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Std 320-1972

An American National Standard

IEEE Standard Application Guide for
AC High-Voltage Circuit Breakers
Rated on a Symmetrical Current Basis

Sponsor

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

Approved December 3, 1970

IEEE Standards Committee

Secretariat

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American National Standards Institute

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Foreword

(This Foreword is not a part of IEEE and American National Standard Application Guide for AC High-Voltage Circuit Breakers, IEEE Std 320-1972 (C37.010-1972).

This standard was written as a guide to aid in the selection and application of ac high-voltage circuit breakers on electrical power systems. This guide conforms with American National Standard Rating Structure for AC High-Voltage Circuit Breakers, C37.04-1964 (R 1969) and American National Standard Test Procedure for AC High-Voltage Circuit Breakers, C37.09-1964 (R 1969).

Described in the guide are the general application conditions, application considerations, and short-circuit considerations necessary to apply alternating current breakers. In addition to the short-circuit considerations utilizing a modification of the simplified method previously described in American National Standard Methods for Determining the RMS Value of a Sinusoidal Current Wave and a Normal-Frequency Recovery Voltage and Guide for Calculation of Fault Currents for Application of AC High-Voltage Circuit Breakers Rated on a Total Current Basis, C37.5-1969, a method of calculation that recognizes the effect of ac as well as dc decrements is also presented.

This application guide is one of a series of supplementary American National Standards. The basic material was first published in AIEE Transactions in 1941, was revised from time to time, and is now supplementary to ANSI C37.5-1969.

The following list of American National Standards shows the comparable standards prepared under the total current basis of rating and those prepared under the symmetrical basis of rating (see back cover for complete titles):

Total Current Basis of Rating	Symmetrical Basis of Rating	Specific Subjects Applicable to AC HVCB Rated on a Symmetrical Current Basis
C37.4-1953 (R 1966)	C37.03-1964 (R 1969)	C37.071-1969
	C37.04-1964 (R 1969)	C37.072-1971
C37.5-1969	C37.05-1964 (R 1969)	C37.0721-1971
C37.6-1966	C37.06-1971	C37.0722-1971
C37.7-1960 (R 1966)	C37.07-1969	C37.073-1972
C37.8-1952 (R 1966)		C37.0731
C37.9-1953 (R 1966)	C37.09-1964 (R 1969)	C37.0732-1972
	C37.010-1972	C37.074-1972
	C37.11-1972	C37.076-1972
	C37.12-1969	C37.077
		C37.078-1972
		C37.0781-1972
		C37.079

The standards listed in the right columns are supplementary to those in the left column and do not replace them. When a changeover from the total current basis of rating to the symmetrical basis of rating is effected by the manufacturer, the standards in the left column will be withdrawn.

It is recognized that this changeover program will require time for completion, even though it is anticipated that the manufacturers of circuit breakers will expend efforts to meet the new standards as soon as possible. This depends upon the demand for the various circuit breakers manufactured and the economics involved. Since it will be impractical to revise the various sections of the standards every time a circuit breaker is transferred from the old to the new standards, the users are cautioned to confer with the manufacturers on the status of the various circuit breaker ratings.

The breaker selection factors (E/X multiplying factors) contained in this supplement apply only to breakers rated on the new symmetrical basis, in accordance with American National Standard C37.04-1964, although the fault current calculation procedure described in the Appendix can be made independent of breaker rating structure. To avoid confusion and possible misapplication during the rating changeover period, it is recommended that American National Standard C37.5-1969 be employed for application of those breakers not covered by the new rating structure and continue in use until transfer to the new rating basis occurs.

*The corresponding material is included in American National Standard C37.06-1971.

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An American National Standard

IEEE Standard Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

1. Scope

This application guide applies to ac high-voltage circuit breakers rated in accordance with the methods given in American National Standard Rating Structure for AC High-Voltage Circuit Breakers, C37.04-1964 (R 1969) and listed in American National Standard Preferred Ratings and Related Required Capabilities for AC High-Voltage Circuit Breakers, C37.06-1971. Circuit breakers rated and manufactured to meet other standards, or used in switchgear assemblies, should be applied in accordance with application procedures adapted to their specific ratings or applications.

