10.2.2.4 Transfer switches

Automatic transfer switches of double-throw construction are primarily used for emergency and standby power generation systems rated 600 V and less. These transfer switches do not normally incorporate overcurrent protection and are designed and applied in accordance with ANSI/NFPA 110-1993 [B16] and the NEC [B15], particularly Articles 230, 517, 700, 701, and 702. They are available in ratings from 30–4000 A. For reliability, most automatic transfer switches rated above 100 A are mechanically held and are electrically operated from the power source to which the load is to be transferred.

These switches are applied to provide protection against failure of the normal service. The transfer switch's control logic usually includes full-phase close differential voltage sensing of the normal source, voltage and frequency sensing of the emergency source, time delays for programmed operation, and in-phase monitoring for motor load transfer. In addition to utility failures, continuity of power to critical loads can also be disrupted by the following:

a) An open circuit within the building area on the load side of the incoming service
b) Overload or fault conditions
c) Electrical or mechanical failure of the electric power distribution system within the building

Therefore, many engineers advocate the use of lower-current-rated transfer switches located near the load rather than one large transfer switch at the point of incoming service. For critical applications, where load interruptions must be minimized, transfer switches are available with built-in bypass/isolation switches to enable maintenance without any load interruption. Other types provide closed transition operation to momentarily parallel the sources for load transfer without interruption. For additional information, see IEEE Std 446-1987 [B41].

10.2.3 Fuses

10.2.3.1 Types and rating basis

A fuse is an overcurrent-protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent through it. Fuses are available in a wide range of voltage, current, and interrupting ratings, current-limiting types, and for indoor and outdoor applications.

Fuses rated greater than 600 V have an interrupting capability based on asymmetrical current, although their published ratings are expressed in symmetrical amperes. Current-limiting fuses interrupt a short circuit within the first half-cycle, and their equivalent asymmetrical rating includes a 1.6 multiplier to provide for the maximum expected current asymmetry.

Standard fuses without current-limiting capabilities are widely applied above 600 V. They are generally available in higher current ratings, but lower interrupting ratings, than current-limiting fuses.

Fuse ratings for 600 V and below are also published as symmetrical current values. These current-limiting fuses are extremely fast in operation at very high values of fault current, and act to limit the current in less than one-quarter cycle to a value well below the available peak short-circuit current. Several types of current-limiting fuses for 600 V and below are now available for ac service with interrupting ratings as high as 300 000 A rms symmetrical. For more information on fuses, see Chapter 5.

10.2.3.2 Application considerations

There is no general rule for deciding whether to use fuses or a circuit breaker. The designer's decision should be based on the demands of the particular application. The following considerations may be of assistance to the designer:

a) *Interrupting ratings*. Current-limiting fuses with 300 000 A rms symmetrical ratings are available for 600 V and below applications.
b) *Component protection*
    1) Current-limiting fuses permit minimal short-circuit current let-throughs, thus minimizing damage to lower interrupting capacity-rated and withstand-rated components.
    2) Current-limiting fuses can cause transient voltages in clearing faults that may be detrimental to the system components, such as motors, surge arresters, etc. However, techniques are available to determine the suitability of equipment during the engineering phase.
    3) Fuses, in conjunction with shunt-trip switches and ground-fault sensing systems, can provide sensitive protection.
c) *Selective coordination*. Fuse time–current clearing curves are accurate, and fuses' characteristics usually do not change over time. Selective coordination can be achieved by referring to manufacturers' published fuse ratio charts. By adhering to these recommended ratios and exercising sound engineering judgment, coordination between different types of protective devices can be achieved. Also, protective coordination studies may be done on computers. Protective coordination software exists which contains libraries of fuse manufacturers' curves and other protective devices.
d) *Space requirements*. Fusible switching devices require more space than circuit breakers.
e) *Economics*. Initial capital cost and maintenance costs are lower for fusible equipment.
f) *Automatic switching*. Fuses alone are not capable of automatic switching, but can be installed in suitable shunt-trip equipped switches to provide this service. Care must be exercised in applying a shunt-tripped switch. If the shunt-trip is actuated by a protective or phase failure relay, the switch must be capable of interrupting the fault duty to which it may be subjected.

