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IEEE Guide for Low-Voltage AC (635 V and below) Power Circuit Breakers Applied with Separately-Mounted Current-Limiting Fuses

IEEE Power and Energy Society

Sponsored by the
Switchgear Committee

IEEE
3 Park Avenue
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USA

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(Revision of
IEEE Std C37.27-2008)

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Abstract: Application recommendations to assist in selection of separately mounted current-limiting fuses to be installed in series with low-voltage ac power circuit breakers are provided in this guide.

Keywords: circuit breaker, current-limiting fuse, IEEE C37.27™, low-voltage ac power circuit breaker, open-fuse trip device

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Introduction

This introduction is not part of IEEE Std C37.27™-2015, IEEE Guide for Low-Voltage AC (635 V and below) Power Circuit Breakers Applied with Separately-Mounted Current-Limiting Fuses.

IEEE Std C37.27™-2008 revised IEEE Std C37.27-1987 to address the following issues:

a) Modification of all dimensional information to provide metric dimensions,

b) General revision for harmonization with related standards,

c) General revision for current products and applications including details associated with electronic and electromechanical trip devices, and

d) Clarification of the differences between low-voltage nonintegrally fused circuit breakers (covered by IEEE Std C37.13™)[1] and low-voltage ac power circuit breakers with separately mounted fuses.

Nonintegrally fused circuit breaker construction is not the same as separately mounted fuses construction. The previous title of IEEE Std C37.27-1987 included the reference to nonintegrally fused power circuit breakers. This reference is removed from the 2008 revision and only the reference to separately mounted fuses is used to clarify this construction difference and the applicability of this guide only to low-voltage AC power circuit breaker using separately mounted current-limiting fuses.

While this document is intended as a guide for application of fuses in low-voltage ac power circuit breakers with separately mounted current-limiting fuses, the guide may also be useful as an application guide for low-voltage integrally or nonintegrally fused power circuit breakers.

The present revision updates the references to preferred ratings from IEEE Std C37.16™, which will be withdrawn when IEEE Std C37.13 and IEEE Std C37.14™ revisions have been completed to incorporate the information previously included within IEEE Std C37.16.

[1]Information of references can be found in Clause 2.

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1. Overview

1.1 Scope

This guide applies to unfused low-voltage ac power circuit breakers of the 635 V maximum voltage class with separately-mounted current-limiting fuses for use on ac circuits with available short-circuit currents of 200 000 A (rms symmetrical) or less. Low-voltage ac fused power circuit breakers and combinations of fuses and molded-case circuit breakers are not covered by this guide.

In this guide, the term circuit breaker means unfused low-voltage ac power circuit breaker.

1.2 Purpose

This guide sets forth recommendations believed essential for the selection of current-limiting fuses (see NEMA FU-1 and UL 248-1) for use in combination with low-voltage ac power circuit breakers, rated in accordance with IEEE Std C37.13™ and applied in metal-enclosed low-voltage power circuit breaker switchgear in accordance with IEEE Std C37.20.1™.

NOTE—The combination of a circuit breaker and separately mounted fuses is limited to 600 V based on fuse maximum voltage ratings.[2]

2. Normative references

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

ANSI C37.50, American National Standard For Switchgear—Low-Voltage AC Power Circuit Breakers Used in Enclosures—Test Procedures.[3]

IEEE Std C37.13™, IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures.[4,5]

IEEE Std C37.20.1™, IEEE Standard for Metal-Enclosed Low-Voltage (1000 V ac and below, 3200 V dc and below) Power Circuit Breaker Switchgear.

IEEE Std C37.59™, IEEE Standard Requirements for Conversion of Power Switchgear Equipment.

IEEE Std 141™, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (*IEEE Red Book*™).

IEEE Std 241™, IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (*IEEE Gray Book*™).

IEEE Std 242™, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (*IEEE Buff Book*™).