2. Purpose

This guide is intended for general use in the application of circuit breakers. Familiarity with other American National Standards applying to circuit breakers is assumed, and provisions of those standards are indicated herein only when necessary for clarity in describing application requirements.

3. General Application Conditions

3.1 Usual Service Conditions. Service conditions for circuit breakers are defined in American National Standard C37.04-1964. These conditions specify limits in altitude and in ambient temperature.

3.1.1 Provision for System Growth. Power system facilities must be increased from time to time to serve larger loads. This usually results in higher values of short-circuit current. Therefore, liberal allowance for expected future increase in short-circuit current is advisable.

3.1.2 System Design. Methods of limiting the magnitude of short-circuit currents or reducing

the probability of high-current faults by system design are outside the scope of this guide. Such methods should be considered where short-circuit currents approach the maximum capability of the circuit breakers. Many station design features may depend on available circuit breaker ratings. System design should take into account the necessity for circuit breaker inspection and maintenance.

3.2 Unusual Service Conditions. Unusual service conditions are listed in 04-3.2 of American National Standard C37.04-1964 and include those conditions listed below. Special installation, operation, and maintenance provisions should be considered where these conditions are encountered.

3.2.1 Applications at Altitudes Above 3300 ft (1000 m). Rating corrections for altitudes above 3300 ft (1000 m) are listed in Table 1 of American National Standard C37.04-1964.

EXAMPLE: Consider a circuit breaker having a rated maximum voltage of 38 kV, a continuous current rating of 1200 A, a rated short-circuit current of 7300 A at 38 kV, a maximum symmetrical interrupting capability of 12 000 A, and a rated interrupting time of 5 cycles. Assume that this breaker is to be operated at an altitude of 7000 ft (2100 m). The operating voltage and the normal-frequency recovery voltage should be [interpolating between the values given for 5000 and 10 000 (1500 and 3000 m)]:

$$38 \text{ kV} \left[0.95 - (0.95 - 0.80) \left(\frac{7000 - 5000}{10\,000 - 5000} \right) \right] = 33.8 \text{ kV}$$

Rated withstand voltages should be multiplied by the same factor. The continuous current must be similarly interpolated:

$$1200 \text{ A} \left[0.99 - (0.99 - 0.96) \left(\frac{7000 - 5000}{10\,000 - 5000} \right) \right] = 1174 \text{ A}$$

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

3.2.2 Exposure to Damaging Fumes, Vapor, Steam, Oil Vapors, Salt Air, Hot and Humid Climate.

(1) Provision may be necessary to avoid condensation on all electrical insulation and current-carrying parts

(2) Bushings with extra creep distance may be required

(3) In cases where particular exposure represents a hazard to insulation security, special maintenance including insulator washing may be necessary

(4) Materials resistant to fungus growth may be required

3.2.3 Exposure to Excessive Dust or Abrasive, Magnetic, or Metallic Dust.

(1) Totally enclosed nonventilated equipment or compartments may be necessary

(2) Where current-carrying equipment designed for ventilated operation is enclosed in a nonventilated compartment, derating may be necessary.

3.2.4 Exposure to Explosive Mixtures of Dust or Gases. Standard circuit breakers are not designed for use in explosive atmospheres. For this type of service, special consideration should be given in conjunction with applicable regulatory bodies so that acceptable equipment is selected.

3.2.5 Exposure to Abnormal Vibration, Shock, or Tilting. Standard circuit breakers are designed for mounting on substantially level structures free from excessive vibration, shock, or tilting. Where any of these abnormal conditions exist, recommendations for the particular application should be obtained from the manufacturer.

