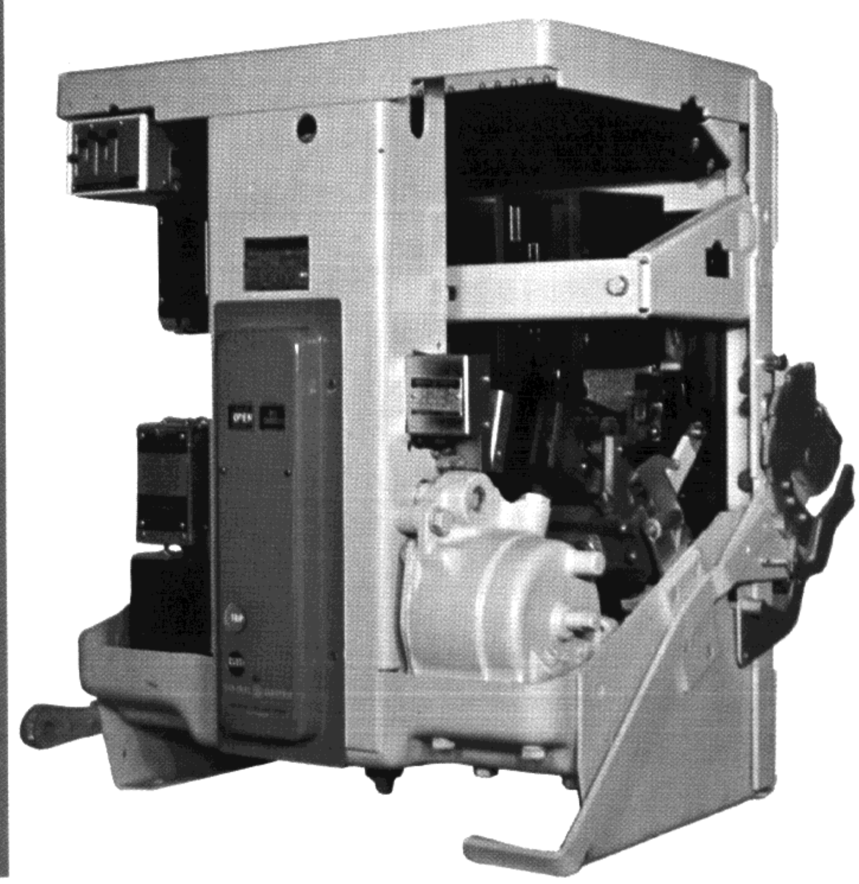
GEA-8733

Selection and Application of

Low Voltage Power Circuit Breakers

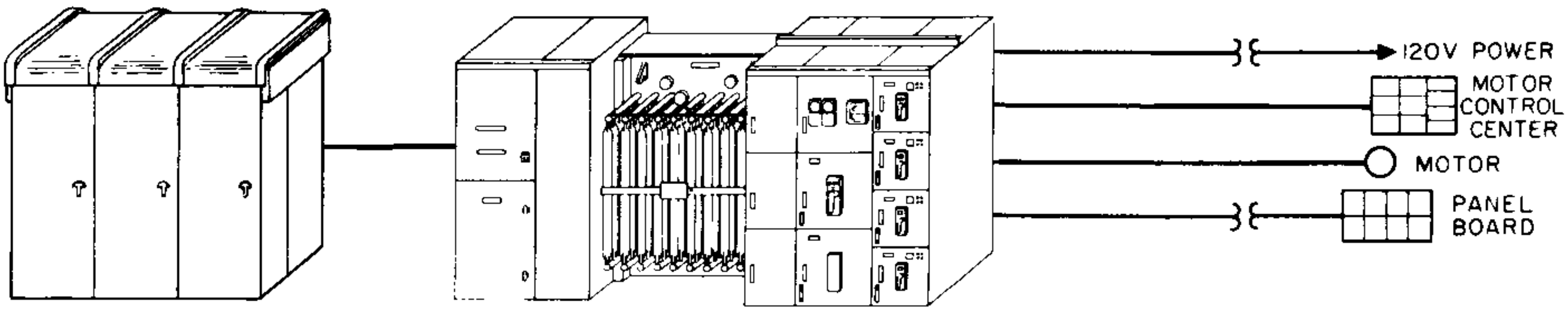


featuring

- —A-C application to 600V
- —Current rating through 4000 amps
- —D-C application to 500V
- —Electro mechanical trips
- —Fuse breaker applications
- —Power Sensor solid-state trips

GENERAL ELECTRIC

Application Information



Co-ordinated system provides best possible combination of continuous power, continuous protection

The highest degree of service reliability can be secured by the careful selection of main and feeder circuit breaker time-current characteristics with proper relation to one another. This is what is meant by circuit breaker co-ordination.

Electrical distribution systems—no matter how carefully constructed and thoroughly insulated—can have faults. With proper co-ordination, it is possible to protect the system from unnecessary downtime caused by faults. This is achieved by matching the characteristics of protective devices from the power source to utilization in order to achieve the highest degree of service reliability. This co-ordination is provided in addition to proper mechanical design of the equipment, insulation levels, thermal capacity and short-circuit bracing. Coordinated, the system provides the most desirable combination of continuous power and continuous protection.

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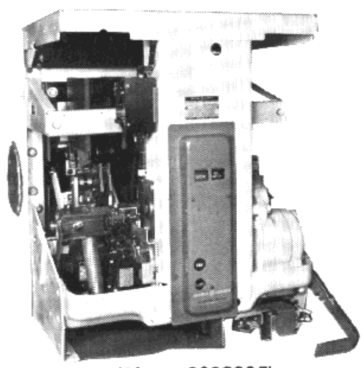
FOREWORD

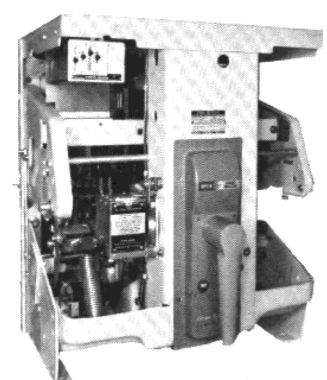
The selection of power circuit breakers for the protection of low-voltage circuits is similar to the problem of selecting other types of electrical equipment. To be properly applied, a circuit breaker should be suited to the power system on which it is to be used; it should be able to withstand the service conditions to be encountered, and should provide the necessary overcurrent protection either by itself or in co-ordination with other protective devices.

Most of the factors pertaining to the characteristics of the power system and the service conditions under which the breakers will operate will be obvious by inspection. One exception to this is the value of the maximum available short-circuit current which the breakers must interrupt. This must be determined either by calculation or with assistance from the local power company. The characteristics of the load to be supplied and the coordination required with other breakers in the system, dictate the type of overcurrent trip devices which should be selected for a particular breaker.

The material in this section is intended to assist in the selection of general-purpose low-voltage power circuit breakers and their trip devices as recommended by the NEMA Standards. A summary of breaker types and ratings is given in Table I.



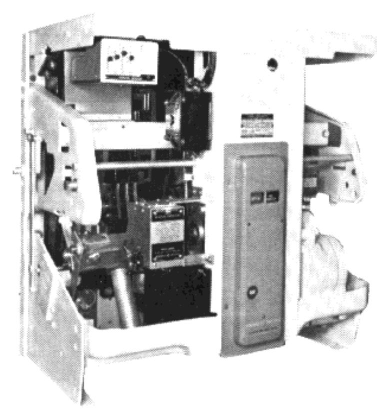
(Photo 8039335)
Fig. 3. AK-2-50



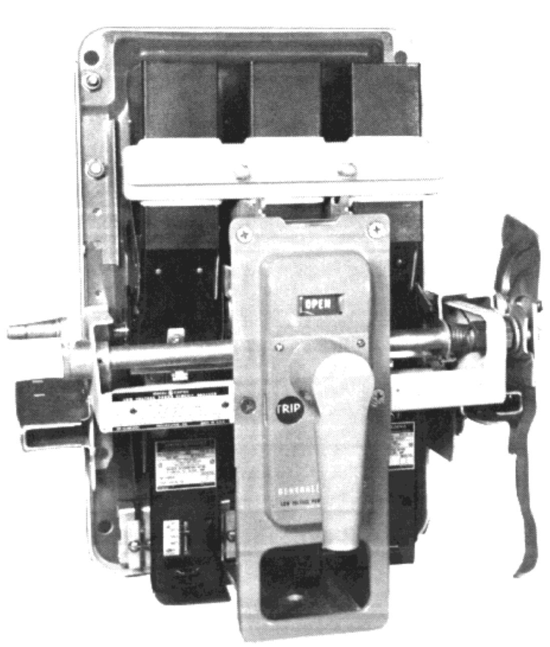
(Photo 8039338)
Fig. 4. AK-3A-75

TABLE I—Summary of Breaker Types, Ratings

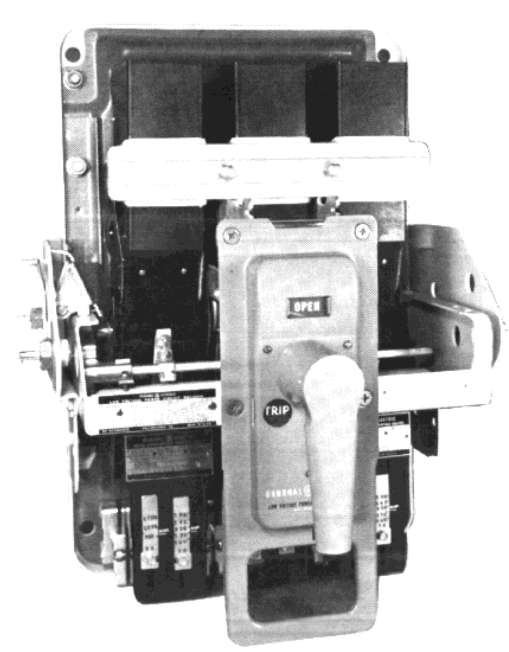
G-E Breaker Type	Voltage Rating 60 Cycles A-c	Interrupting Rating in Amperes, RMS Symmetrical		Overcurrent Trip Device Rating					Short-time Rating Symmetrical Amperes	Short Circuit Limit for 2-step Cascade Operation Amperes RMS Symmetrical
		With Inst. Trips	Without Inst. Trips	Min. with Instantaneous Characteristic	Min. with 2C Short-time Characteristic	Min. with 2B Short-time Characteristic	Min. with 2A Short-time Characteristic	Max. Breaker Rating		
AK-15		14,000	9,000	15	100	125	150	225	9,000	25,000
AK-25		22,000	22,000	40	175	200	250	600	22,000	42,000
AK-50	600	42,000	42,000	200	350	400	500	1600	42,000	85,000
AKT-50		42,000	42,000	200	350	400	500	2000	42,000	85,000
AK-75		65,000	65,000	2000	2000	2000	2000	3000	65,000	85,000
AK-100		85,000	85,000	2000	2000	2000	2000	4000	85,000	85,000
AK-15		22,000	9,000	20	100	125	150	225	9,000	42,000
AK-25		30,000	22,000	100	175	200	250	600	22,000	60,000
AK-50	480	50,000	50,000	400	350	400	500	1600	50,000	85,000
AKT-50		50,000	50,000	400	330	400	500	2000	50,000	85,000
AK-75		65,000	65,000	2000	2000	2000	2000	3000	65,000	85,000
AK-100		85,000	85,000	2000	2000	2000	2000	4000	85,000	85,000
AK-15		25,000	9,000	30	100	125	150	225	9,000	50,000
AK-25		42,000	22,000	150	175	200	250	600	22,000	85,000
AK-50	240	65,000	50,000	600	350	400	500	1600	50,000	100,000
AKT-50		65,000	50,000	600	350	400	500	2000	50,000	100,000
AK-75		85,000	65,000	2000	2000	2000	2000	3000	65,000	130,000
AK-100		130,000	85,000	2000	2000	2000	2000	4000	85,000	130,000



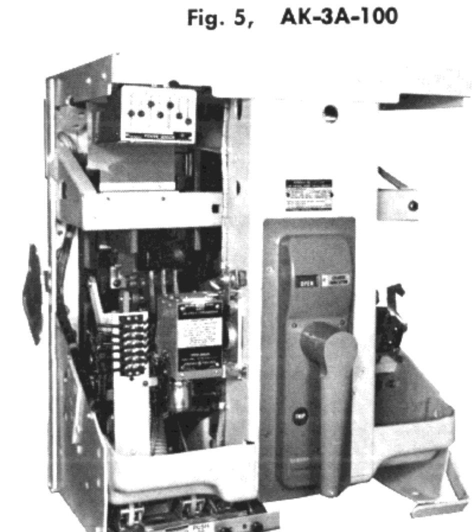
(Photo 8039337)
Fig. 5, AK-3A-100



(Photo 8039334)
Fig. 1. AK-2-15



(Photo 8039333)
Fig. 2. AK-2A-25



(Photo 8039339)
Fig. 6. AKU-3-50

*AKT-50 not physically interchangeable with AK-50

Application Information

Low-voltage power circuit breakers may be used for many applications—either individually mounted or in equipments.

Feeders — motors, lighting panel boards and motor control centers.

Main breakers — unit substations and service entrances.

Motors—branch circuit and combination starter.

Others including—capacitor switching, resistance welding machines, and field switching of rotating machines.

In selecting power circuit breakers, the following factors relating to the characteristics of the power system to which the breakers are to be applied and the conditions under which they will operate should be considered.

1. Circuit voltage.
2. Circuit-load current.
3. Available short-circuit current.
4. System frequency.
5. The ambient temperature.
6. Frequency of operation.
7. Altitude.
8. Local electrical codes.
9. Unusual service conditions.
10. Special duty cycles

1. Circuit Voltage

The voltage rating of the circuit breaker should equal or exceed the nominal voltage of the circuit to which it is to be applied.

2. Circuit-load Current

The continuous current rating of a circuit breaker should equal or exceed the maximum-load current which the circuit will carry as established by the overload or thermal ratings of the apparatus serviced by the circuit. In this connection attention is directed to the following quotation which is a paragraph under Section SG3-3.03 of NEMA Low-voltage Power Circuit Breaker Standards, Pub. No. SG3-1958.