NEMA FU-1, Low-Voltage Cartridge Fuses.[6]

UL 248-1, UL Standard for Low-Voltage Fuses—Part 1: General Requirements.[7]

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[8]

clearing time (of a mechanical switching device): The interval between the time the actuating quantity in the main circuit reaches the value causing actuation of the release and the instant of final arc extinction on all poles of the primary arcing contacts.

[2]Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.
[3]ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY. 10036, USA (http://www.ansi.org).
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NOTE—Clearing time is numerically equal to the sum of the trip system time, contact parting time, and arcing time.

current-limiting (peak let-through or cutoff) characteristic curve: A curve showing the relationship between the maximum peak current passed by a device and the correlated rms available current magnitude under specified voltage and circuit impedance conditions.

current-limiting fuse: A fuse that, within a specified overcurrent range, limits the clearing time at rated voltage to an interval equal to or less than the first major or symmetrical current loop duration; and limits the peak current to a value less than the available peak current.

NOTE—The values specified in standards for the threshold ratio, peak let-through current, and I^2t characteristics are used as the measures of current-limiting ability.

current-limiting range (of a current-limiting fuse): That specified range of currents between the threshold current and the rated interrupting current within which current limitation occurs.

fuse: An overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent through it.

NOTE—A fuse comprises all the parts that form a unit capable of performing the prescribed functions. It may or may not be the complete device necessary to connect it into an electric circuit.

low-voltage fused power circuit breaker: An assembly of an ac low-voltage power circuit breaker with either integrally mounted or nonintegrally mounted current-limiting fuses that together function as a coordinated protective device.

low-voltage integrally fused power circuit breaker: An assembly of an ac low-voltage power circuit breaker with current-limiting fuses integrally mounted to the circuit breaker and that function together as a coordinated protective device.

low-voltage nonintegrally fused power circuit breaker: An assembly of an ac low-voltage power circuit breaker and nonintegrally mounted current-limiting fuses that together function as a coordinated protective device.

low-voltage power circuit breaker applied with separately mounted current-limiting fuses: Any combination of a low-voltage power circuit breaker and current-limiting fuses other than integrally and nonintegrally fused ac low-voltage power circuit breakers as defined by IEEE Std C37.13.

peak let-through cutoff current (of a current-limiting fuse): The highest instantaneous current passed by the fuse during the interruption of the circuit.

total clearing time of a fuse: The time elapsing from the beginning of a specified overcurrent to the final circuit interruption, at rated maximum voltage.

NOTE—The clearing time is equal to the sum of melting time and the arcing time.

4. General

Combinations of low-voltage ac power circuit breakers and current-limiting fuses provide a broader range of circuit protection than either device can provide alone. Such combinations, when properly selected, can retain the versatility of switching and overload protection that circuit breakers can provide, and be applied on systems with available short-circuit current up to 200 000 A (rms symmetrical), which may be appreciably higher than the short-circuit current rating of unfused circuit breaker.

Fuses with identical continuous current ratings per NEMA FU-1 made by different manufacturers exhibit a range of clearing I^2t, temperature rise, time-current, maximum peak let-through current, and arc voltage characteristics. Therefore, it is not feasible to select a circuit breaker-fuse combination by continuous current ratings alone. The degree of protection provided for a circuit breaker, by a fuse at current levels above the unfused circuit breaker short-circuit current rating may vary with different values of maximum clearing I^2t, maximum peak let-through current, and arc voltage of the fuse. At short-circuit current levels slightly above the short-circuit current rating of the circuit breaker, the duty on a circuit breaker may be more severe than at very high short-circuit current levels. For a specific fuse type, the use of peak current as a criterion is only an approximation for the combined effects of maximum clearing I^2t, maximum peak let-through current, and arc voltage of the fuse.