10.2.4 Circuit breakers

A circuit breaker is a device designed to open and close a circuit by nonautomatic means, and to open the circuit automatically on a predetermined overload of current without damage to itself when properly applied within its rating. Circuit breakers are required to operate infrequently, although some classes of circuit breakers are suitable for more frequent operation. The interrupting and momentary ratings of a circuit breaker must be equal to or greater than the available system short-circuit currents.

To provide essential switching flexibility and circuit protection, power circuit breakers are used on medium- and low-voltage systems of utility and industrial distribution circuits.

Circuit breakers are available for the entire voltage range. They may be furnished single-, double-, triple-, or four-pole, and arranged for indoor or outdoor use. SF_6 gas-insulated circuit breakers are available for medium and high voltages, such as gas-insulated substations.

10.2.4.1 Circuit breakers over 600 V

The close-and-latch rating and current-interrupting capabilities are very important factors for use in the application of circuit breakers over 600 V. The close-and-latch capability is a measure of the equipment's ability to withstand the mechanical stresses produced by the asymmetrical short-circuit current during the first cycle without mechanical damage, and is normally expressed as total rms current. An asymmetrical current consists of a dc component superimposed on an ac component. The dc component decays with time, depending upon the resistance and reactance, or the *X*/*R* ratio of the circuit. The initial value of the dc component of the short-circuit current depends on the point of the normal voltage wave at which the fault occurs. The procedure to be used for short-circuit selection of power circuit breakers in the over 600 V class is covered in Chapter 5. Application data can be found in IEEE Std C37.010-1979 [B18].

For the rating of power circuit breakers in the over 600 V class, refer to IEEE Std C37.06-1987 [B1]. Circuit breakers currently being manufactured are rated on the symmetrical basis. In specifying these circuit breakers, consideration should be given to the related values and required capabilities listed as headings in tables 10-2(a) and 10-2(b). These tables list preferred ratings for indoor oilless circuit breakers. These ratings are applicable for service at altitudes up to 3300 ft. For service beyond 3300 ft, derating factors must be applied in accordance with IEEE Std C37.04-1979 [B21].

Power circuit breakers used for applications through 15 kV have been predominantly of the air-magnetic type; however, vacuum and SF_6 types are now used almost exclusively for new installations. For voltages above 15 kV, the available types of circuit breakers include oil, compressed air or gas, and vacuum interrupters. In general, vacuum power circuit breakers are applied in accordance with the specific continuous and short-circuit current requirements in the same manner as air-magnetic power circuit breakers. However, under certain conditions vacuum interrupters have characteristics that are different from air-magnetic power circuit breakers. Vacuum interrupters will sometimes, in special applications, force a premature current zero by opening ("chopping") the circuit in an unusually short time. When this occurs, a higher than normal transient recovery voltage occurs that can be of a magnitude that will impose excessive dielectric stress on the connected equipment. In some equipment, this magnitude may be greater than the basic impulse insulation level of any connected device, and failure may result.