"NOTE: Circuit breakers are rated upon a maximum basis. They are circuit interrupters and protective devices and, as such, may be called upon at any time successfully to remove from service other equipment or circuits. Furthermore, after such a circuit interruption, their current carrying ability may be materially reduced. Because of these conditions which differ from those for generators, motors, transformers, and similar apparatus, it is not practical to establish standard overload or thermal ratings."

3. Available Short-circuit Current

The available short-circuit current at a given point in a power system is the maximum current which the power system, when operating with maximum generating capacity and connected motor load can deliver to zero impedance short circuits simultaneously applied from all phases or polarities to ground. For a-c systems the calculated value of the short-circuit current available must be less than the interrupting rating of the circuit breaker. For d-c systems the maximum steady-state current should be less than the interrupting rating of the circuit breaker.

For a discussion of the interrupting ratings of G-E breakers, refer to page 6.

In addition to the above factors, the following factors may have to be considered depending upon the applications:

4. System Frequency

The frequency rating of the circuit breaker should agree with the nominal frequency of the power system. Standard G-E circuit breakers are rated for frequencies of 60–25 cycles or d-c. Special recommendations should be requested from the Company for applications of circuit breakers to circuits of higher frequencies or circuits on which higher order harmonics are present, such as capacitors, rectifiers, or induction furnaces.

5. Ambient Temperature

General Electric power circuit breakers are designed in accordance with NEMA Standards to carry rated current without exceeding allowable temperature rises when operated in an ambient temperature of 40 C. When the circuit breakers are mounted in enclosures the average ambient temperature inside the enclosure may be not more than 15 degrees higher than the standard ambient temperature of 40 C outside the enclosure. Applications requiring operation in ambient temperatures in excess of 40 C should be referred to the Company with complete information relative to temperature and ventilation conditions at the proposed site of installation.

6. Frequency of Operation

Power circuit breakers may be applied to most of the more commonly encountered power circuits such as generator, transformer, and feeder circuits without normally questioning the frequency of operation. Where repetitive operations are involved such as on circuits feeding industrial process motors, furnaces, etc., the application should be considered in light of the published information on page 23, Table XII.

7. Altitude

In the rarefied air above 3300-ft altitude, both insulation and current-carrying capacity are affected, and for such applications the published ratings of power circuit breakers are modified by multiplying the ratings by the following factors established in USASI, AIEE, and NEMA standards:

Altitude in Feet	Correction Factors	
	Voltage	Current
3300	1.00	1.00
4000	0.98	0.996
5000	0.95	0.99
10000	0.80	0.96

8. Local Electrical Codes

All G-E standard power circuit breakers are built to conform to applicable provisions of the USASI and NEMA standards. Requirements for breakers having special characteristics in order to meet certain city, state, or other electrical codes should be referred to the Company.

9. Unusual Service Conditions

It is recommended that, wherever possible, steps should be taken at the site of installation to control unusual service conditions so that standard equipment can be installed. When such steps are not practical or standard equipments such as dust-tight, water-tight, dripproof, or explosion-proof enclosures adaptable to the unusual condition are not listed, recommendations for special features necessary to adapt the equipment to the unusual conditions should be obtained from the Company in advance of placing the order. Among such unusual conditions are the following:

1. Exposure to damaging fumes or vapor.
2. Exposure to steam.
3. Exposure to salt air.
4. Exposure to oil vapors.
5. Exposure to hot and humid climate.
6. Exposure to dust, abrasive dust, magnetic dust, or metallic dust.
7. Exposure to dripping water or falling dirt.
8. Exposure to explosive mixtures of dust or gases.
9. Exposure to abnormal vibration, shock, or tilting.
10. Seasonal or infrequent use.
11. Unusual insulation requirements.
12. Exposure to extreme temperatures or sudden changes in temperature.
13. Unusual space limitations affecting use or installation.
14. Unusual configuration of enclosing rooms causing hot air pockets, rooms not having normal ventilation, or rooms containing large amounts of magnetic material.
15. Unusual operating duty, frequency of operation, or difficulty of maintenance.
16. Unusual or special operating requirements.

10. Special Duty Cycles

Breakers are used occasionally on special duty cycles, including currents above the normal rating for short periods, followed by rest periods, etc. Under these conditions it may be necessary to integrate the combined effect of the various load currents at different parts of the duty cycle as far as heating effect is concerned. It is seldom necessary to use a breaker of rating corresponding to the highest current of the duty cycle. Recommendations for such applications should be requested from the Company.

INTERRUPTING RATINGS

Modern design circuit interrupters such as are used on General Electric low-voltage power circuit breakers have interrupting capabilities which are a function of voltage. This is reflected in the differences in interrupting ratings assigned to circuit breakers with instantaneous trip devices at the three voltage levels of 600, 480 and 240 volts. Table I indicates these ratings, as well as the interrupting ratings without instantaneous trips, which are not a function of voltage. The latter ratings are to be used when breakers are applied without instantaneous trips, as they would be when equipped with selective trips or when direct-acting overcurrent trips are omitted—for example, when separate overcurrent relays are used.

The rated interrupting current is the maximum current at the rated voltage which a circuit breaker is required to interrupt under the operating duty specified and with a normal frequency recovery voltage not less than the rated voltage.

Interrupting ratings of General Electric power circuit breakers are based on the test procedure, applicable operating duty (duty cycle), performance and conditions given in USASI, C37.13, P 13-8.2.5, which are standards for low voltage AC power circuit breakers.

13-8.2.5 Short-Circuit Current Interrupting Test. The interrupting test shall be made on circuit breakers to determine their ability to close, carry, and interrupt currents within their assigned ratings as given in 13-4.

13-8.2.5.1 Types of Tests. (1) A single-phase test with line-to-line voltage equal to rated maximum voltage applied across one pole and with the current equal to or greater than 87 percent of the short-circuit current rating.

APPLICATION FACTORS

NOTE: A single-phase test is not a required test to establish the short-circuit interrupting rating of a circuit breaker without direct-acting instantaneous trip elements (see Table 1, Column 5 of American Standard C37.16-1963), provided that this test has been made on the breaker at the higher values of current when equipped with direct-acting instantaneous trip elements (see Table 2, Column 5 of American Standard C37.16-1963).

(2) Three-phase tests with line-to-line voltage equal to rated maximum voltage and the average of the three-phase current equal to or greater than the applicable short-circuit current rating.

13-8.2.5.2 Test Circuit. (1) The symmetrical current that verifies the short circuit rating shall be determined by calibrating the test circuit with the circuit breaker short-circuited or omitted, and shall be measured one-half cycle after inception of the current flow in the test circuit. This current shall be calculated in accordance with American Standard C37.5-1953.

(2) The power factor of the test circuit shall be 15 percent or less (X/R ratio 6.6 or greater), with X and R in series connection.

(3) The transient characteristics of the test circuit shall be such that the alternating component of the current at the end of one-half second shall not be less than 80 percent of the alternating component of the current at the end of the first one-half cycle.

(4) The test circuit voltage prior to the inception of current flow shall be the rated maximum voltage for the short circuit rating being verified.

(5) The frequency of the test circuit shall be 60 cps.

(6) On three-phase tests, either the power source or fault connection shall be grounded, but not both. The enclosure, the frame of the circuit breaker, or both shall be connected to the point of ground connection.

13-8.2.5.3 General Condition of Circuit Breaker. The circuit breaker used for the short-circuit interrupting test shall be new, completely assembled, and in good condition.

13-8.2-5.4 Breaker Settings. The following specifies the settings of the circuit-breaker tripping devices that shall exist at the time of the test.

(1) Circuit breakers equipped with direct-acting instantaneous trip elements shall have the tripping element set at values listed in the following. The direct-acting trip device shall have the maximum applicable coil. (a) For circuit breakers having a continuous current rating of 2,000 amp and below, set tripping element to operate at 15 times the rated continuous current of the circuit breaker. (b) For circuit breakers having a continuous current rating above 2,000 amp, set tripping element to operate at 12 times the rated continuous current of the circuit breaker.

(2) Circuit breakers equipped with direct-acting short-time-delay trip elements shall have their trip elements set at their maximum delay. The direct-acting trip device shall have the maximum applicable coil. Since the short-circuit ratings for all three voltage ratings are the same for a given frame size of circuit breaker having direct-acting short-time-delay trip elements, these tests shall be made at the maximum design voltage.

(3) Circuit breakers with no direct-acting trip devices shall be tripped from a separate timing device adjusted for a delay equal to the maximum obtainable under (2) preceding. Since the short-circuit ratings for all three voltage ratings are the same for a given frame size of circuit breaker having direct-acting short-time-delay trip elements, these tests shall be made at the maximum design voltage.

13-8.2.5.5 Short-Circuit Current Duty Cycle. Each test shall consist of an open operation followed after a 15-second interval by a close-open operation. If time-delay tripping devices are used, the tripping on each opening shall be delayed by the associated tripping devices.

13-8.2.5.6 Test Procedure. (1) The circuit breaker shall be inserted in the test circuit and tested in accordance with 13-8.2.5.5.

(2) For the first opening operation on each duty cycle, the current shall be initiated in the test circuit in such a manner that the maximum peak current will be equal to or greater than 2.0 times the rms symmetrical value in one phase for the three-phase tests.

(3) During the test, measurements shall be made of the current in each phase and the voltage across the breaker contacts by means of oscillographic equipment, prior to, during, and for approximately 5 cycles after the circuit-breaker operation.

(4) The value of the normal frequency recovery voltage shall be at least 95 percent of the rated maximum voltage of short-circuit tests on circuit breakers with direct acting instantaneous trip devices; and shall be at least 80 percent of the rated maximum voltage for short-circuit tests on circuit breakers without direct-acting instantaneous trip devices.

13-8.2.5.7 Performance. After performance of an interrupting duty cycle at its short-circuit rating, the circuit breaker shall be in the following condition:

(1) Mechanical: It shall be substantially in the same mechanical condition as before the test.

(2) Electrical: It shall be capable of withstanding a dielectric test of 60 percent of the test voltage specified in 13-8.2.2. The circuit breaker shall be capable of carrying rated continuous current, but not necessarily without exceeding the temperature rises specified in 13-5, and shall be capable of operating automatically within the manufacturer's specified limits at 300 percent calibrated point. The circuit breaker shall be inspected and, if necessary, repaired before being subjected to an additional duty cycle.

SHORT-TIME RATINGS

The short-time rating of a circuit breaker must be taken into account when the breaker is applied without direct-acting over-current trips.

The rated short-time current is the maximum current which a circuit breaker will carry without injury for specified short-time intervals. The rating recognizes the limitations imposed by both thermal and electromagnetic effects.

Short-time ratings of General Electric air circuit breakers are based on the test procedure, operating duty (duty cycle), performance, and conditions given in paragraph 13-8.2.4 of USASI C37.13.

Application Information

A-C POWER SYSTEM APPLICATION

13-8.2.4 Short-Time Current Test. The short-time current test shall be made to verify the ability of the circuit breaker to carry fault currents for a short time period, when applied without direct-acting trip devices.

13-8.2.4.1 Test Circuit. The test current used shall be a 60-cps rms sinusoidal current at rated maximum voltage calculated in accordance with American Standard Methods for Determining the Rms Value of a Sinusoidal Current Wave and a Normal-Frequency Recovery Voltage and for Simplified Calculation of Fault Currents, C37.5-1953. The current shall be measured with the circuit breaker short-circuited or omitted and shall be measured one-half cycle after inception of current flow. The test circuit shall have a power factor not greater than 15 percent (X/R ratio 6.6 or greater), with X and R in series connection. The alternating component at the end of the first one-half second shall not be less than 80% of the alternating component at the end of the first one-half cycle. A three-pole circuit breaker shall be tested using a three-phase circuit.

13-8.2.4.2 Short-Time Current Duty Cycle. With the circuit breaker in the closed position, the short-time current shall be applied and maintained within the limitations stated in the preceding for two periods of one-half second each with a fifteen-second interval of zero current between the one-half second period.

13-8.2.4.3 Performance. After the performance of a duty cycle at (or less than) its short-time current rating, the circuit breaker shall be capable of carrying rated continuous current without exceeding the rated temperature rise of the various parts and shall be capable of meeting its short-circuit current interrupting rating.

NOTE: It is not the intention of this paragraph to require that short-circuit current interrupting tests be performed, following short-time tests, to demonstrate satisfactory performance and condition of the breaker.

SYSTEM APPLICATION OF BREAKERS

System Application of Breakers—A complete application study considers the breaker in relation to the equipment which it protects, as well as in its relation to other breakers in the system. Load Center Unit Substations are perhaps the principal method of using breakers in which the functioning of one breaker with respect to another must be taken into consideration.

More than just trip characteristics must be taken into account—the relationship of interrupting ratings to available short-circuit current must also be carefully considered.

Basically there are two types of systems of breaker application:

1. Fully rated breakers are applied within their interrupting ratings:
   a. with instantaneous trips—tripping is instantaneous for short circuits.
   b. with selective trips—tripping is intentionally delayed up to interrupting rating of breaker.

FULLY RATED SYSTEM—The fully rated system uses main and feeder breakers which are fully rated, that is, they have interrupting ratings equal to or greater than the available short circuit current. These breakers are equipped with general-purpose trip devices combining long time delay and instantaneous trip characteristics. No intentional time delay is introduced in the tripping characteristics at short circuit current levels to achieve selective tripping between the main and feeder breakers and/or the feeder breaker and branch circuit protective devices.

The current level of a fault on a feeder circuit depends on the location of the fault along the feeder conductors and may be as high as that available at the load terminals at the feeder breaker.

Due to the difference in current ratings between the main and feeder breakers and therefore the amount of time delay for a given level of fault current, some selectivity might exist depending on the magnitude of the fault current and the settings of the instantaneous trips.

In order for selectivity to exist for all possible levels of fault current on a feeder circuit, it is necessary that the main breaker be equipped with selective trips, that is, combinations of long time and short time delay *without* instantaneous trips.

SELECTIVE SYSTEM—The selective system is a term used to identify a series of protective devices, i.e. relays, breakers, and fuses, the time current characteristics of which have been selectively coordinated, so that under fault conditions power is removed only from that portion of the system on which the fault exists. The first place on a low-voltage distribution system that such coordination is usually established is within a unit substation between the main secondary and the feeder breakers. Such a substation is sometimes referred to as a "selective substation." This type of selective coordination is not to be confused with the "primary selective" or "secondary selective" load center distribution systems.