The criteria necessary for making the proper fuse selection are as follows:

- Continuous current ratings of the circuit breaker and fuse
- Available short-circuit current level at the application point
- Short-circuit current rating of the circuit breaker
- Time-current characteristics of the circuit breaker and the fuse
- Peak let-through current characteristic of the fuse

For each circuit breaker on a system there is a maximum fuse rating that will provide the required short circuit protection for the circuit breaker. Also, there is a minimum fuse rating that will coordinate with the circuit breaker time-current characteristic as well as its continuous-current rating based on temperature rise limits. The selection of a fuse rating within these two limits will provide adequate protection for the circuit breaker and avoid unnecessary fuse opening for fault current within the short-circuit rating of the circuit breaker. Recommendations for establishing the range of fuse ratings to provide the required protection and coordination for a given application should be based on fuse and circuit breaker characteristics as provided in Clause 5.

5. Coordination of circuit breaker and fuse

A current-limiting fuse should be chosen that has operating characteristics that will protect the circuit breaker and will allow the circuit breaker to interrupt overloads and faults within its ratings to avoid unnecessary fuse operation. A fuse of the type recommended by the circuit breaker manufacturer should be selected with a rating that complies with the criteria outlined in 5.1 and 5.2.

5.1 Maximum fuse rating to be used

The maximum continuous current rating for the fuse that will adequately protect the circuit breaker should be determined by the information outlined in 5.1.1, 5.1.2, 5.1.3, and 5.1.4.

5.1.1 Current limiting region

The lower limit of the current limiting region (rms symmetrical value) of the fuse (Point A of Figure 1) shall be lower than the unfused circuit breaker short-circuit current rating at the specific application voltage and shall extend up to and include the maximum available short-circuit current at the point of application of the system.

5.1.2 Instantaneous peak let-through

In the absence of current limiting fuses, the peak current available is 2.3 times the system available short circuit current (rms symmetrical). The unfused circuit breaker is tested to demonstrate that it withstands 2.3 times the symmetrical short-circuit current rating when equipped with instantaneous direct-acting trip elements. The preferred values for short-circuit current ratings (symmetrical) are shown in IEEE Std C37.13.

The instantaneous peak let-through current of the fuse at the system available short-circuit current shall not exceed the short-circuit current rating (symmetrical) of the unfused circuit breaker with instantaneous direct-acting trip elements.

NOTE—Reference IEEE Std C37.20.1 and IEEE Std C37.26 for explanation of the 2.3 factor.