3.2.6 Seasonal or Infrequent Use. Equipment stored or deenergized for long periods should be protected against accelerated deterioration. Before energizing for service, operating performance and insulation security should be checked.

4. Application Consideration

In the application of circuit breakers to electrical systems, careful attention must be given to many items of technical importance to assure that a misapplication does not occur. In the usual application, the principal function of the circuit breaker is to carry load current and provide a means for the interruption of short-

circuit current. However, it may be used for frequent load, exciting current, or capacitive-current switching. In some cases, switching requirements may be the determining factor in selection rather than the requirements of short-circuit current interruption. Special attention must also be given to applications where frequent operations are essential.

In the selection of a circuit breaker, consideration must be given to the future as well as to the present needs for interrupting capacity and for current-carrying capability. These considerations include the possibility of connected circuit changes, such as additions of supplemental cooling means for transformers or connection of multiple cable or overhead lines to the breaker, or possible future transfer of the circuit breaker from its initial position to some other location.

In the United States, two types of circuit breakers are available for use at most voltage ratings. These types come under the general classification of oil and oilless power circuit breakers, and the preferred ratings available are listed in American National Standard C37.06-1971. The choice of breaker type may be influenced by such considerations as attended versus nonattended operation, contaminated atmosphere, location, maintenance, ease of handling the interrupting medium, and cost of the installation.

4.1 Maximum Voltage for Application. The operating voltage and the normal-frequency recovery voltage should not exceed the rated maximum voltage, since this is the upper limit for operation.

4.2 Voltage Range Factor. The voltage range factor, K , is published in American National Standard C37.06-1971. In most cases, the voltage range is within the range commonly used. (See Section 4.5.1)

4.3 Frequency. Rated frequency for circuit breakers is 60 Hz.

At slightly lower frequencies, such as 50 Hz, the main current-carrying parts will be adequate, but ac control devices may not be suitable for the application.

At 25 Hz, the continuous current ratings in amperes are higher and are listed in American National Standard C37.06-1971.

Interruption of fault currents on systems operating at frequencies other than rated fre-

quency may require modification of mechanisms to change speed of opening or may require a change in interrupting ratings of the circuit breakers.

In any case, special consideration should be given to applications at frequencies differing from 60 Hz.

4.4 Continuous Current. Circuit breakers are designed for normal application where the sustained load current does not exceed the rated continuous current, the altitude above sea level is 3300 ft (1000 m) or less, and the ambient temperature does not exceed 40°C. Rated continuous current of a circuit breaker should not be exceeded except for short periods such as in starting of motors or synchronous condensers or energizing cold loads.

4.4.1 Normal Operation. The conditions to be followed when making an application are:

(1) Breakers designed for installation in enclosures may be so used without any further derating

(2) Breakers designed for use in open rooms and outdoors cannot be used in enclosures without derating so that none of their temperature limits is exceeded

(3) As far as temperature limits are concerned, any high-voltage circuit breaker may be used with cables having an 85°C or lower temperature limit, provided that the temperature limit of the cable insulation is not exceeded. Among the methods of accomplishing this are:

(a) Operate the breaker at a continuous current sufficiently below its rating

(b) Use a section of oversize conductors or a special terminal connector ahead of the cable to reduce the temperature at the cable terminal (See IEEE Std 55-1953, Guide for Temperature Correlation in the Connection of Insulated Wire and Cables to Electric Equipment)

(4) The possible adverse effect on or by closely associated equipment operating at a higher or a lower temperature than the breaker should be examined

(5) It is recognized that when a circuit breaker is properly selected for continuous current operation, it may also be used for starting such equipment as motors, synchronous condensers, and cold loads on an infrequent basis; under this condition, the con-

tinuous current rating may be exceeded without causing damage to the circuit breaker

4.4.2 Rated Continuous Current for Capacitor Banks. When a high-voltage circuit breaker is used in a circuit supplying static capacitors, the continuous current rating should be selected to include the effects of:

(1) Operation at voltages below and up to 10 percent above the capacitor rated voltage

(2) The positive tolerance in capacitance of static capacitors (−0+15 percent)

(3) The additional heating caused by harmonic currents

(4) The effect of grounded or nongrounded neutral connection of the capacitor

In the absence of specific information, it will usually be conservative to use 1.25 times the nominal capacitor current at rated capacitor voltage for nongrounded neutral operation or 1.35 times the nominal current for grounded neutral operation.