Table 10-2(a)—Preferred ratings for indoor oilless circuit breakers

Rated maximum voltage (1) (kV, rms)	Rated voltage range factor K (2)	Rated continuous current at 60 Hz (3) (amperes, rms)	Rated short-circuit current* (at rated maximum kV) (4) (5) (6) (9) (kA, rms)	Rated interrupting time (7) (cycles)	Rated maximum voltage divided by K (kV, rms)	Maximum symmetrical interrupting capability and rated short-time current (4) (5) (8) (kA, rms)	Closing and latching capability 2.7K times rated short-circuit current (4) (kA, crest)
4.76	1.36	1200	8.8	5	3.5	12	32
4.76	1.24	1200, 2000	29	5	3.85	36	97
4.76	1.19	1200, 2000, 3000	41	5	4.0	49	132
8.25	1.25	1200, 2000	33	5	6.6	41	111
15.0	1.30	1200	18	5	11.5	23	62
15.0	1.30	1200, 2000	28	5	11.5	36	97
15.0	1.30	1200, 2000, 3000	37	5	11.5	48	130
38.0	1.65	1200, 2000, 3000	21	5	23.0	35	95
38.0	1.0	1200, 3000	40	5	38.0	40	108

Source: Based on ANSI C37.06-1987 [B1].

*For the related required capabilities associated with the rated short-circuit current of the circuit breaker, see Note 4.

NOTES—Numbers in parentheses in the tables refer to the following correspondingly numbered notes:

For service conditions, definitions, and interpretation of ratings, tests, and qualifying terms, see IEEE Std C37.04-1979, IEEE Std C37.09-1979, and IEEE Std C37.100-1981.

The interrupting ratings are for 60 Hz systems. Applications on 25 Hz systems should receive special consideration.

Current values have been rounded off to the nearest kiloampere (kA) except that two significant figures are used for values below 10 kA.

(1) The voltage rating is based on ANSI C84.1-1989, where applicable, and is the maximum voltage for which the breaker is designed and the upper limit for operation.

(2) The rated voltage range factor, *K*, is the ratio of rated maximum voltage to the lower limit of the range of operating voltage in which the required symmetrical and asymmetrical current interrupting capabilities vary in inverse proportion to the operating voltage.

(3) The 25 Hz continuous current ratings in amperes are given herewith following the respective 60 Hz rating: 600–700; 1200–1400; 2000–2250; 3000–3500.

(4) Related Required Capabilities. The following related required capabilities are associated with the short-circuit current rating of the circuit breaker.

(a) Maximum symmetrical interrupting capability (kA, rms) of the circuit breaker is equal to *K* times rated short-circuit current.

(b) 3 s short-time current-carrying capability (kA, rms) of the circuit breaker is equal to *K* times rated short-circuit current.

(c) Closing and latching capability (kA, rms) of the circuit breaker is equal to 1.6 *K* times rated short-circuit current. If expressed in peak amperes, the value is equal to 2.7 *K* times rated short-circuit current.

(d) 3 s short-time current-carrying capability and closing and latching capability are independent of operating voltage up to and including rated maximum voltage.

(5) To obtain the required symmetrical current interrupting capability of a circuit breaker at an operating voltage between 1/*K* times rated maximum voltage and rated maximum voltage, the following formula shall be used:

$$\text{Required symmetrical current interrupting capability} = \text{rated short-circuit current} \cdot \frac{\text{(rated maximum voltage)}}{\text{(operating voltage)}}$$

For operating voltages below 1/*K* times rated maximum voltage, the required symmetrical current interrupting the circuit breaker shall be equal to *K* times rated short-circuit current.

Table 10-2(a)—Preferred ratings for indoor oilless circuit breakers (continued)

(6) With the limitation stated in 5.10 of IEEE Std C37.04-1979, all values apply for polyphase and line-to-line faults. For single phase-to-ground faults, the specific conditions stated in 5.10.2.3 of IEEE Std C37.04-1979 apply.

(7) The ratings in this column are on a 60 Hz basis and are the maximum time interval to be expected during a breaker opening operation between the instant of energizing the trip circuit and interruption of the main circuit on the primary arcing contacts under certain specified conditions as specified in 5.7 of IEEE Std C37.04-1979.

(8) Current values in this column are not to be exceeded even for operating voltages below $1/K$ times rated maximum voltage. For voltages between rated maximum voltage and $1/K$ times rated maximum voltage, follow (5) above.

(9) Rated permissible tripping delay time (Y) = 2 s.