As manufacturing processes become more critical and the need for continuity of service increases it is usually found that the "selective coordination" of protection devices or the selective system is extended beyond the load center to include motor control centers, panelboards, and the like.

In considering a load center unit substation and the low voltage distribution circuits which are fed from it, two circuit areas become apparent:

1. The area that takes in the main breaker and any one feeder breaker. The impedance between these two protective devices is so small, that faults at the load terminals of the feeder breaker will be for all practical purposes the same magnitude as faults at the load terminals of the main breaker. For selectivity to exist between these two breakers, at all levels of short circuit current up to the maximum available, the main breaker must be equipped with long-time and short-time delay trips.
2. The area which encompasses the feeder breaker, the feeder cable and the next protective device which is frequently a molded case breaker, part of a combination starter in a grouped motor control equipment. In this area which overlaps the first area to the extent of the feeder breaker, appreciable impedance may exist between the feeder breaker and the fault at the load terminals of the combination starter. This means that fault current at the load terminals of the starter may be appreciably less than fault current which would exist for a fault at the load terminals of the feeder breaker. Even for short cable runs (50 feet) this can be true depending on the size of the cable.

The second area permits the use of the feeder breaker equipped with long- and short-time delay trips having an additional instantaneous element with its setting equal to or greater than the available short circuit current at the motor control center bus.

Application Information

A-C POWER SYSTEM APPLICATION

NUMBER OF POLES AND TRIPS REQUIRED

The following data gives the correct power circuit breaker for protection of the more commonly used circuits.

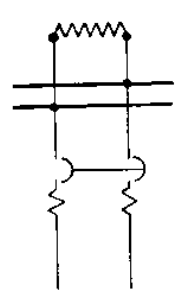


Fig. 7. Single-phase, two-wire, ungrounded

One 2-pole breaker with two overcurrent trips

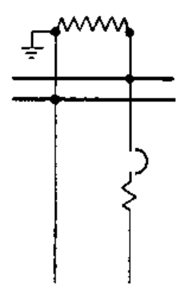


Fig. 8. Single-phase, two-wire, grounded

¶ One 1-pole breaker with overcurrent trip

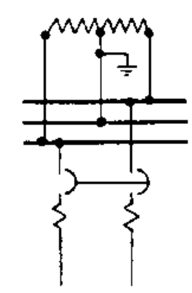


Fig. 9. Single-phase, two-wire, grounded

One 2-pole breaker with two overcurrent trips

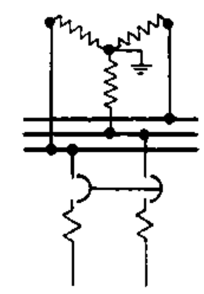


Fig. 10. Single-phase, two-wire, grounded

One 2-pole breaker with two overcurrent trips

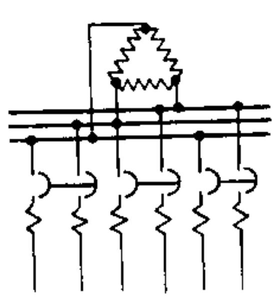


Fig. 11. Single-phase, two-wire, ungrounded

One 2-pole breaker with two overcurrent trips

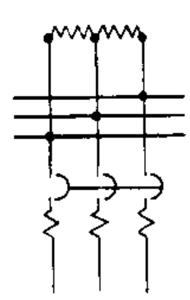


Fig. 12. Single-phase, three-wire, ungrounded

One 3-pole breaker with three overcurrent trips

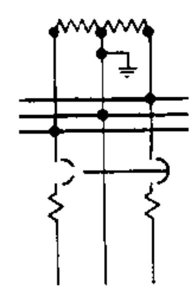


Fig. 13. Single-phase, three-wire, grounded

¶ One 2-pole breaker with two overcurrent trips (one in each conductor, except neutral)

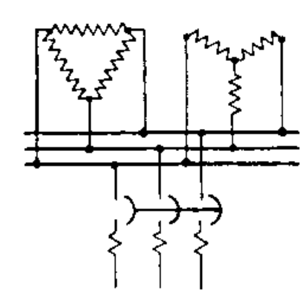


Fig. 14. Three-phase, three-wire, ungrounded

One 3-pole breaker with three overcurrent trips

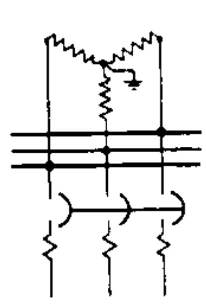


Fig. 15. Three-phase, three-wire, grounded

One 3-pole breaker with three overcurrent trips

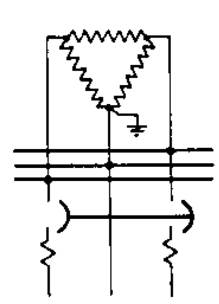


Fig. 16. Three-phase, three-wire, grounded

One 2-pole breaker with two overcurrent trips (one in each ungrounded conductor)

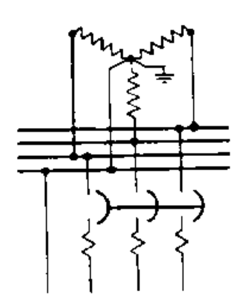


Fig. 17. Three-phase, four-wire, grounded

¶ One 3-pole breaker with three overcurrent trips

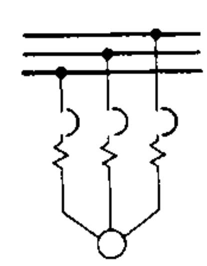


Fig. 18. Three-phase, a-c generator

One 3-pole breaker with three overcurrent trips. ‡ See note below.

¶ On incoming service lines, where the Underwriters' rules apply, provide some means of disconnecting the grounded neutral in accordance with the following requirements: 230-70 (i) of the National Electrical Code: "If the switch or circuit breaker does not interrupt the grounded conductor, other means shall be provided in the service cabinet or on the switchboard for disconnecting the grounded conductor from the interior wiring."

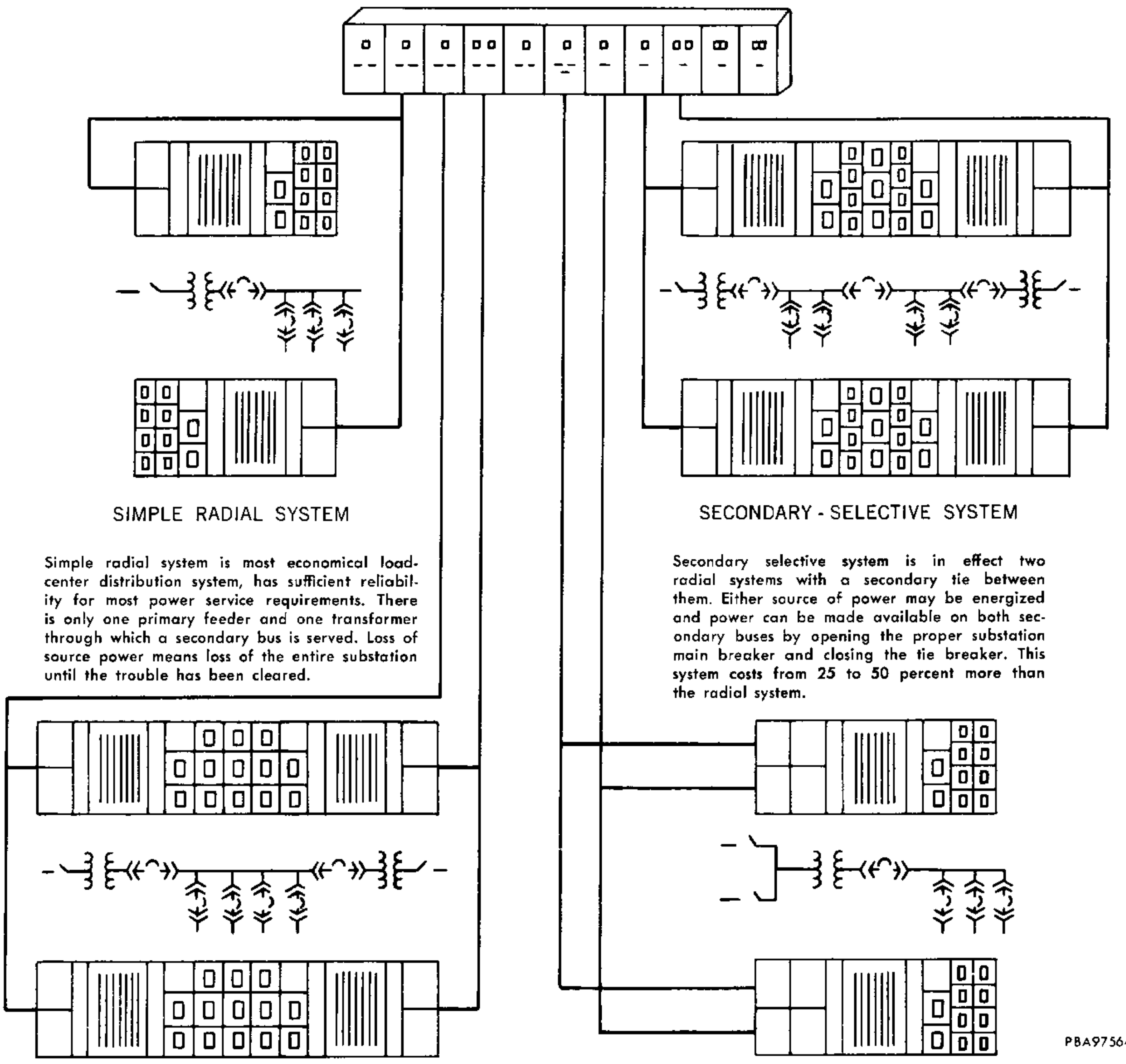
‡ Provides overcurrent and short-circuit protection only. Switchgear relays can be furnished to give reverse power, undervoltage, phase sequence, ground-current protection, etc. Such application should be referred to the Company.

Application Information

A-C POWER SYSTEM APPLICATION

Four basic circuits for power distribution have evolved from the many possible types and variations of substations and circuit arrangements.

The load center philosophy of power distribution—that is, the use of substations located in or near the load area—is basic to all of these arrangements providing good design at minimum cost. Power is supplied to the load center unit substations at the primary voltage level, stepped down to utilization voltage, and distributed to utilization devices on relatively short, low-voltage feeders. Selective co-ordination of protective devices is recommended where processes require continuous power. G-E load centers can be provided for any of these arrangements. Combinations of the various systems may be utilized.



SIMPLE RADIAL SYSTEM

Simple radial system is most economical load-center distribution system, has sufficient reliability for most power service requirements. There is only one primary feeder and one transformer through which a secondary bus is served. Loss of source power means loss of the entire substation until the trouble has been cleared.

SECONDARY - SELECTIVE SYSTEM

Secondary selective system is in effect two radial systems with a secondary tie between them. Either source of power may be energized and power can be made available on both secondary buses by opening the proper substation main breaker and closing the tie breaker. This system costs from 25 to 50 percent more than the radial system.

SPOT - NETWORK SYSTEM

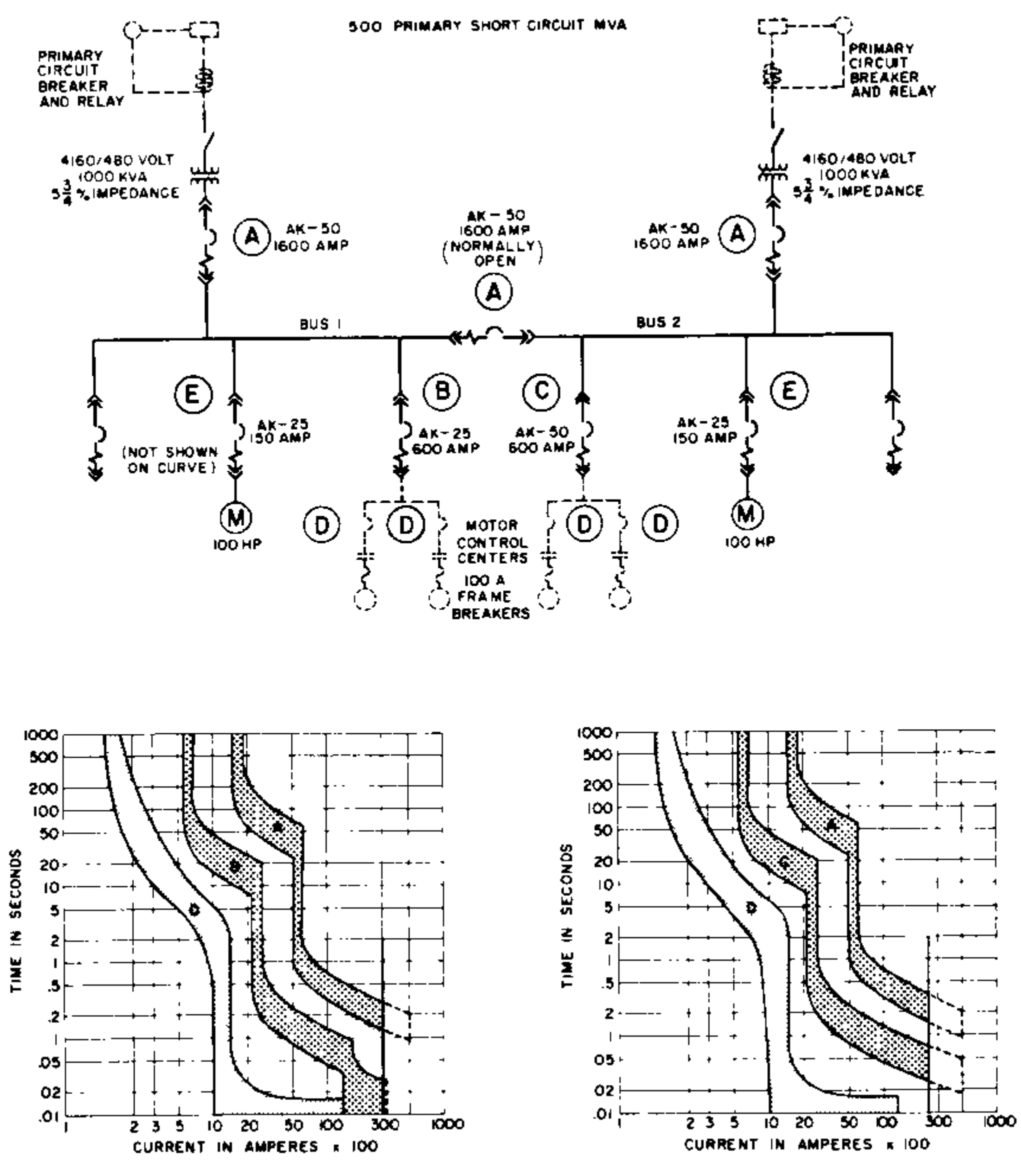
Spot network system parallels the transformer secondaries to provide continuous service for an outrage of one primary circuit. Failure of transformer or primary feeder results in automatic removal of the faulty equipment. This system costs from 20 to 50 percent more than the radial system.