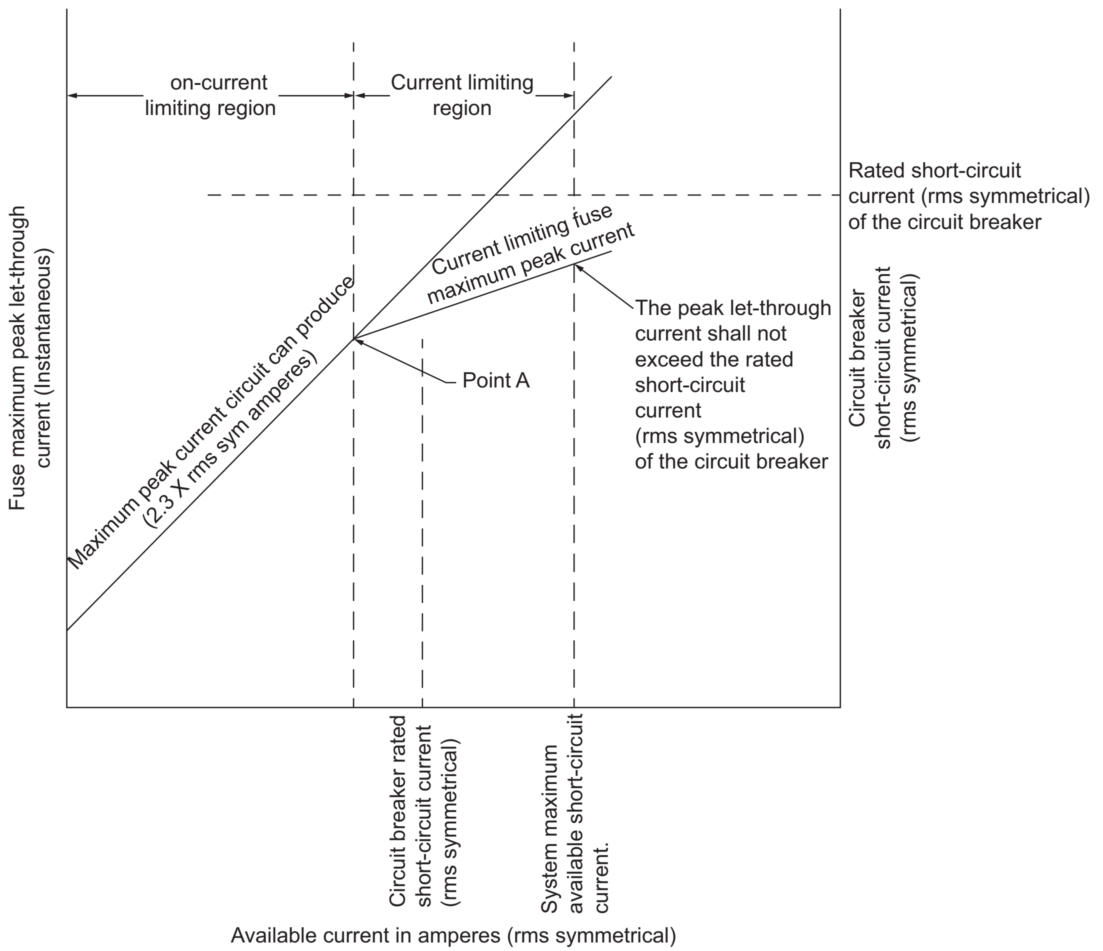


Figure 1—Illustrative peak let-through current characteristics

For single-phase ac circuits, the current should be calculated using the same considerations as used for three-phase circuits. When a circuit breaker is applied in such a way on a single-phase circuit that the system voltage impressed across a single pole is no greater than 58% of any one of the rated maximum voltages, the maximum available short-circuit current may be equal to 100% of the corresponding three phase short-circuit current rating.

When a circuit breaker is applied in such a manner on a three-phase system that the voltage impressed across a single pole exceeds 58% of the rated maximum voltage, the maximum available short-circuit current shall be limited to 87% of the corresponding three-phase short-circuit current rating. Preferred three-phase short-circuit current ratings are listed in IEEE Std C37.13.

In determining the suitability of a circuit breaker for the short-circuit current conditions of a system, consideration should be given to the following:

- Source contribution
- Motor contribution
- Effects of power factor
- Types of operating mechanism
- Duty cycle
- Direct-acting trip devices
- Effect of remote protective devices

Recommended guidance in calculating short-circuit currents is given in IEEE Std 141, IEEE Std 241, and IEEE Std 242.

5.1.3 Total clearing time

The total clearing time of the fuse should be less than the minimum total clearing time of the circuit breaker at the current equal to the short-circuit current rating (unfused) of the circuit breaker at the system voltage (see Figure 2). Since the circuit breaker manufacturer's published data is usually for the maximum total clearing time for instantaneous tripping characteristics, subtract one electrical cycle to approximate the minimum total clearing time of the circuit breaker.

5.1.4 Electromechanical trip devices

When the circuit breaker is equipped with electromechanical trip devices having trip device long-time pickup current settings less than the minimum trip device long-time pickup current settings at 254 V, as shown in IEEE Std C37.13, restrictions in short-circuit current ratings for different maximum voltage ratings should be observed. The maximum fuse rating should be reduced to limit the peak let-through current to twice the 508 V or 635 V rms short-circuit current rating of the circuit breaker, whichever current applies to the installation voltage.

5.2 Minimum fuse rating to be used

The minimum continuous current rating for the fuse to coordinate with the circuit breaker should be determined as outlined in 5.2.1, 5.2.2, 5.2.3, and 5.2.4.