(10) The rated values for T_2 are not standardized for indoor oilless circuit breakers; however, E_2 = 1.88 times rated maximum voltage; E_2 = transient recovery voltage; T_2 = rated time to point P μs.

Table 10-2(b)—Preferred capacitance current switching ratings for indoor oilless circuit breakers

			General-purpose circuit breakers rated capacitance switching current (1) (2)		Definite-purpose circuit breakers rated capacitance switching current (2)				
				Shunt capacitor bank or cable		Shunt capacitor bank or cable	Back-to-back	Inrush current (4)	
Rated maximum voltage (kV, rms)	Rated short-circuit current (kA, rms)	Rated continuous current (3) (amperes, rms)	Overhead line current (amperes, rms)	Isolated current (3) (amperes, rms)	Overhead line current (amperes, rms)	Isolated current (3) (amperes, rms)	Current (3) (amperes, rms)	Peak current (kA)	Frequency (Hz)
4.76	8.8	1200	1	400	1	630	630	15	2000
4.76	29	1200	1	400	1	630	630	15	2000
4.76	29	2000	1	400	1	1000	1000	15	1270
4.76	41	1200, 2000	1	400	1	630	630	15	2000
4.76	41	3000	1	400	1	1000	1000	15	1270
8.25	33	1200	1	250	1	630	630	15	2000
8.25	33	2000	1	250	1	1000	1000	15	1270
15.0	18	1200	2	250	2	630	630	15	2000
15.0	18	2000	2	250	2	1000	1000	15	1270
15.0	28	1200	2	250	2	630	630	15	2000
15.0	28	2000	2	250	2	1000	1000	15	1270
15.0	37	1200	2	250	2	630	630	15	2000
15.0	37	2000	2	250	2	1000	1000	18	2400
15.0	37	3000	2	250	2	1600	1600	25	1330
38.0	21	1200, 2000, 3000	5	50	5	250	250	18	6000
38.0	40	1200, 3000	5	50	5	250	250	25	8480

Source: Based on ANSI C37.06-1987 [B1].

NOTES—Numbers in parentheses in the tables refer to the following correspondingly numbered notes:.

(1) No ratings for back-to-back shunt capacitor bank or cable switching applications are established for general-purpose circuit breakers. The shunt capacitor bank or cable shall be electrically isolated as defined in 5.13.2 of IEEE Std C37.04-1979.

Table 10-2(b)—Preferred capacitance current switching ratings for indoor oilless circuit breakers (continued)

For general-purpose circuit breakers exposed to transient inrush currents from nearby capacitor banks during fault conditions, the capacitance transient inrush peak current on closing shall not exceed the lower of either $\sqrt{2} \cdot K \cdot$ rated short-circuit current ($\sqrt{2} \cdot K \cdot 1$), or 50 000 peak A. The product of transient inrush current peak and transient inrush current frequency shall not exceed $2 \cdot 10^7$. The service capability and circuit breaker condition for this duty shall be as specified in IEEE Std C37.04-1979, 5.10.3.3. For reference, see IEEE Std C37.012-1979, 4.10.2.

(2) The capacitance switching current ratings are the highest values that the circuit breaker shall be required to switch at any voltage up to rated maximum voltage.

(3) When applied on shunt capacitor banks, the current rating shall be selected to include the effects of a positive tolerance in capacitance, system and capacitor bank grounding, and additional current magnitude and heating due to harmonics.

(4) The rated transient inrush current peak is the highest magnitude that the circuit breaker shall be required to close at any voltage up to the rated maximum voltage, and shall be as determined by the system and unmodified by the circuit breaker. The rated transient inrush current frequency is the natural frequency that the circuit breaker shall be required to close at 100% of its rated back-to-back shunt capacitor bank or cable switching current.

For application at less than 100% of rating, the product of the inrush current peak and natural frequency shall not exceed the product of the rated transient current peak and the rated transient inrush current frequency. (This product defines a maximum rate of change of inrush current and a minimum inductance between the banks or cables.)