PRIMARY - SELECTIVE SYSTEM

Primary selective system provides an alternate supply to the primary of each transformer. If a primary fault occurs, the associated primary breaker opens and interrupts service to half of the load area. The de-energized transformers . . . out of service . . . are manually switched to the other feeder. Cost is 15 to 40 percent more than radial systems.

Application Information

A-C POWER SYSTEM APPLICATION



ZONE SELECTIVE SYSTEM

STANDARD SELECTIVE SYSTEM

Fig. 19

The instantaneous element provides short-circuit protection for the feeder cable and, where needed, backup for the molded case breakers in the starters.

Tests indicate that, for the limit of application of 100 ampere frame molded case breakers in starters of General Electric motor control centers, selectivity is obtained with an instantaneous trip setting of 12,000 amperes on the AK feeder breaker. For faults beyond the starters, the short-circuit current will be below the instantaneous trip setting and in the region of current that would cause the feeder breaker to trip on short-time delay. The AK breaker will therefore be selective with molded case breakers.

The requirements for zone selective feeders established in this manner differ from the requirements for the selective main breaker. AK breakers using a combination of long time delay short time delay, and instantaneous trip characteristics can be applied up to the interrupting rating with instantaneous trips.

The practice of providing selective tripping for faults beyond the second protective device and instantaneous tripping for faults between devices (cable circuits) gives rise to the term "zone selective system."

The requirements for applying power circuit breakers to obtain selective tripping are given in the following paragraphs. The discussion centers around Fig. 19, but the principles are basic to any application.

1. All circuit breakers, both main and feeder, must have interrupting ratings at least equal to the maximum available short-circuit current. The interrupting rating is a function of the voltage and the presence or absence of an instantaneous trip device. A suitable selection can be made from Tables I or XIV.
2. Breaker A is a typical main breaker, without an instantaneous trip, and must be applied on the basis of ratings listed for breakers without instantaneous trips.
3. Feeder breaker C, which is selective with breakers D in the motor control center, should be selected on the same basis as A.
4. Feeder breaker B is equipped with instantaneous trips as well as with long time and short time delay trips, following the concept of a zone-selective system. This method of application may permit the use of a smaller frame size circuit breaker, as in the example.
5. Feeder breaker E, which is not required to be selective with a downstream protective device, is equipped with an instantaneous trip and applied on that basis.
6. The overcurrent tripping devices of the main breaker A must be so coordinated with the feeder breakers, that all feeder faults are cleared by the feeder breaker involved. The main breaker will trip only in the case of bus faults or the failure of the feeder breaker to trip. A feeder fault is, therefore, always cleared without interruption of service on other feeders.
7. Proper coordinating steps should be taken in fuse and relay application on the high-voltage side of the transformer when coordination with the rest of the system is desired.

Application Information

EFFECT OF MOTOR CONTRIBUTION

When short circuits occur, motors (both synchronous and induction) in operation from the same source become generators for the time being and add their contributions to the short-circuit current. Where accurate data are not available, it is customary to assume, for 240-, 480-, and 600-volt systems, that the motor load is equal to the kva rating of the source, and that the characteristics of the motors are such that the motor short-circuit contribution will be four times the normal current. In 208 or lower voltage systems, lighting, heating, welding, and other classes of nonregenerative load are likely to be present and hence, for such systems it is customary to assume the motor load to be 50 percent of the total available power and the motor short-circuit contribution will be two times the normal current.

Short-circuit contributions from induction motors are very short-lived and by the time the breakers have opened, they will have decreased to very low values. Synchronous motors, however, maintain their voltage for longer times and consequently they impose a heavier opening duty on the breakers. This may affect the satisfactory operation of the "C" breakers in the cascade (Fig. 20). Accordingly it has been made a condition of cascading that if more than 25 percent of the motor load is synchronous the problem should be referred to the Company for recommendations. The ratings in Tables XV, XVI, XVII, and XVIII are based on these considerations.

CASCADE SYSTEMS

Low-voltage power circuit breakers may be applied on circuits where the available fault current exceeds the interrupting rating of the breaker but these conditions must be fulfilled:

1. Provided there is a fully rated breaker backing up the breaker so applied. This is illustrated in Fig. 20 where "M" is the fully rated main breaker and "C" is the cascaded feeder breaker applied above its interrupting rating.
2. The feeder breaker "C" must have instantaneous trips. NEMA Standards recommend that these breakers be electrically operated.
3. The back-up breaker "M" must have its instantaneous trip set in accordance with NEMA Standards, so that it will trip when the fault current through the feeder breaker reaches 80% of the feeder breaker interrupting rating. The difference in fault currents between breakers "M" and "C" due to motor contributions must be taken into account in calculating the maximum allowable instantaneous trip setting on breaker "M".

Under the cascade system of application, a short circuit on a feeder breaker will be very likely to trip the main breaker and thus remove power from all feeder breakers. Herein lies the advantages of the fully rated system with selective trips on the main breaker. Since the feeder breakers of a fully rated system are able to open on a short circuit without assistance from the main breaker, selective trips delay tripping of the main breaker and permit it to ride over a fault on a feeder. In case of a bus fault between the main and feeder breakers or some unusual condition which prevents the feeder from clearing, the main breaker will open and remove the short circuit.

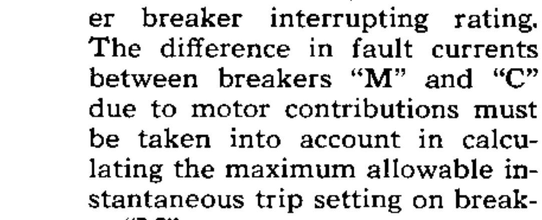


Fig. 20

NEMA Standards state the operation of breakers in excess of their interrupting capacity (as in cascade) is limited to one operation, after which inspection, maintenance, and repair may be required. Cascade systems are used only in a small percentage of applications. Fused breakers are largely replacing breakers applied under the cascade system.

TRANSFORMER SECONDARY BREAKER

A transformer secondary breaker is recommended for one or more of the following purposes:

1. To provide a fast method of removing all load from the transformer. Article 230-70 (g) of the NEC specifies that the disconnecting means for service conductors may consist of not more than six circuit breakers;
2. To provide required transformer secondary overcurrent protection in accordance with NEC Article 450-3;
3. To provide protection for faults on the main bus, both phase-overcurrent and ground fault types;
4. To provide a disconnect for maintenance purposes;
5. To provide for throwover, automatic or manual, to an alternate source in the case of failure of a primary feeder or transformer (Secondary selective circuit arrangement);
6. To back-up lower rated cascaded feeder breakers;
7. To simplify key interlocking schemes when the number of feeder breakers exceeds the practical limit.

Selection of the rating of the transformer secondary breaker should be based on the fact that forced cooling may be applied at some future time to increase the transformer rating as much as 33 percent.

GENERAL PURPOSE FEEDERS

For a-c circuits, there should be one breaker pole with overcurrent trip in each ungrounded conductor. For polyphase circuits, it is essential that all phases be disconnected simultaneously; therefore multipole breakers are used.

The dual-magnetic trip (Long time-instantaneous) with a 1B long time-delay characteristic is commonly used for general purpose a-c feeders. Instantaneous trip settings should be determined on the basis of the type of load and the type of protection desired. For instance, where arcing fault protection is a consideration, as low a setting as is consistent with the inrush characteristic of the load should be used.

A-C MOTOR STARTING AND FEEDER BREAKERS

Low-voltage power circuit breakers may be applied in motor branch circuits. They are particularly suited both economically and from good system design viewpoint for motors rated above 100 hp.

A motor branch circuit is a circuit including a single motor and a single breaker. A motor feeder circuit is a circuit including a breaker which supplies more than one motor branch circuit. Circuit breakers may also be used for motor-running overcurrent protection and as the motor controller for starting. The elements of a motor branch circuit are shown below.

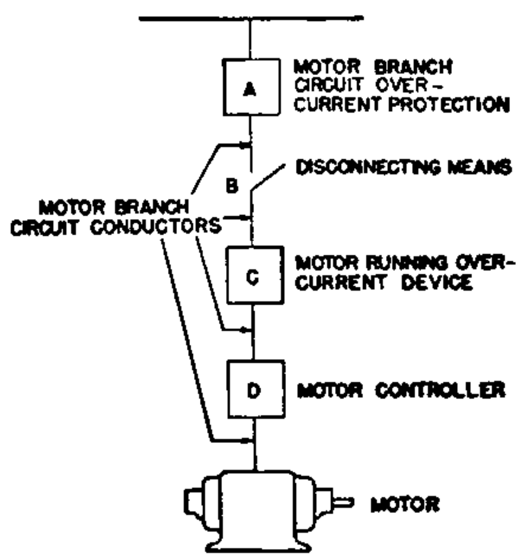


Fig. 21. Elements of a motor-branch circuit

A circuit breaker with its accessories will provide some or all of the elements of a motor circuit shown in NEC 430-1, either in itself or in combination with a motor controller. Because of the high inrush current associated with motor starting, only breakers with either an electrically or manually operated stored-energy mechanism should be used.

In single-motor circuits where the breaker is providing either branch circuit or motor-running overcurrent protection the breaker and its trip devices must have the following characteristics:

1. Continuous current-carrying capability at least 115 per cent of motor full-load current. (Enclosed motors may have other service factors.) See table II for the selection of the continuous current rating.

2. Interrupting capacity sufficient for available short-circuit current.

3. Sufficient time delay in the overload trip to ride over the starting current of the motor.

The breaker ratings indicated in the table below, when equipped with a 1B-3 trip characteristic, are satisfactory for starting normal motors and their loads with locked rotor currents up to 6 times motor full-load current.

4. Instantaneous tripping for protection of the motor and its circuit, set low enough to protect, and not so low that tripping occurs on transient inrush. A setting of 2 times the locked rotor current is considered adequate for most conditions.

NUMBER OF OPERATIONS

In applications where the AK low-voltage power circuit is performing the function of motor controller as well as motor branch circuit protection, the number of operations which the breaker can perform without maintenance should be considered. Based on closing currents up to 600% of the frame size rating and opening currents equal to the frame size rating, AK breakers can be expected to perform at least the number of operations indicated in Table III.

Frequently, a particular frame size of breaker will be used to control a motor considerably smaller in size than those shown under the column headed "Maximum HP at 440 Volts". In these cases the number of operations which the breaker can successfully perform between inspection and possible servicing will increase appreciably.

TABLE II—Application of Power Circuit Breakers to Full-voltage Starting and Running Duty of 3-phase, 60-cycle, 40 C Rise Induction Motors

Horsepower Rating of 3-phase Alternating-current Motors — Induction Motors			Trip Coil Rating of Circuit Breaker Amperes	Motor Full-load Current Amp		Max. Permissible Locked-rotor Cur. 60 Cycles Amperes*
220 Volts	440 Volts	550 Volts		Min.	Max.	
3	7.5	7.5, 10	15	9.6	13	120
5	10	15	20	13	17	160
7.5	15,20	20, 25	30	19	26	240
10	25	30	40	26	35	320
15	30	40	50	32	44	400
20	40	50, 60	70	45	61	560
25, 30	50, 60	75	90	58	78	720
40	75	100	125	80	109	1000
50	100	125	150	96	131	1200
60	....	150	175	112	152	1400
	125	..	200	128	174	1600
75	150	200	225	144	196	1800
			250	160	218	2000
100	200	250	300	192	261	2400
....	250	300	350	224	304	2800
125	....	350	400	256	348	3200
150	300, 350	400, 450	500	320	435	4000
200	400	500	600	384	522	4800
250	450, 500	600, 700	800	512	696	6400
300, 350	600, 700	800, 900	1000	640	870	8000
400	800	1000	1200	768	1044	9600
450, 500	900, 1000	....	1600	1023	1392	12800

* Locked-rotor currents are based upon motors having NEC code letters "a" through "j" inclusive. If the locked-rotor current exceeds this value, select the circuit breaker having the next higher continuous current rating, provided there is a calibration point on the breaker which is less than 140 percent of the motor full-load current.

Application Information

A-C POWER SYSTEM APPLICATION

INHERENT MOTOR PROTECTION— THE THERMO-TECTOR®

Additional protection for the motor may be obtained through the use of separate thermal relays or Thermo-tectors built into G-E motors. Either of these protective devices can be used to trip the breaker in response to abnormal conditions.

A Thermo-tector device is a specially designed heat-sensing switch embedded in the stator windings of some G-E motors. It is responsive to rate-of-rise of temperature as well as actual temperature. It will protect for locked rotor, overload, high-ambient, loss of ventilation, and single phase operating conditions; in fact, any short- or long-time abnormal condition that can raise the temperature of a winding to a dangerous degree.

Each Thermo-tector (there are at least three) has a single normally closed contact (circuit opening on rising temperature) that must be connected in the coil circuit of the motor controller. When using Type AK Power Circuit Breakers as motor controllers, the control will be arranged so that the Thermo-tector trips the circuit breaker by opening the undervoltage device or by dropping out an auxiliary relay to trip the breaker by means of the shunt trip device.