5.2.1 Average melting-time

The fuse should be selected so that its average melting-time current characteristics curve does not overlap the circuit breaker total clearing time in the long-time-delay portion of the circuit breaker curve. The average melting time of the fuse t_2 should be at least twice the total clearing time of breaker t_1 at the current level where the long-time-delay current characteristic shifts to the short-time delay or instantaneous element (see fuse characteristic A of Figure 3).

5.2.2 Addition of short-time element

The addition of a short-time element makes it possible to use a fuse with a smaller continuous current rating than would otherwise be recommended (t_4 should also be at least twice t_3). (See fuse characteristic B of Figure 3.)

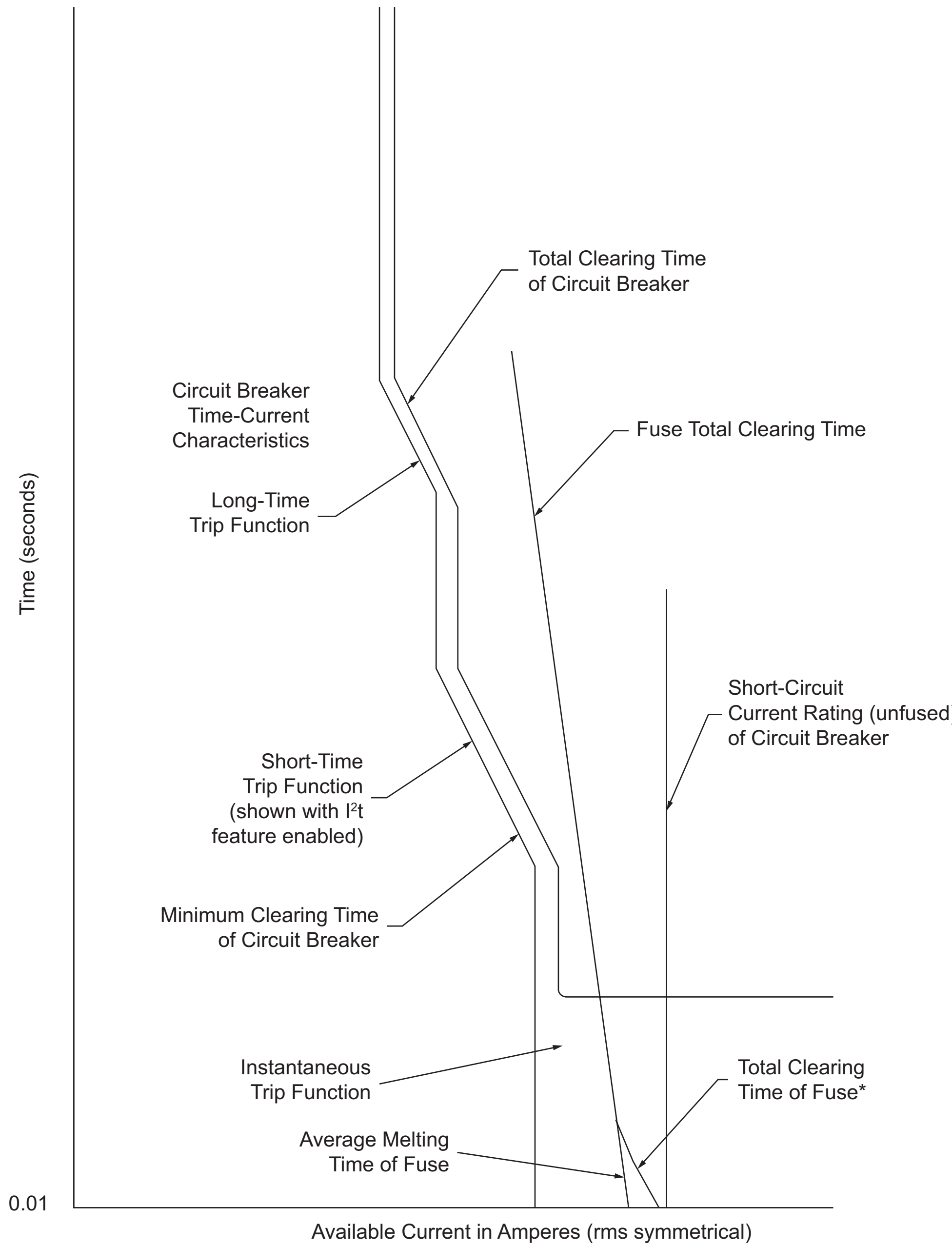
5.2.3 Thermal coordination

In order to maintain thermal coordination between the fuse and the circuit breaker, the manufacturer should be consulted.