When applying vacuum power circuit breakers, the following precautions should be taken:

a) *Switching unloaded transformers*. When switching power transformers that are unloaded, that is, interrupting just the small magnetizing current on an infrequent basis (less than 50 operations per year), and where the basic impulse insulation level is 95 kV or higher, no special attention is required. However, should either a dry-type transformer be involved with less than a 95 kV basic impulse insulation level rating, or all switching be highly repetitive, then the applications should be checked with the transformer manufacturer.

b) *Switching loaded transformers*. When a power transformer has a permanently connected load in kilovoltamperes of 5% or more of its nameplate rating, no special consideration is needed.

c) *Switching motors*. When vacuum power circuit breakers are utilized to switch motors, the standard rotating-machine protection package of capacitors and surge arresters should be considered, if required by the manufacturer's design.

Although *transient recovery voltage* (TRV) parameters have yet to be established for indoor types of circuit breakers, they remain an important consideration for proper application. Transformer-limited faults and air-core reactors are known to produce TRV stress exceeding TRV limits established for outdoor types of circuit breakers. Vacuum circuit breakers are typically less sensitive to excessive TRV stress. SF_6-type units typically meet requirements for outdoor service. Circuits shall meet the TRV requirements as established by IEEE Std C37.04-1979 [B21] and ANSI C37.06-1987 [B1]. For guidance, consult IEEE Std C37.011-1979 [B19] and the circuit breaker manufacturer.

10.2.4.2 Circuit breakers of 600 V and below

Circuit breakers rated 600 V and below are divided into two basic classes and three types:

Classifications:

a) Low-voltage power circuit breaker class
b) Molded-case circuit breaker class

Types: The first two types are derived from the above classifications. The third type offers features from both the first and the second class.

a) Low-voltage power circuit breakers (LVPCBs)
b) Molded-case circuit breakers (MCCBs)
c) Insulated-case circuit breakers (ICCBs)

Low-voltage power circuit breakers (LVPCBs). Power circuit breakers of 600 V and below are open-construction assemblies on metal frames with all parts designed for accessible maintenance, repair, and ease of replacement. They are intended for service in switchgear compartments or other enclosures of dead-front construction. Tripping units are field-adjustable over a wide range and are interchangeable within their frame sizes. The tripping units used are the electromagnetic overcurrent direct-acting type, solid-state type, and microprocessor-based units with various selectivity and additional monitoring capabilities.

These types of breakers can be used with integral current-limiting fuses in drawout construction to meet interrupting current requirements up to 200 000 A rms symmetrical. When part of the circuit breaker, the fuses are combined with an integral-mounted open-fuse trip device to prevent single-phasing if one fuse should blow.

In current designs of air circuit breakers of 600 V and below, contacts often begin to part during the first cycle of short-circuit current but have a multicycle total clearing time. Consequently, these breakers should be designed to interrupt the maximum available quarter-cycle asymmetrical current. However, since air circuit breakers of 600 V and below are rated on a symmetrical current basis, the need for applying dc offset multipliers to determine their interrupting ratings is eliminated provided they are applied at a system location where the X/R ratio is equal to or lower than the X/R ratios at which they are tested. (Note that caution should be applied when these air circuit breakers are supplied with short-time delay trips because increases in short-circuit stress on the breaker could result in both a lower breaker interrupting capacity rating and extensive equipment damage from exceeding withstand ratings. Manufacturers' literature should be consulted.)

Power circuit breakers 600 V and below can be applied on a symmetrical basis to its name plate rating up to X/R ratios of 6.6 for unfused breakers and up to X/R ratios of 4.9 for fused breakers. Power circuit breakers may be applied to systems with higher X/R ratios when applied in accordance with the application information provided in 10.1.4.3 of IEEE Std C37.13-1990 [B22].