The branch circuit breaker for motors with inherent thermal protection should be provided with the usual instantaneous overcurrent trips set at twice locked rotor current and with long-time overcurrent trips for cable and for back-up protection and with sufficient delay to allow motor to start. Since the breaker long-time trip element is not being depended upon for motor running overcurrent or stalled rotor protection, the long-time trips can be set somewhat higher than usual for motor circuits, usually 150-200 percent of motor rating depending on the cable size.

GENERATOR CIRCUITS

The power circuit breaker for a generator should be fast closing for synchronizing and should have a continuous current rating of about 125 percent of the maximum current rating of the generator. Each pole of the breaker should be provided with overcurrent trip devices having the following characteristics:

1. Long time, set for about 125 percent of the generator continuous current rating and for maximum time, for continued moderate overcurrent protection of the generator.

2. Short time, set at about 2.5 times generator continuous current rating, or as required for selectivity with feeder breakers, for protection against bus faults.

3. Instantaneous, set at 10 to 12 times generator continuous current rating, for generator circuit protection on internal faults fed from other sources in system.

The generator breaker must have an interrupting rating equal to or greater than the available short-circuit current at the breaker location from all power sources on the system, including motors. The initial value of short-circuit current calculated from the generator sub-transient reactance should be used in determining the interrupting rating required. This current may be 7 to 15 times the continuous current rating of the generator.

The short-circuit current from a generator is the large value determined by the sub-transient reactance. This current decays with time until it reaches a lower sustained value that is dependent on machine synchronous reactance and excitation system characteristics. The actual sustained value may be any value between substantially zero and about three times generator continuous current rating.

The plotted values of generator output current and time under short-circuit conditions is called the decrement curve. It determines the settings and time-current characteristics required on the generator and feeder breakers in a selective system. The decrement curve of a particular generator may not be available, but the two most important points, the initial value and the sustained value of short-circuit current, can be obtained from the manufacturer.

Self-excited generators (generator field or exciter field energized from generator voltage) require special consideration because of the rapid decrement of short-circuit current to zero. Proper tripping of the generator breaker, and selectivity between the generator and feeder breakers, can be obtained with such generators only if provision is made in the excitation system for forcing the generator to sustain short-circuit current of sufficient magnitude and duration to operate the overcurrent trip devices.

For better protection of the generator, induction type overcurrent relays with voltage restraint, type IJCV, may be used to provide tripping through a shunt trip device on the breaker. D-c tripping power, or capacitor trip, is required for reliable trip under short-circuit conditions. Suitable current and potential transformers and a lockout relay are required in addition to the IJCV relays.

When generators are operated in parallel with other sources, a reverse power relay should be included for anti-motoring protection. A shunt trip device, which may be a-c operated, is required on the breaker.

TABLE III—AK Breakers for Motor-starting Applications

Induction Motor Starter Type	Max. Motor Horsepower Ratings			Endurance At Max. Rated Horsepower (No. of Operations on Motor Starting Duty†)
	220V	440V	550V	
AK-15	75 hp	150 hp	200 hp	9000
AK-25	200 hp	400 hp	500 hp	9000
AKU-25	150 hp‡	300 hp‡	400 hp‡	9000
AK-50	500 hp	1000 hp	1000 hp	9000
AKU-50	250 hp‡	500 hp‡	600 hp	9000

† Number of operations before repair which may include replacement of interrupting unit parts. These numbers apply only to fully completed starts, and not to interrupted starts such as jogging, inching, automatic sequencing or protective relay operations. See USASI-C-37.13.

These endurance ratings do not eliminate the need for periodic maintenance as indicated in the applicable instruction book for the breaker.

‡ Motor ratings are limited by the maximum ratings of fuses which can be used on AKU breakers.

Application Information

A-C POWER SYSTEM APPLICATION

RESISTANCE WELDING MACHINE CIRCUITS

Certain forms of low voltage power circuit breakers are particularly adaptable to and recommended for the protection of circuits which feed welding machines for spot, seam, projection, and flash welding.

Welding-type breakers are equipped with instantaneous trips and will promptly and safely interrupt overcurrents or short circuits and permit immediate restoration of service.

Breakers with time delay overcurrent trip devices are not recommended for use in circuits feeding welding machines because the relatively high intermittent welding currents sometimes cause undue wear in trip devices, resulting in calibration changes and nuisance tripping. Where overload protection is required, thermal overload relays and current transformers give better results.

The breaker which should be selected is one whose maximum load curve is just above the greatest load (during-weld current or kva) at a duty-cycle value for the welding application. After this has been selected, the maximum available RMS Symmetrical short current must be determined to complete the breaker application.

Examples for Selecting a Breaker

WHEN DURING-WELD KVA IS KNOWN

(a) During-weld kva = 600
Duty cycle = 0.15
Voltage = 440

Referring to Chart II (kva at 440 volts) on page 14, the point of 600 during-weld kva and 0.15 duty cycle is below the maximum loading curve of the AK-25Y1 (or AK-50Y3). This breaker is suitable for the conditions given.

WHEN DURING-WELD CURRENT IS KNOWN

(b) During-weld current = 1360 amp
Duty cycle = 0.15

Referring to Chart IV, we find that the point of 1360 amperes during-weld current and 0.15 duty cycle is below the maximum loading curve of the AK-25Y1 (or AK-50Y3), which is the breaker to select.

AMP AND KV VALUES

The following tables list the maximum during-weld ampere and kva values, at various duty cycles, for which the breakers can be used. The values are obtained from the curves in the charts on page 14.

* Where the interrupting capacity required for a particular installation is in excess of that of the rating of the breaker identified in the charts as suitable for an application, then a breaker of the required interrupting rating should be selected in each case.

TABLE IV

Duty Cycle	During-weld Amp Rms	During-weld Kva 220 Volts	During-weld Kva 440 Volts	During-weld Kva 550 Volts
AK-15Y1 and AK-25Y2 Breakers				
0.03	1530	337	674	841
.04	1325	292	584	729
.05	1185	261	522	652
.06	1080	238	475	594
.07	1000	220	440	550
.08	936	206	412	516
.09	884	194	388	486
.10	839	185	370	461
.20	594	131	262	327
.30	484	108	215	266
.40	419	92	184	231
.50	375	83	165	206
.60	342	75	150	188
AK-25Y1 and AK-50Y3 Breakers				
0.03	4040	890	1780	2225
.04	3500	770	1540	1925
.05	3130	689	1378	1722
.06	2860	629	1258	1574
.07	2740	580	1161	1453
.08	2640	544	1086	1360
.09	2330	513	1025	1282
.10	2215	487	974	1219
.20	1566	345	689	861
.30	1278	281	562	703
.40	1107	244	487	609
.50	990	218	436	545
.60	903	199	398	497
AK-50Y2 Breaker				
0.03	10680	2350	4100	5870
.04	9260	2040	4080	5100
.05	8280	1820	3640	4550
.06	7550	1660	3320	4150
.07	6990	1540	3080	3840
.08	6540	1440	2880	3600
.09	6170	1360	2720	3390
.10	5860	1290	2580	3220
.20	4140	910	1820	2280
.30	3380	744	1488	1860
.40	2925	644	1288	1610
.50	2620	576	1152	1440
.60	2390	526	1052	1315

TABLE V—Available Resistance Welding Breakers

Type of Breaker	Interrupting Rating RMS Symmetrical Amperes 60 Cycles A.C. 600 V	480 V	240 V	Range of Instantaneous Trip Calibration Amperes
AK-15Y1	14000	22000	25000	300 to 800, or
AK-25Y2	22000	30000	42000	600 to 1500
AK-25Y1	22000	30000	42000	600 to 1500, or
AK-50Y3	42000	50000	65000	1400 to 4000, or
				2000 to 5000
AK-50Y2	42000	50000	65000	1000 to 2500, or
				2000 to 5000, or
				4000 to 10000

Application Information

A-C POWER SYSTEM APPLICATION

MAXIMUM LOADING CURVES FOR WELDING-TYPE BREAKERS

Chart I—For 220 Volts

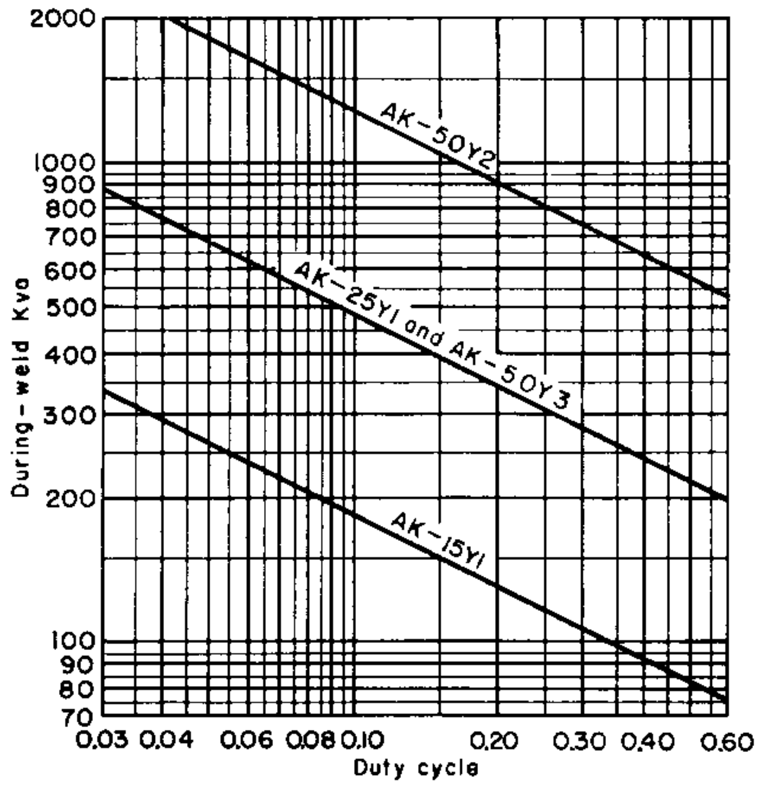


Fig. 22

Chart II—For 440 Volts

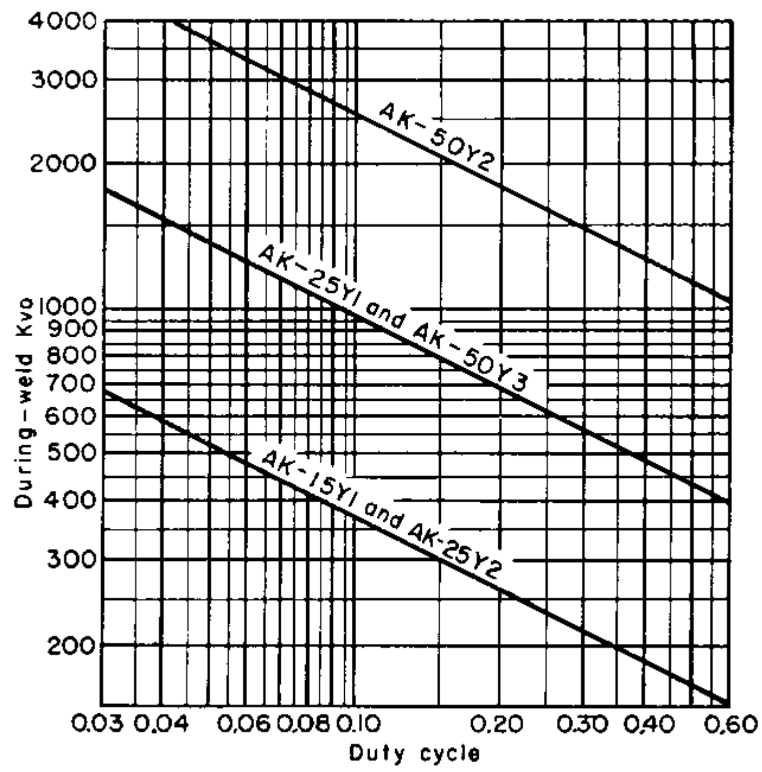


Fig. 23

Chart III—For 550 Volts

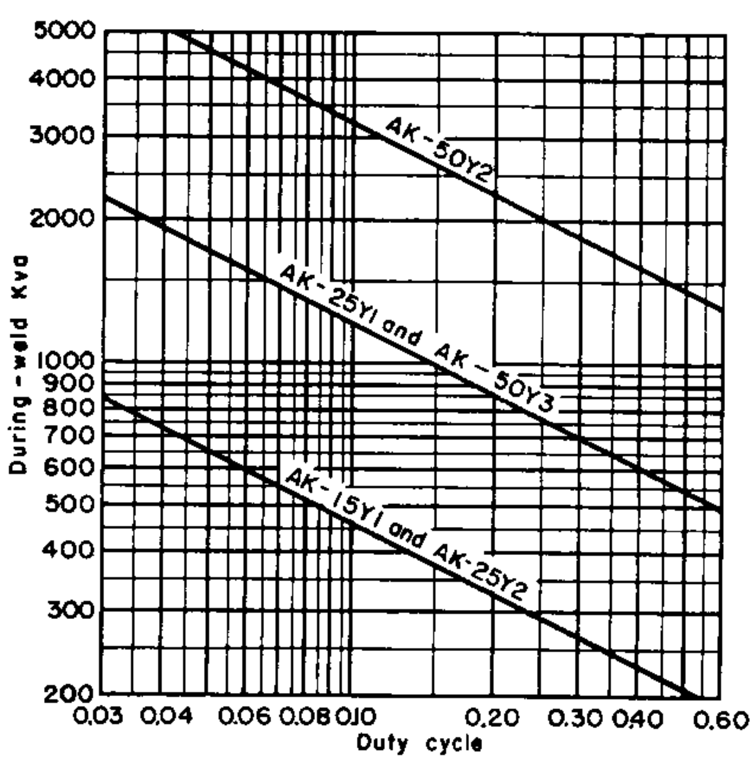


Fig. 24

Chart IV

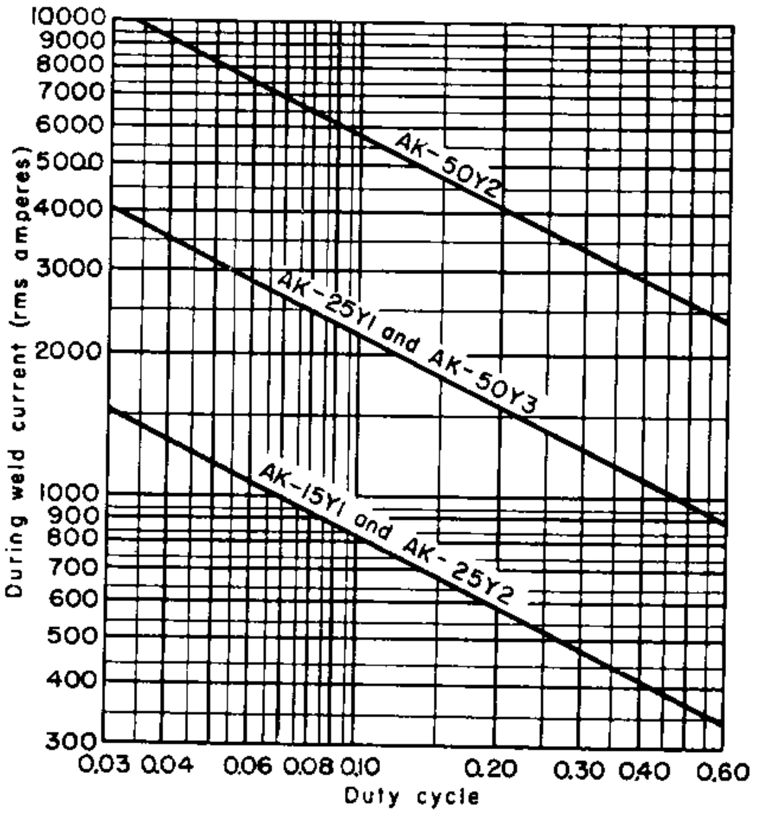


Fig. 25

The duty cycle is the fraction of time that current flows in any one minute.