5.2.4 Trip device coordination

The continuous current rating of the fuse should not be less than 150% of the trip device long time pickup current setting when located within 1.2 m (4 ft) measured along the primary current conductors' path of the circuit breaker.

This limitation may not apply when electronic trip devices are installed on the circuit breaker. The manufacturer should be consulted in such cases.



* Fuse Curves from Manufacturer are usually based on average melting time.
Add 0.004 seconds to approximate the Total Clearing Time.

Figure 2—Typical time-current characteristics with maximum fuse rating

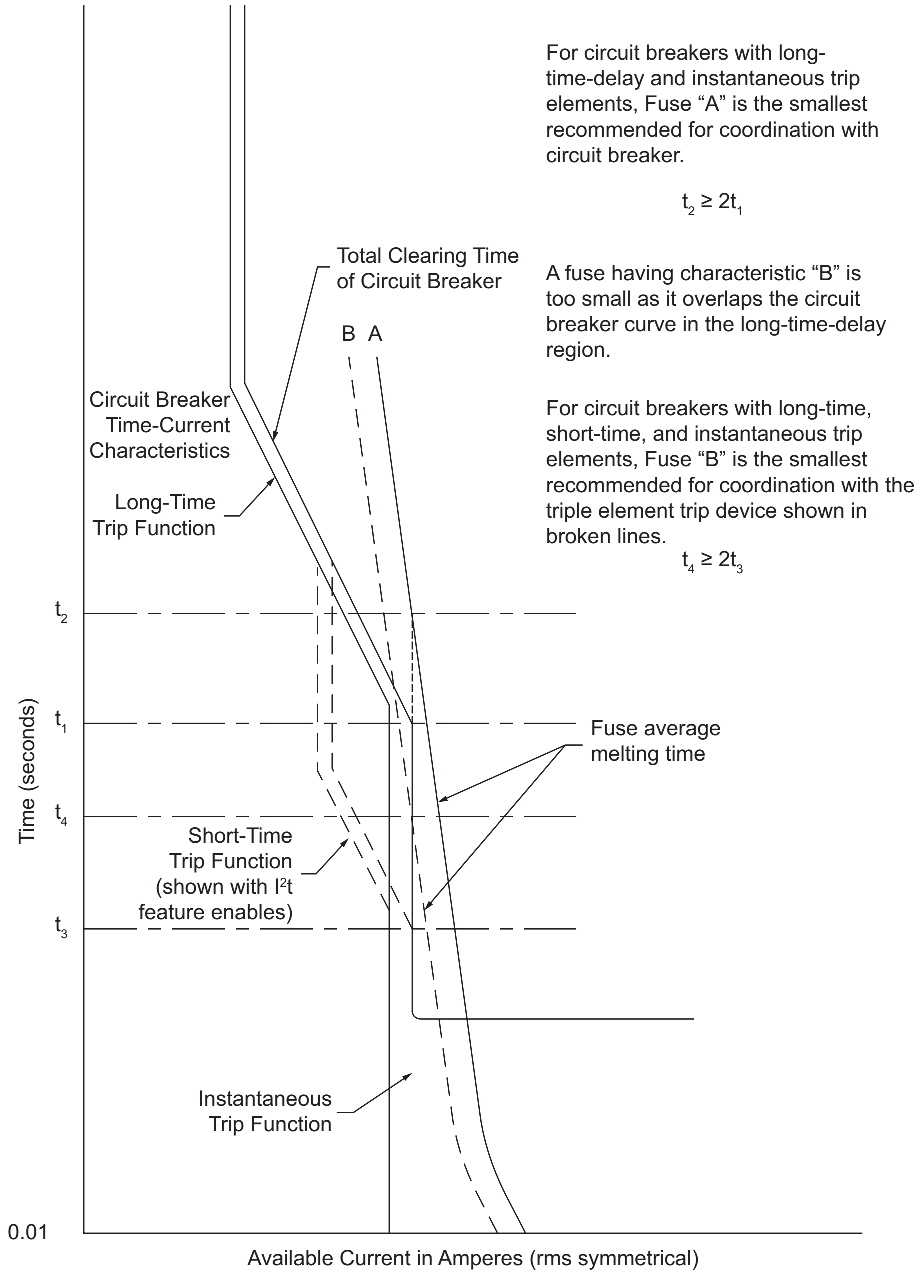


Figure 3—Typical time-current characteristics with minimum fuse rating

6. Location of fuses

It is desirable that the fuse is located on the power source side of the circuit breaker, and the two devices should be located as close to each other as is practical. When conditions prevent this, the installation should be arranged so as to minimize the chances of a fault occurring between the circuit breaker and fuse.

Access to the separately mounted fuses shall meet the requirements stated in IEEE Std C37.20.1.

7. Open-fuse trip devices

Low-voltage nonintegrally fused power circuit breakers are equipped with open-fuse trip devices. The open-fuse trip device may be located either on the circuit breaker frame or with the fuses.

After operating, the device prevents closing of the circuit breaker until a reset operation is performed.

Since some open-fuse trip devices may operate by sensing the voltage across the fuses, if they are reset with an open or missing fuse, they may not prevent closing of the circuit breaker. In most cases, if this type of operation is performed it results in an immediate trip. There is a practical limit of load impedance above which the device (sensing voltage across an open or missing fuse) cannot function as described.

8. Addition or substitution of fuses in existing installations

Applications arise where it is desirable to add fuses in combination with circuit breakers in existing installations. Since these circuit breakers may antedate the rating structure upon which this guide is based, the circuit breaker manufacturer should be consulted.