Power circuit breakers are designed for periodic planned maintenance. This design permits higher endurance ratings and repetitive duty capabilities and some basis for a broader range of applications.

Molded-case circuit breakers (MCCBs). A molded-case circuit breaker (NEMA AB 1-1986 [B43]) is a switching device and an automatic protective device assembled in an integral housing of insulating material. These breakers are generally capable of clearing a fault more rapidly than power circuit breakers and are available in the following general types:

a) *Thermal magnetic*. This type employs thermal tripping for overloads and instantaneous magnetic tripping for short circuits. These are the most widely applicable molded-case circuit breakers.
b) *Magnetic*. This type employs only instantaneous magnetic tripping where only short-circuit interruption is required. The NEC [B15] recognizes adjustable magnetic types for motor circuit protection.
c) *Integrally fused*. This type combines regular thermal magnetic protection against overloads and lower value short-circuit faults with current-limiting fuses responding to higher short-circuit currents. Interlocks are provided to ensure safe and proper operation.
d) *High interruption rating*. This fuseless type provides interrupting capabilities for higher short-circuit currents than do standard constructed thermal magnetic circuit breakers. This line incorporates sturdier construction of contacts and mechanism, plus a special high-impact molded casing.
e) *Current-limiting*. This type provides high interruption rating protection, plus it limits let-through current and energy to a value significantly lower than the corresponding value for a conventional molded-case circuit breaker. Clearing time is also limited, and restoration of service is possible by resetting without replacement of any fusible elements or other parts.

With the advent of electronic trip devices being incorporated into molded-cased circuit breakers, the possibility for coordination with power circuit breakers is improved, but requires close scrutiny for proper application. Molded-case circuit breakers have an instantaneous override even when they are set on short-time delay. When a load-side (downstream) circuit breaker sees a large fault, not only will it trip, but if the fault exceeds the instantaneous setting of the line-side (upstream) circuit breaker, it will also trip. For system integrity, care must be exercised to ensure that coordination is maintained with line-side (upstream) devices and that load-side (downstream) equipment withstand ratings are not exceeded.

Molded-case circuit breakers generally are not designed to be maintained in the field as are power circuit breakers. Many molded-case breakers are sealed to prevent tampering, thereby precluding inspection of the contacts. In addition, replacement parts are not generally available. Manufacturers recommend total replacement of the molded-case circuit breaker if a defect appears, or if the unit begins to overheat. Molded-case circuit breakers, particularly the larger sizes, are not suitable for repetitive switching. Maintenance should be performed upon molded-case circuit breakers after they experience a fault which was near its interruption rating. It is important to recognize that differences in test criteria between power circuit breakers and molded-case circuit breakers can be significant in the application of circuit breakers at or near their interrupting rating. A combination of circumstances can reduce the performance of molded-case circuit breakers to less than adequate if they are applied at or near their interrupting rating on a par with power circuit breakers.

Insulated-case circuit breakers (ICCBs). Insulated-case circuit breakers utilize characteristics of design from both power- and molded-case types. The frame size of this type of breaker is larger than the frame size for molded-case breakers. The trip unit can be interchanged, and the breakers can be designed for fix-mounting as well as with drawout configuration. The interruption duty of this type of breaker can be faster than that of molded-case breakers. In general, interruption of ICCBs is not fast enough to be a current-limiting type. Insulated-case circuit breakers are partially field-maintainable. The circuit breaker must be capable of closing, carrying, and interrupting the highest fault current within its rating at that location. It is essential to select a circuit breaker whose interrupting rating at the circuit voltage is equal to or greater than the available short-circuit current at the point of installation. The procedure to be used for selection of power circuit breakers of 600 V and below with the proper interrupting rating is covered in Chapter 6.

Manufacturers' publications give specific information on mechanical and electrical features of circuit breakers 600 V and below. Refer to IEEE Std C37.13-1990 [B22], ANSI C37.16-1988 [B2], and tables 10-3 and 10-4 for lists of standard ratings for 600 V and below circuit breakers. For service at altitudes above 6600 ft above sea level, derating factors must be applied in accordance with IEEE Std C37.13-1990 [B22].