TYPES OF LOW-VOLTAGE POWER CIRCUIT BREAKERS AVAILABLE

STANDARD BREAKER

Low-voltage power circuit breakers whether unfused or fused are capable of closing and opening circuits under normal or abnormal conditions. Fused power circuit breakers consist of a standard breaker with integrally mounted current limiting fuses. Basic operating mechanisms and trip devices are common to both types of breakers.

OPERATING MECHANISMS

Basically operating mechanisms fall into two categories.

a. Direct acting in which the closing force is furnished by an operator (manual) solenoid or motor (electrical).

b. Stored energy (both manual and electrical) in which an energy storing means is interposed between the control source and the breaker contacts.

Advantages include: increased safety of operation, prolonged contact and breaker life, wider breaker application, particularly selective tripping and motor starting, reduced maintenance and a reduction in control power requirements for electrical breakers.

General Electric Type AK circuit breakers utilize stored energy closing mechanisms. Models are available for either manual or electrical operation.

STORED ENERGY CLOSING

AK-15-25. A spring-operated "stored energy" closing mechanism provides fast, constant-speed closing for either electrical or manual AK-2-15 and AK-2-25 power circuit breakers, providing a closing speed completely independent of the operator (manual) or the voltage level of the control power source (electrical).

To close the breaker, the handle is first rotated counter clockwise through approximately 100 degrees. This resets the mechanism and partially stores energy in the closing spring. The handle is then rotated clockwise, completing the charging of the springs. As it approaches the normal rest position, the mechanism goes "over center," releasing energy to close the contacts. Upon receiving a tripping impulse, the breaker contacts are driven open at high speed by the same springs that are used for closing. A unique "rebound latch" which operates only during opening, prevents the contacts from rebounding in the closing direction.

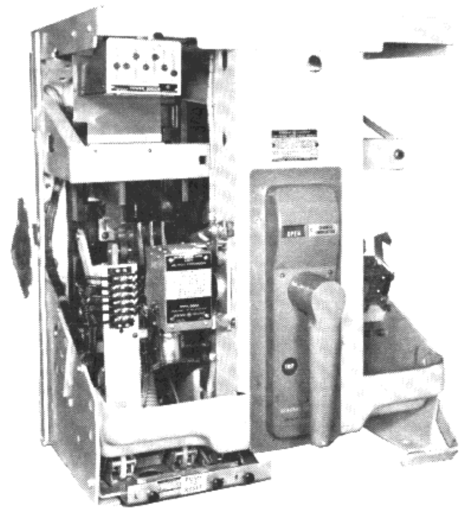


Fig. 26

Open fuse lockout device on AKU-3-50 breaker protects against single phasing

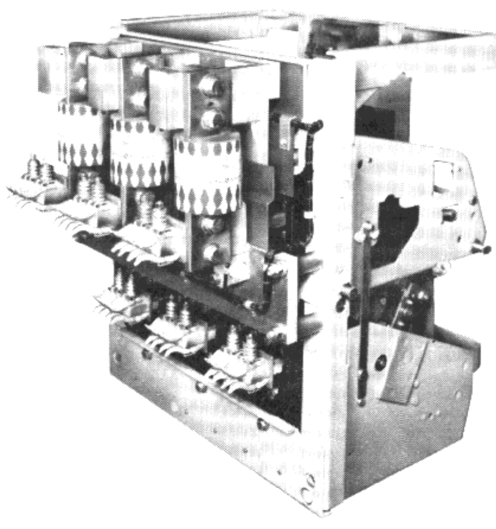


Fig. 27

Heavy-duty fuse mountings are shown in rear view of AKU-2A-50 circuit breaker

Electrically operated models use an a-c or d-c solenoid to charge the closing spring and provide total closing time of less than 5 cycles from the instant the close button is energized. Electrically operated breakers are normally furnished without manual handles, but with a maintenance closing device.

AK-50-75-100. The electrical stored energy closing mechanism utilizes energy stored in powerful closing springs to close the breaker contacts. A small univeral motor, which can be operated from ac or dc, drives a gear reducer unit. The output of this unit charges the closing springs through a charging crank and cam.

In the charged position, the springs are positively blocked by the "advance of center" location of the charging crank with respect to the charging cam. When the closing switch is operated the motor quickly drives the crank over center, releasing the springs and closing the contacts. Once the springs are released, the contacts will close regardless of continuity of control power. This is important when breakers are accidentally closed in on a short circuit and the control power source is the main bus.

Recharging is done immediately after a tripping operation at a low rate of energy input. This means low closing current—only 4 amp at 115 volts ac.

Contacts require considerably more energy for closing under short circuit or overload conditions than under normal load. Each time the springs are charged, there is enough energy stored to close the contacts under full short-circuit conditions.

A second set of springs is used to open the contacts when the breaker receives a trip impulse.

A detachable rachet handle, which can be slipped over the extension shaft of the gear box, is provided for maintenance operation.

Application Information

FUSED BREAKERS

For overcurrent and short-circuit protection of low voltage circuits (up to 600 volts) interrupting rating—200,000 amperes continuous ratings up to 1600 amperes.

Field-proven Type AKU low voltage power circuit breakers are available with integrally mounted General Electric Type CLF® current limiting fuses in 600 and 1600 ampere frame sizes. In addition, Types AK-2A-75 and AK-2A-100 power circuit breakers are available with coordinated, separately mounted Type CLF fuses. The separate mounting consists of a drawout fuse carriage mounted in the compartment directly below the power circuit breaker.

These fused power circuit breakers provide reliable overcurrent and short-circuit protection for systems with available fault current up to 200,000 amperes RMS symmetrical. They may also be applied in motor branch circuits and in motor feeder circuits, and are available in AKD-5 Powermaster switchgear construction.

Reliable overcurrent protection is afforded by the breaker and high-speed protection is provided by the fuse on faults exceeding the interrupting rating of the breaker.

General Electric's fused breaker contains an open fuse lockout device which prevents single phasing as a result of one fuse blowing. Should only one fuse blow, this direct acting device trips the breaker to open all three poles simultaneously. An indicator tells you which fuse has blown. To prevent re-energizing with a single-phase condition, the breaker remains locked out or in the trip-free position until the fuse is replaced and the device reset.

Time-current co-ordination of the breaker tripping characteristics and the fuse melting characteristics can usually be obtained through the use of a combination of long time delay and instantaneous tripping characteristics of the breaker as shown in Figure 28.

Where the required co-ordinations cannot be obtained through the use of long time-delay and instantaneous trip characteristics, combinations of long time-delay, short time-delay and instantaneous trip characteristics can be used.

CO-ORDINATION TABLE

Table VII shows the minimum fuse rating which co-ordinates with a particular rating of the EC-2A overcurrent trip device. The commonly used combinations of long time-delay and instantaneous tripping characteristics were used in making up the table. Both the intermediate (1B) and the minimum (1C) long-time-delay bands of the EC-2A trip device are presented in combination with instantaneous trip settings from 4X through 12X.

Larger fuse ratings than those shown in the table may be used provided that the maximum fuse ratings for the breaker frame sizes (Table VI) are not exceeded.

Table VII has been prepared so that the knee of the trip device curve does not overlap the minus 10 per cent tolerance of the average melting curve of the fuse as shown in Figure 28.

Fuse performance under short-circuit conditions (Table VI), is based on tests using General Electric CLF current limiting fuses of either NEMA classes J or L, depending on the current rating.

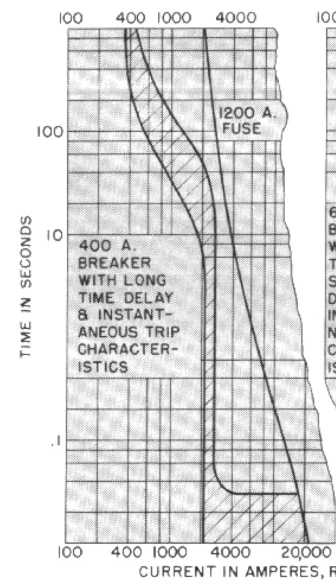


Fig. 28

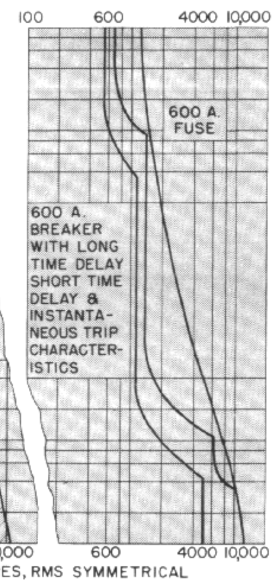


Fig. 29

TABLE VI

Breaker Type	Frame Size Amperes	Voltage AC	Breaker Trip Coil Rating	*CLF Fuse Rating Amperes Min.	*CLF Fuse Rating Amperes Max.	Interrupting Rating Amperes— RMS Symmetrical
AKU-2A-25	600	up to 600	160-600	400	1200	200,000
AKU-2A-50	1600	up to 600	200-1600	400	2000	200,000
AK-2A-75	3000	up to 600	2000-3000	2000**	3000**	200,000
AK-2A-100	4000	up to 600	2000-4000	2000**	4000	200,000

**The maximum fuse rating is the largest fuse which tests show will result in proper performance of the breaker and fuse in combination under short-circuit conditions.*
***Fuses are separately mounted on drawout carriage.*

TABLE VII

Breaker Type	Overcurrent Trip Device Rating-Amperes	Long Time Delay Band	Fuse Rating — Instantaneous Trip Setting 4X	6X	9X	12X
AKU-25	150	1C	400	400	600	600
		1B	400	400	600	800
	200	1C	400	600	600	1000
		1B	400	600	1000	1000
	300	1C	600	800	1000	1200
		1B	600	1000	1200	1200(1)
	400	1C	600	1000	1200(1)	1200(2)
		1B	800	1200	1200(2)	1200(2)
	600	1C	1000	1200(1)	1200(2)	1200(3)
		1B	1200	1200(2)	1200(3)	1200(3)
AKU-50	200	1C	....	....	....	1000
		1B	....	....	1000	1000
	300	1C	....	800	1000	1200
		1B	....	1000	1200	1600
	400	1C	....	1000	1200(1)	1600
		1B	800	1200	1600	2000
	600	1C	1000	1600	2000	2000(1)
		1B	1200	1600	2000	2000(2)
	800	1C	1200	2000	2000(1)	2000(2)
		1B	1600	2000	2000(2)	2000(3)
	1000	1C	1600	2000	2000(2)	2000(3)
		1B	2000	2000(2)	2000(2)	2000(3)
	1200	1C	2000(1)	2000(2)	2000(3)	2000(3)
		1B	2000(1)	2000(2)	2000(3)	2000(3)
	1600	1C	2000(1)	2000(2)	2000(3)	2000(3)
		1B	2000(1)	2000(3)	2000(3)	2000(3)

(1) In these ratings, the knee of the trip device curve passes through the minus 10% tolerance of the average melting curve of the fuse and it approaches or becomes target to the average melting curve.
(2) In these ratings, the average melting curve of the fuse passes through the knee cf the trip device curve.
(3) For these combinations, the addition of short time-delay to the breaker tripping characteristic is recommended to improve the coordination with the fuse at the knee of the trip device curve. Contact the nearest General Electric sales office to obtain the specific breaker trip characteristics required for your application.
(4) Although these specific trip ratings are not available in Power Sensor, the next nearest rating or setting can generally be used.

Application Information

POWER SENSOR SOLID-STATE AC OVERCURRENT TRIP DEVICE

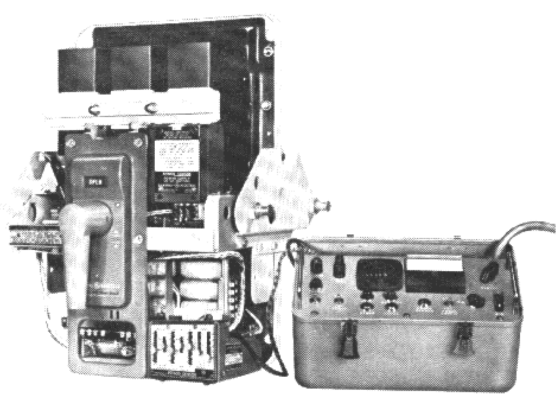


Fig. 30. Lightweight test set corrected to Power Sensor equipped breaker

GE LEADERSHIP IN SOLID-STATE TECHNOLOGY

For more than a decade General Electric has pioneered in the development of solid-state components associated with industrial apparatus. As a result of the experience acquired in the design and application of solid-state equipments, such as Silcomatic rectifiers and inverters, significant improvements have been and are continually being made in higher efficiencies and reliability of electrical apparatus with inherent reduction in required maintenance.