When fuses of different manufacturers or types are being substituted in existing installations, the characteristics of all the fuses and circuit breakers in the system should be evaluated, since both the melting time current characteristic and peak let-through current of a given fuse rating may vary substantially.

Modifications of existing switchgear equipment are conversions and should be evaluated in accordance with IEEE Std C37.59.

9. Protection of connected equipment

When applied on high short-circuit current capacity systems, the effects of the let-through characteristics of the low-voltage fused power circuit breaker on the connected equipment should be considered. The presence of the current-limiting fuse as part of the fused circuit breaker does not necessarily imply that the connected equipment can adequately withstand these effects. It should be noted that the fused circuit breaker does not have any current limiting effect until the current associated with the fault exceeds the current-limiting threshold of the fuse.

10. Tested combinations of circuit breakers and fuses

It is recognized that the selection of a fuse by the criteria of this standard is conservative. Combinations of fuses and circuit breakers, other than as covered in this guide, may be acceptable when testing of the combination has demonstrated acceptable performance in accordance with ANSI C37.50 or IEEE Std C37.59 as applicable.

Annex A

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

[B1] IEEE Std C37.17™, IEEE Standard for Trip Systems for Low-Voltage (1000 V and below) AC and General Purpose (1500 V and below) DC Power Circuit Breakers.[9,10]

[B2] IEEE Std C37.26™, IEEE Guide for Methods of Power Factor Measurement for Low-Voltage (1000 V AC or lower) Inductive Test Circuits.

[B3] UL 248-8, Low-Voltage Fuses—Part 8: Class J Fuses.

[B4] UL 248-10, Low-Voltage Fuses—Part 10: Class L Fuses.

[B5] UL 248-12, Low-Voltage Fuses—Part 12: Class R Fuses.[11]

[9]IEEE publications are available from The Institute of Electrical and Electronic Engineers, Service Center, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08854, USA http://www.standards.ieee.org/).
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