4.4.3 Load Current Carrying Capability Under Various Conditions of Ambient Temperature and Load.

4.4.3.1 General. Circuit breakers are designed for normal application in accordance with Sections 04-3.1 and 04-4.4 of American National Standard C37.04-1964, where the sustained load current does not exceed the rated continuous current, the altitude above sea level is 3300 ft (1000 m) or less, and the ambient temperature does not exceed 40°C. The rated continuous current is based on the maximum permissible total temperature limitations of the various parts of the circuit breaker when it is carrying rated current at an ambient temperature of 40°C. The total temperature of these parts under service conditions depends both on the actual load current and the actual ambient temperature. It is therefore possible to operate at a current higher than rated continuous current when the ambient temperature is less than 40°C, provided that the allowable total temperature limit is not exceeded. Similarly, when the ambient temperature is greater than 40°C, the current must be reduced to less than rated continuous current to keep total temperatures within allowable limits.

Operation at a current higher than rated continuous current will usually cause the allowable temperature limitations to be exceeded and should be avoided except in these instances:

(1) For short periods, such as in the starting of motors or synchronous condensers, or when energizing cold loads. Generally, the time duration of this type of current increase is short enough that it does not raise temperatures significantly.

(2) When operating at an ambient temperature below 40°C, as covered in Section 4.4.3.2.

(3) For short periods following operation at a current less than that permitted by the existing ambient temperature, as covered in Section 4.4.3.3.

The method of calculating the allowable current at an ambient temperature above 40°C is given in Section 4.4.3.2. For some high ambient temperature conditions, it may not be practical to reduce current sufficiently to keep the total temperatures within their allowable limits. Forced ventilation will help in many cases. Temperature limits of associated equipment such as cables and current transformers must be considered. Effect of solar radiation must also be considered. (See IEEE Std 144-1971, Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Clad Switchgear (ANSI C37.24-1971).

Where ambient temperature is below the minimum limit of -30°C, special lubricants may be required, and additional heater capacity beyond that normally used should be provided in mechanism enclosures. Whenever freezing temperatures occur, precautions may be necessary to dry the air in pneumatic systems to avoid condensation and freezing.

4.4.3.2 Continuous Load Current Capability Based on Actual Ambient Temperature. The continuous current which a circuit breaker can carry at a given ambient temperature without exceeding its total temperature limitations is given by the formula:

$$I_a = I_r \left(\frac{\theta_{max} - \theta_a}{\theta_r} \right)^{1/1.8}$$

where

I_a = allowable continuous load current, in amperes, at the actual ambient temperature θ_a ; I_a is not to exceed two times I_r)

I_r = rated continuous current, in amperes

θ_{max} = allowable hottest spot total temperature ($\theta_{max} = \theta_r + 40^\circ\text{C}$), in °C

θ_a = actual ambient temperature expected (between -30°C and 60°C), in °C

θ_r = allowable hottest spot temperature rise at rated current, in °C

NOTE: The temperature rise of a current-carrying part is proportional to an exponential value of the current flowing through it. Experience has shown that although the exponent may have different values, depending on breaker design and components within a breaker, it generally is in the range of 1/1.6 to 1/2.0. The exponent value of 1/1.8 represents a compromise that is suitable for this application guide.