A significant improvement can be made in low-voltage switchgear equipments by taking advantage of solid-state technology to provide the tripping function for power circuit breakers. Solid-state circuitry affords greater accuracy, improved flexibility and reliability in this new trip device, setting it apart from electromechanical types of overcurrent trip devices.

IMPROVED SYSTEM SELECTIVITY AND PROTECTION

System selectivity is improved since the characteristic tripping curve of the Power Sensor has a narrower tripping band, shown in Figure 36 than the tripping curve of the electromechanical trip device. This band permits closer coordination, in that the characteristic can be more precisely matched or nested with the characteristics of the other protective devices in the power system. This narrower tripping curve also provides for improved circuit protection in that lower trip settings may be used without sacrificing selectivity.

ECONOMICAL GROUND FAULT PROTECTION

Power Sensor provides an economical answer to solving the problem of ground fault protection. Electromechanical overcurrent trip devices must be set above normal load currents and therefore are insensitive to detecting low level ground fault currents. To provide for this detection with electromechanical devices, a separate doughnut-type ground sensor transformer must be used with relays to trip the breaker. Because of the initial cost and complexity of installation, many users were less than enthusiastic in their acceptance of ground fault protection schemes. Now, with Power Sensor, the ground fault protective function can be incorporated as an integral part of the solid-state trip unit . . . for either three-phase three-wire systems or three-phase four-wire systems.

GENERAL DESCRIPTION

The Power Sensor is a three-phase over-current trip device for type AK breakers. Four basic parts all mounted on the circuit breaker comprise the complete trip device—the current sensors, the power supply, the solid-state unit and the tripping solenoid.

ELIMINATION OF PRE-ENGINEERING IN SELECTING TRIPPING CHARACTERISTICS

The wide range of characteristics available with the Power Sensor may be conveniently set in the field. It is no longer necessary, therefore, to establish these characteristics before the device is ordered. Since pick-up settings and time bands may be selected by merely changing an adjustment knob in the field, pre-engineering is eliminated. Changes in load requirements within the breaker rating do not require replacement of trip devices as is the case with the electromechanical type. A simple adjustment of the Power Sensor will take care of this situation.

GREATER ACCURACY FOR SYSTEM RELIABILITY

Repetitive tripping accuracy over long periods of inactivity is afforded by the solid-state trip unit using industrial grade components. The electronic circuit has been designed so that tripping characteristics fall within the published curve from $-20°C$ to $+55°C$ ambient temperature.

FREEDOM FROM MECHANICAL WEAR

Solid-state components now replace electromechanical parts to provide various degrees of time delay before tripping. The only mechanical part in the Power Sensor system is the solenoid trip armature itself.

POWER SENSOR FLEXIBILITY

The three-phase Power Sensor solid-state unit is identical in all type AK-3 (AK-3 designates breakers equipped with Power Sensor low-voltage power circuit breakers rated 225 amp frame through 4000 amp frame 60 cycles, and up to 600v a-c. Three-phase adjustment of the long time-delay pickup setting is accomplished by positioning one adjustment knob on the calibration plate. Combining the range of this adjustment with the range of the current sensor tap settings results in an over-all current pickup range of up to 10-to-1. Repeated accuracy and precise settings of the solid-state unit are assured by fixed resistor circuitry since this value of resistance is the only value that can be in the circuit at any one time. Potentiometers are not used since they are not repeatable in their setting. This wide flexibility is advantageous when unforeseen increases in load require field adjustment to a higher pickup setting. In the case of mechanical trips it is necessary to replace three trip devices. Selection of bands and tap settings is accomplished with adjustable captive thumb screws. In the remote possibility that a thumb screw is inadvertently left loose, "fail safe" circuitry is incorporated in the solid-state unit so that the set will revert to the minimum and the time band to the maximum. A single knob adjusts all three phases for any particular characteristic.

TAP CHANGER FLEXIBILITY

A tap changer is located at each current sensor. Various pickup settings are available by selecting the proper tap changer setting. The current rating of each tap is clearly marked and is accessible for field adjustment.

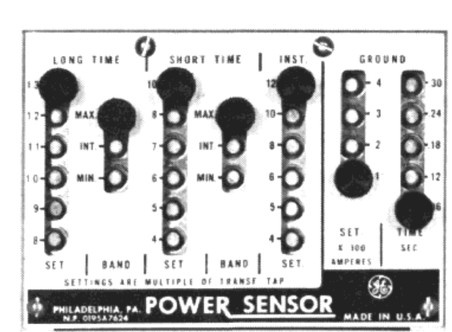


Fig. 31. Calibration plate showing all characteristics

Application Information

THERMAL STABILITY

The long time-delay characteristic is provided with an oscillator and integrator circuit. The circuits have been designed to provide a constant I^2t characteristic.

SURGE PROTECTION

The Power Sensor solid-state unit is protected against transient voltage surges by gas-filled surge arresters connected across the output of each current sensor.

FIELD TESTING

An accurate portable test set with input of 110v a-c is available for field testing of the Power Sensor unit. Testing can be performed at the substation after the breaker is racked to test position. If it is more convenient to test in a laboratory, the Power Sensor unit may be removed from the breaker by loosening one screw and disconnecting the input lead connection plug. In either case, it is possible to check the pickup point and time delay by setting an input level and reading the pickup meter and elapsed time meter. The tripping circuit may be checked on the breaker by rearrangement of connection plugs and setting the adjustment knob at a particular value which will cause the breaker to trip.

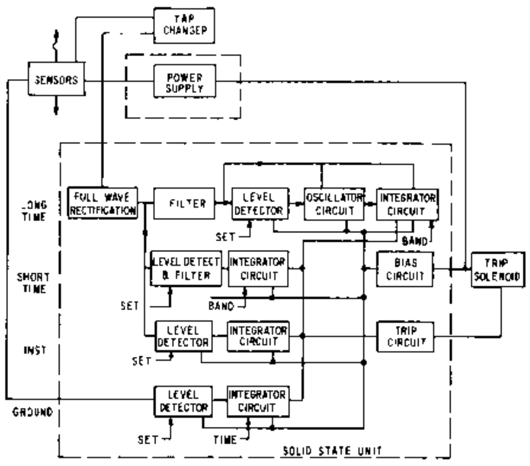


Fig. 32.

TRIP DEVICE RATINGS

The solid-state circuitry used to establish the pickup current setting and to provide time delay before tripping, receives its signal from current sensors. Taps on the current sensors make it possible to select the following trip device ratings:

Breaker Frame	Trip Rating-Amperes
AK-15, AK-25	45, 70, 90, 125, 175, 225
AK-25, AK-50	200, 300, 400, 500, 600
AK-50	600, 800, 1200, 1600
AK-75	1500, 2000, 2500, 3000
AK-100	2000, 2500, 3000, 4000

CHARACTERISTICS

Four basic characteristics are provided by the solid-state circuitry:

1. Long time-delay
2. Short time-delay
3. Instantaneous
4. Ground fault

TABLE VIII

Trip Characteristic†	Range of Pickup Adjustment % of Tap Setting	Time Delay Band	Amount of Time Delay
Long time-delay	80-130% of trip device rating (Fixed point settings at 80, 90, 100, 110, 120 and 130%)	Maximum Intermediate Minimum	30 seconds 15 seconds 5 seconds △
Short time-delay	200%(2X)-500%(5X) or 400%(4X)-1000%(10X) (Fixed point settings at 2X, 2½X, 3X, 3½X, 4X, & 5X and 4X, 5X, 6X, 7X, 8X & 10X)	Maximum Intermediate Minimum	21 cycles 9.6 cycles 4.2 cycles *
Instantaneous	400%(4X)-1200%(12X) (Fixed point settings at 4X, 5X, 6X, 8X, 10X, 12X)		No Intentional Delay

△Above are times at 600% of device rating measured at the lower limit of the band.
* Above times are at the lower limit of the band.
† The tolerance on all calibrated pickup settings, long time, short time and instantaneous, is ±10%.

TABLE IX—GROUND FAULT PROTECTION FOR 3φ 3 WIRE AND 3φ 4 WIRE CIRCUITS

Ground Fault Pickup Range	Limited to Breaker	Amount of Time Delay
100, 200, 300, 400 amps	AK 3-15, 25	.06, .12, .18, .24, .30 seconds
300, 600, 900, 1200 amps	AK 3-25, 50	
750, 1500, 2250, 3000 amps	AK 3-75, 100	

Application Information

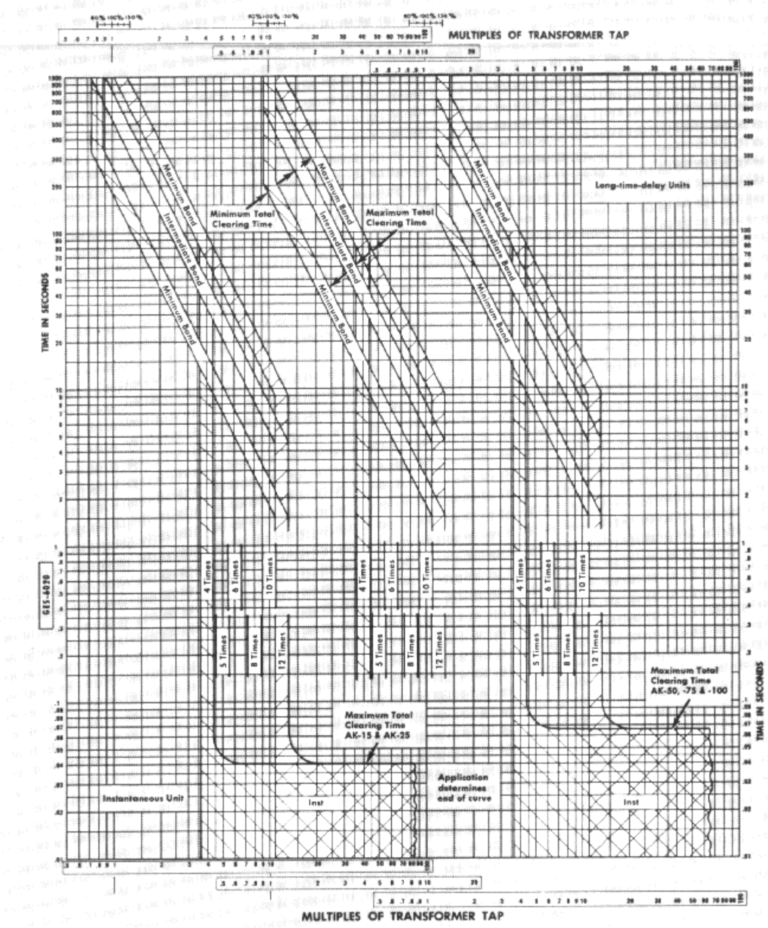


Fig. 34. Long time and instantaneous characteristics

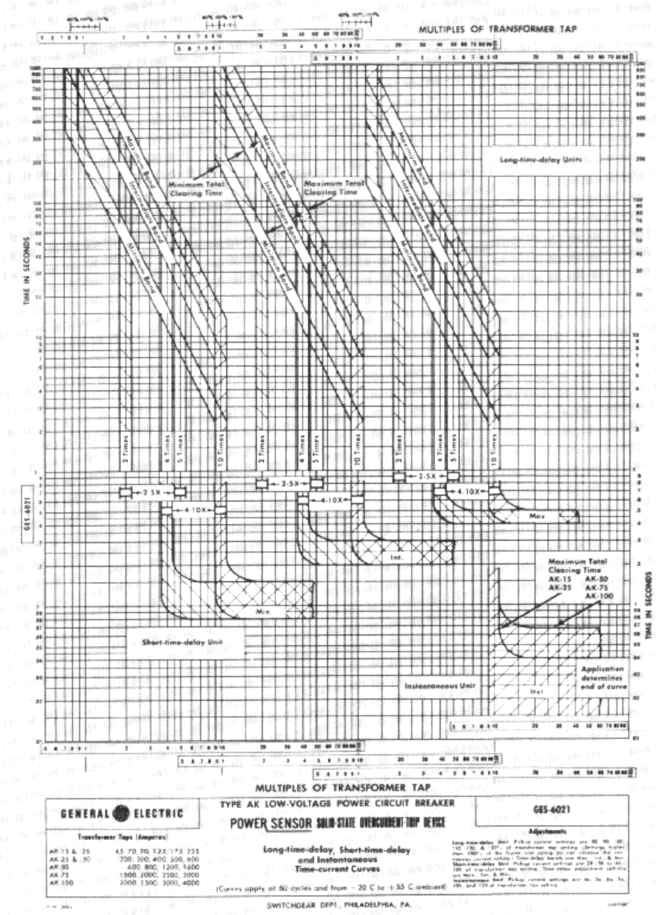


Fig. 35. Long time and short time-delay characteristics

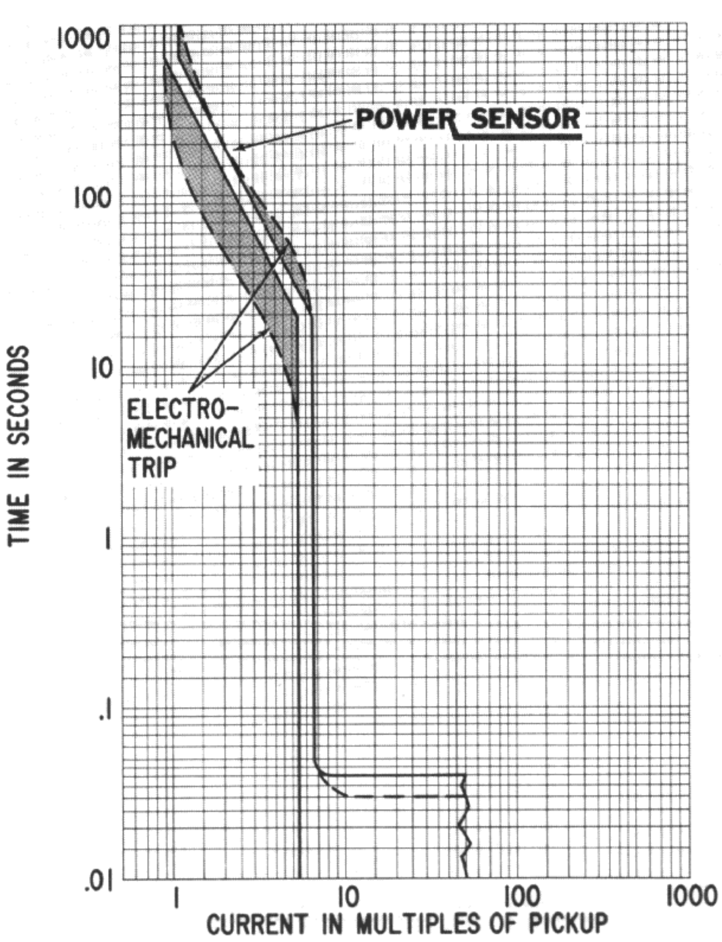


Fig. 36. Comparison of typical electro-mechanical tripping characteristics and Power Sensor characteristics