Unusual service conditions, as defined in IEEE Std C37.04-1979 [B21] and IEEE Std C37.13-1990 [B22], should be considered when applying power circuit breakers. Such conditions should be brought to the attention of the circuit breaker manufacturer at the earliest possible time.

10.2.5 Service protectors

A service protector consists of a current-limiting fuse and nonautomatic circuit-breaker-type switching device in a single enclosure. Stored energy operation provides for manual or electrical closing. The service protector, utilizing basic circuit-breaker principles, permits frequent repetitive operation under normal and abnormal current conditions up to 12 times the device's continuous-current rating. In combination with current-limiting fuses, it is capable of closing and latching against fault currents up to 200000 A rms symmetrical. During fault interruption, the service protector will withstand the stresses created by the let-through current of the fuses.

Service protectors are available at continuous-current ratings of 800, 1200, 1600, 2000, 3000, 4000, 5000, and 6000 A for use on 240 and 480 Vac systems, in two-pole and three-pole construction. An open-fuse trip device, which prevents the occurrence of single phasing after a fuse opening, is included in the design of the service protector.

Table 10-3—Preferred ratings for low-voltage ac power circuit breakers with instantaneous direct-acting phase trip elements

Line no.	System nominal voltage (volts) Col. 1	Rated maximum voltage (volts) Col. 2	Insulation (dielectric) withstand (volts) Col. 3	Three-phase short-circuit current rating (symmetrical amperes)* Col. 4	Frame size (amperes) Col. 5	Range of trip-device current ratings (amperes) Col. 6
1	600	635	2200	14 000	225	40–225
2	600	635	2200	22 000	600	40–600
3	600	635	2200	22 000	800	100–800
4	600	635	2200	42 000	1600	200–1600
5	600	635	2200	42 000	2000	200–2000
6	600	635	2200	65 000	3000	2000–3000
7	600	635	2200	65 000	3200	2000–3200
8	600	635	2200	85 000	4000	4000
9	480	508	2200	22 000	225	40–225
10	480	508	2200	30 000	600	100–600
11	480	508	2200	30 000	800	100–800
12	480	508	2200	50 000	1600	400–1600
13	480	508	2200	50 000	2000	400–2000
14	480	508	2200	65 000	3000	2000–3000
15	480	508	2200	65 000	3200	2000–3200
16	480	508	2200	85 000	4000	4000
17	240	254	2200	25 000	225	40–225
18	240	254	2200	42 000	600	150–600
19	240	254	2200	42 000	800	150–800
20	240	254	2200	65 000	1600	600–1600
21	240	254	2200	65 000	2000	600–2000
22	240	254	2200	85 000	3000	2000–3000
23	240	254	2200	85 000	3200	2000–3200
24	240	254	2200	130 000	4000	4000

Source: Based on data taken from IEEE Std C37.13-1981 [B22].

NOTE—Trip devices for both overcurrent and ground-fault protection are readily available from most manufacturers, although the trip ranges given here are based on electromechanical direct or indirect acting types. The manufacturer should be consulted relative to electronic trip characteristics. Electronic trip devices provide many advantages over conventional types and their use should be seriously considered. A major advantage is the inherent provision for sensitive ground-fault protection. For further discussion and trip characteristic curves, see Chapter 5. Particular attention must be given to coordination of load-side fuse devices with instantaneous trip devices of circuit breakers.

*Ratings in this column are rms symmetrical values for single-phase (2-pole) circuit breakers and three-phase average rms symmetrical values of three-phase (3-pole) circuit breakers. When applied on systems where rated maximum voltage may appear across a single pole, the short-circuit current ratings are 87% of these values. See IEEE Std C37.13-1981 [B22], 5.6.