The constructional features of a circuit breaker dictate the appropriate values of θ_{max} and θ_r to be used in the calculation. The major components of a circuit breaker have several different temperature limitations which are specified in American National Standards as follows:

Circuit Breaker Component	American National Standard	
	Number	Section
Circuit breaker insulating materials, main contacts, conducting joints, etc	C37.04-1964	04-4.4.2
Bushings	C76.1 -1964 (R1970)	4
Current transformers	C57.13-1968	3.5

The values of temperature limitations specified in these various standards are summarized in Table 1. In order that none of these limitations be exceeded when the load current is adjusted to the value permitted by the actual ambient temperature, the values for θ_{max} and θ_r should be determined as follows:

(1) If the actual ambient is less than 40°C, the component with the highest specified values of allowable temperature limitations should be used for determining θ_{max} and θ_r .

(2) If the actual ambient is greater than 40°C, the component with the lowest specified values of allowable temperature limitations should be used for determining θ_{max} and θ_r .

The use of these values in the calculation will result in an allowable continuous current which will not cause the temperature of any part of the circuit breaker to exceed the permissible limits.

NOTE: Although circuit breakers are designed to carry rated current continuously while exposed to an ambient temperature of 40°C, most circuit breakers in service are subjected to a much less severe ambient temperature condition which varies with time of day and season of year. The average outdoor air temperature during any 24-h period is usually 5 to 10°C lower than the maximum, and the maximum is usually less than 40°C. This is one important reason for the long

Table 1
Summary of Temperature Limitations for
Circuit Breaker Components

Item Number	Component Description	Limit of Temperature Rise, °C θ_r	Limit of Total Temperature, °C θ_{max}
1	Circuit breaker parts handled by the operator in the normal course of his duties	10	50
2	Copper contacts, copper-to-copper conducting joints, external surfaces accessible to the operator in the normal course of his duties, external terminal connected to bushing	30	70
3	Top oil	40	80
4	Breaker terminals to be connected to 85°C insulated cable	45	85
5	Hottest spot temperature of parts where they contact oil; silver (or equal) contacts in oil; silver (or equal) conducting joints in oil	50	90
6	Silver (or equal) contacts in air; silver (or equal) conducting joints in air; hottest spot of bushing conductor or of bushing metal parts in contact with Class A insulation or with oil; hottest spot winding temperature 55°C rise of current transformers.	65	105
7	External surfaces not accessible to an operator in the normal course of his duties	70	110
8	Hottest spot winding temperature of 80°C dry-type current transformers	110	150

life which circuit breakers historically have demonstrated. Continuous operation at rated current and at an ambient temperature of 40°C likely would result in a life somewhat shorter than that usually experienced.

The user is cautioned that this guide is intended to cover situations where the circuit breaker is used at its total temperature limitations infrequently (a few occasions in the expected lifetime), for relatively short periods of time (perhaps a few days).

The manufacturer should be consulted if operation at maximum allowable temperature is required at frequent intervals or over extended periods of time.

It may not be necessary to include the extreme values of highest and lowest allowable temperature limitations, as listed in Table 1, in this determination. The lowest value is for circuit breaker parts handled by the operator in the normal course of his duties, and the highest value generally is for external surfaces of a circuit breaker, not accessible to an operator in the normal course of his duties. In many cases, overheating of these parts beyond the specified allowable limitations will not impair circuit

breaker performance or expected life. If these parts are neglected, a higher value of permissible continuous load current can be obtained from the calculation. In most cases, this higher value of current may safely be used. However, in some circuit breaker designs there may be gaskets or other components located near such inaccessible external surfaces which would be damaged if overheated. The use of 80°C rise dry-type current transformers would place a further limit on the allowable current for operation at an ambient of less than 40°C. Evaluation of the breaker design should be made to determine whether or not these extreme values of temperature limitation should be included. In case of doubt, the manufacturer should be consulted.

