(s)

The following information shall be given on the nameplates of all circuit breakers when applicable:

- Manufacturer's name and address
- Manufacturer's type of circuit breaker with "high-speed," "semi-high-speed," "rectifier," "feeder," "general purpose," or "mining"
- Frame size
- Rated maximum voltage
- Rated continuous current in rms amperes and type designation of trip devices
- Rated peak current
- Rated short-time current
- Rated short-circuit current
- Rated control voltage
- Year of manufacture—by date or code
- Identification number

6.2 Contact position indicator

The following colors shall be used:

- a) Red background with the word “closed” in contrasting letters to indicate closed contacts
- b) Green background with the word “open” in contrasting letters to indicate open contacts

6.3 Stored energy indicator

The following colors shall be used:

- a) Yellow background with black lettering to indicate charged mechanism
- b) White background with black lettering to indicate discharged mechanism

6.4 Locking

Provisions shall be made for locking the circuit breaker in the open (trip-free) position.

7. Temperature limitations and classification of insulating materials

7.1 Temperature limits

The temperature limits on which the rating of circuit breakers is based are determined by the characteristics of the insulating materials used and the metals that are used in current-carrying parts and springs.

7.2 Limits of observable temperature rise

The observable temperature rise of the various parts of the circuit breaker above the temperature of the air surrounding the circuit breaker test enclosure, when subjected to temperature tests in accordance with this standard, shall not exceed the values given in table 2. This table applies only to a circuit breaker having all contacts silver-surfaced, silver, silver-alloy, or equivalent, and, in addition, having all conducting joints, moving or fixed, including terminal connections, either: a) silver-surfaced and held mechanically, b) brazed, welded, or silver-soldered, or c) fixed rigid mechanical joints surfaced with suitable material other than silver.