Table 2 lists the calculated values of I_a/I_r for each specified temperature limit for the various component parts of the circuit breaker over a range of typical ambient temperatures. The

Table 2
Ratios of (I_a/I_r) for Various Ambient Temperatures

Maximum Ambient Temperature °C	Limiting Temperatures of Different Breaker Components								
	θ_{max}	50	70	80	85	90	105	110	150
	θ_r	10	30	40	45	50	65	70	110
60	—	0.54	0.68	0.72	0.75		0.81	0.82	0.89
50	—	0.79	0.85	0.87	0.88		0.91	0.91	0.95
40		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
30		1.46	1.17	1.13	1.11	1.10	1.08	1.07	1.05
25		1.66	1.25	1.19	1.17	1.15	1.12	1.11	1.08
20		1.84	1.32	1.25	1.22	1.20	1.16	1.15	1.10
10		2.0	1.47	1.36	1.32	1.29	1.23	1.22	1.14
0		2.0	1.60	1.46	1.42	1.38	1.30	1.29	1.19
-10		2.0	1.72	1.56	1.51	1.46	1.37	1.34	1.23
-20		2.0	1.84	1.66	1.60	1.54	1.43	1.41	1.28
-30		2.0	1.95	1.75	1.68	1.61	1.50	1.46	1.32

*For limiting current, use lowest θ_r and θ_{max}

†For limiting current, use highest θ_r and θ_{max}

allowable current in any given situation can be estimated from Table 2 or may be calculated directly from the formula.

EXAMPLE 1: Consider an oil circuit breaker with copper-to-copper contacts, American National Standard bushings, and 55°C rise current transformers. When operating at an ambient temperature of 25°C, the current could be increased by a factor corresponding to the component with the highest temperature rise. In this case, these components are the bushings and the current transformers with a temperature rise limit of 65°C, and according to Table 2, the factor of increase is 1.12 times rated current.

When operating at an ambient temperature of 50°C, the current must be reduced by a factor which corresponds to the component with the lowest temperature limit. In this case, the component is the copper-to-copper contact assembly, with a temperature rise limit of 30°C, and according to Table 2, the reduction factor is 0.79.

EXAMPLE 2: Consider an oil circuit breaker with silver-to-silver contacts, American National Standard bushings, and with 55°C rise current transformers. When the ambient temperature is 25°C, the continuous current can be increased by a factor of 1.12. This factor of increase corresponds to the component with the highest temperature limit, which in this case are the bushings and the current transformers.

If the ambient temperature were 50°C, the reduction factor would be 0.85, corresponding to the component with the lowest temperature limit, which in this case is the top oil.

EXAMPLE 3: Consider an oilless circuit breaker with silver-to-silver contacts, in air, 55°C rise current transformers, and with terminals connected to 85°C insulated cable. When the ambient temperature is 25°C, the current can be increased by a factor of 1.12, corresponding to the temperature rise limitations of 65°C of the silver-to-silver contacts and the current transformers.

If the ambient temperature were 50°C, the reduction factor would be 0.88 corresponding to the temperature rise limitation of 45°C of the connected cable.

Current transformers that form part of a circuit breaker assembly or that are normally considered a part of the breaker installation will usually have heating characteristics similar to those of the circuit breaker. The continuous current permitted by the formula will not cause overheating of a current transformer connected to a ratio tap corresponding to rated current of the circuit breaker. However, if a lower ratio tap is used, the expected secondary current must be evaluated in terms of the continuous thermal rating factor of the current transformer. The effect of the secondary current on apparatus connected to the current transformer terminals should also be considered.

4.4.3.3 Short-Time Load Current Capability. When a circuit breaker has been operating at a current level below its allowable continuous load current I_a , it is possible to increase the load current for a short time to a value greater than the allowable current without exceeding the permissible temperature limitations. The length of time that the short-time load current I_s can be carried depends on these factors:

- (1) The magnitude of current I_s to be carried
- (2) The magnitude of initial current I_i carried prior to application of I_s
- (3) The thermal-time characteristics of the circuit breaker

The time duration of the short-time current may be calculated directly or may be obtained by simple use of Fig. 1 as described below. The