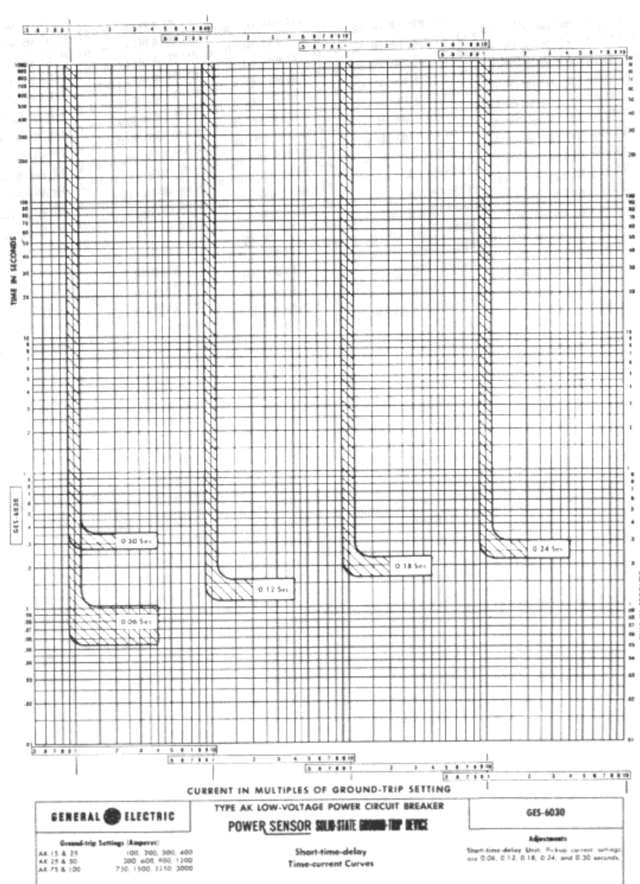


Fig. 37. Ground fault protection characteristics curve

Application Information

TYPE EC ELECTROMECHANICAL OVERCURRENT TRIP DEVICE

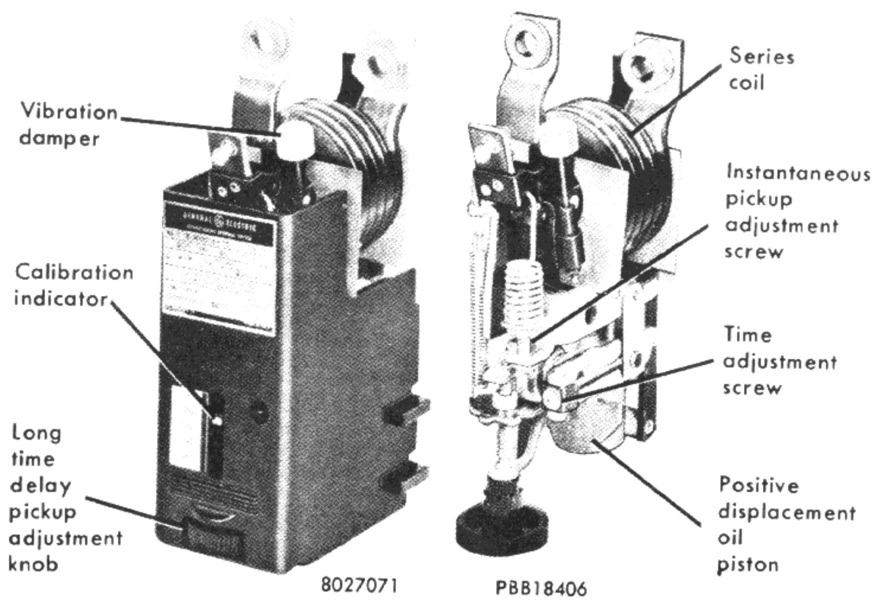


Fig. 38. Type EC-2A magnetic overcurrent tripping device. Series trip for 225, 600 and 1600 amp frame size breakers

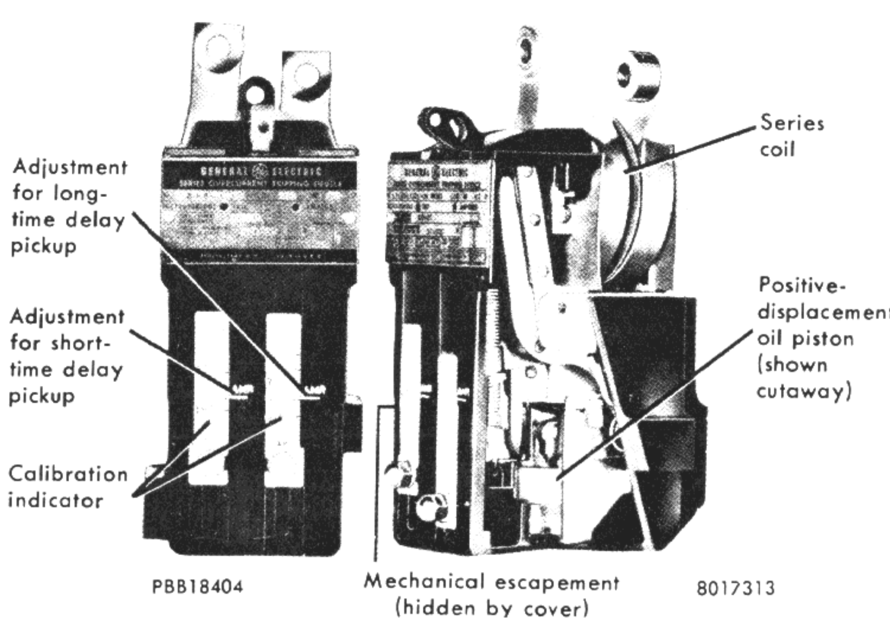


Fig. 39. Type EC-1 magnetic overcurrent tripping device. Series trip for 225, 600 and 1600 amp frame size breakers

General Electric low-voltage power circuit breakers are equipped with tripping devices used for two distinct functions:

a. As a means of opening the breaker during the process of normal switching operations initiated by an operator or an automatic switching equipment.

b. As a means of automatically opening the breaker under abnormal power-system conditions for circuit-protective purposes.

Normal switching tripping is effected by one of the following devices:

1. Manual trip button—supplied on all breakers both manually and electrically operated.
2. Shunt-trip device—supplied on all electrical breakers and optionally available on manual breakers. Shunt trips are normally energized from a reliable constant potential source such as a storage battery or control power transformer.

Automatic protective tripping is effected by one of the following devices, depending on the type of breaker and the means employed for initiating the tripping:

1. Direct-acting series overcurrent tripping device Type EC-1 and EC-1B embodying instantaneous short time-delay and long time-delay elements or specified combinations thereof. This trip is used primarily for selective tripping of breakers.

1. Table X and Fig. 42 show the calibrations and time-current characteristics of these elements available for various ratings of breakers.

2. Direct-acting series overcurrent tripping device Type EX-2A embodies instantaneous and long time-delay elements with adjustable instantaneous pickup and long time-delay elements. This trip is used on breakers in fully-rated and cascaded systems.

TABLE X

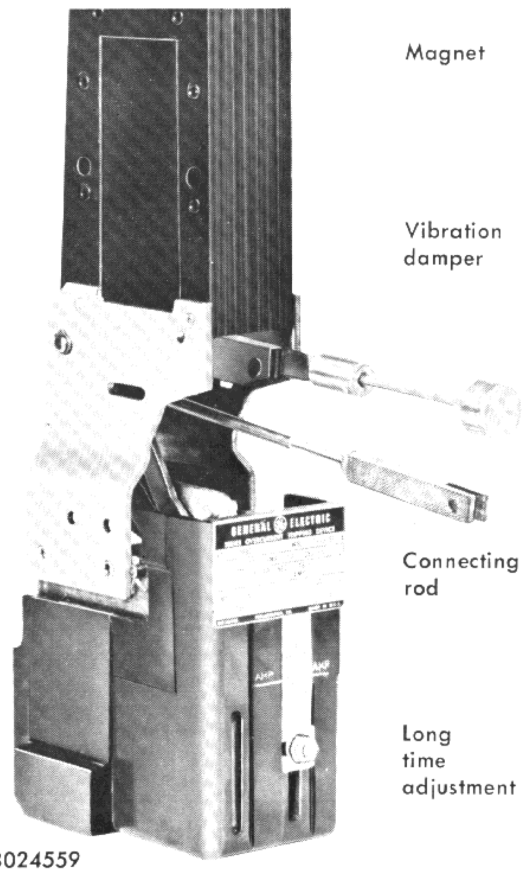
TRIPS FOR 225-, 600-, AND 1600-AMP FRAME SIZE BREAKERS

EC-2A Fully Adjustable Trip for all applications where the combination of long time delay and instantaneous, or instantaneous alone is required.

Available Characteristics	Range of Pickup Adjustment*	Time Delay (at 600% of Pickup Setting) (lower limit of band)	Factory Setting*
Long time	80–100% calibrated at 80, 100, 120, 140 and 160% of coil rating	(1A) Maximum-adj. 15 to 38 sec. (1B) Intermediate-adj. 7.5 to 18 sec. (1C) Minimum-adj. 3.3 to 8.2 sec.	1B—15 sec. 100%
*Instantaneous	6–12X coil rating 4–9X coil rating 9–15X coil rating 80–250% coil rating†	Select one range—6 to 12X furnished unless otherwise specified	12X 9X 15X 100%

† Not available with long time delay.

Table X and Fig. 41 show the calibrations and time-current characteristics of these elements which are available only on circuit breakers Types AK-2-15, -25, and -50.



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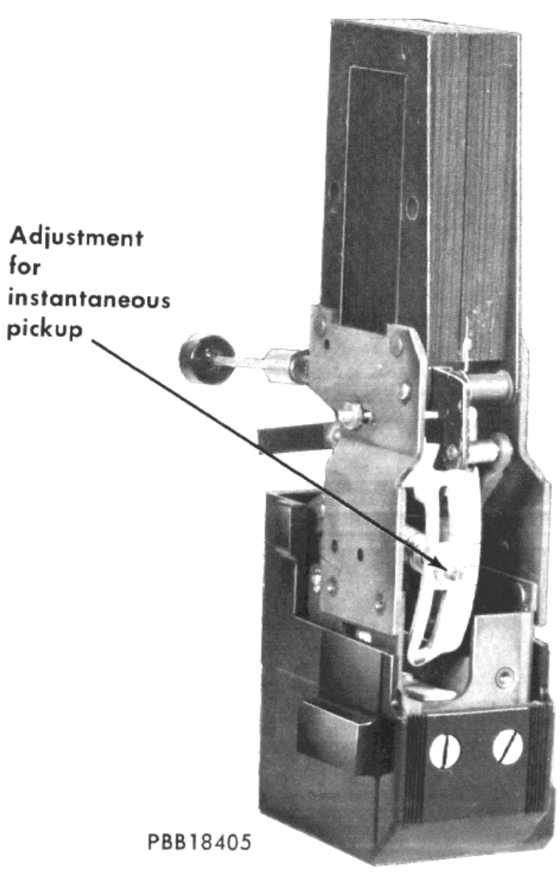

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Fig. 40. Type EC-1B magnetic overcurrent tripping device. Trips for 3000 and 4000 amp frame size breakers

TRIPS FOR 225-, 600-, AND 1600-AMP FRAME SIZE BREAKERS

EC-1 Selective Trips combine long time and short time elements for intentional delay up to the interrupting rating of the breaker. (See Table I, Col. 4.) For special applications, instantaneous may be added.

Available Characteristics	Range of Pickup Adjustment*	Time Delay (lower limit of band)	Factory Setting
Long time	80–160% (Factory set at 100%)	(1A) Max. 30 sec. at 6 x pickup (1B) Inter. 15 sec. at 6 x pickup (1C) Min. 5 sec. at 6 x pickup	1B—100%
Short-time	2–5 x coil rating 3–7 x coil rating 4–10 x coil rating	(2A) Max. 14 cycles at 2½ x pickup (2B) Inter. 9 cycles at 2½ x pickup (2C) Min. 4 cycles at 2½ x pickup	
Instantaneous	Non-adjustable	High Set	Must be specified

* Pickup tolerances are ±10% for EC-2A and EC-1 trip devices.

TRIPS FOR 3000- AND 4000-AMP FRAME SIZE BREAKERS

EC-1B Fully Adjustable Trip and Selective Trips for all applications where combinations of long time delay, and instantaneous, or instantaneous alone is required—short time delay also available.

Available Characteristics	Range of Pickup Adjustment*	Time Delay (lower limit of band)	Factory Setting
Long time	80–160% calibrated at 80, 100, 120, 140 and 160% of coil rating	(1BB) Max. 4.5 sec. @ 6X pickup (1CC) Min. 2 sec. @ 6X pickup	1BB—100%
Short time	Three ranges available—select one 2, 3.5, 5X 3, 5, 7X 4, 7, 10X	(2AA) Max. 24 cycles @ 2½X pickup (2BB) Inter. 16 cycles @ 2½X pickup (2CC) Min. 8 cycles @ 2½X pickup	Must be specified
*Instantaneous	Three ranges available—select one 6–12X coil rating 4–9X coil rating 9–15X coil rating	Select one range— 6 to 12X furnished Unless otherwise specified	12X 9X 15X

* Pickup tolerances are ±15% for EC-1B.

Application Information

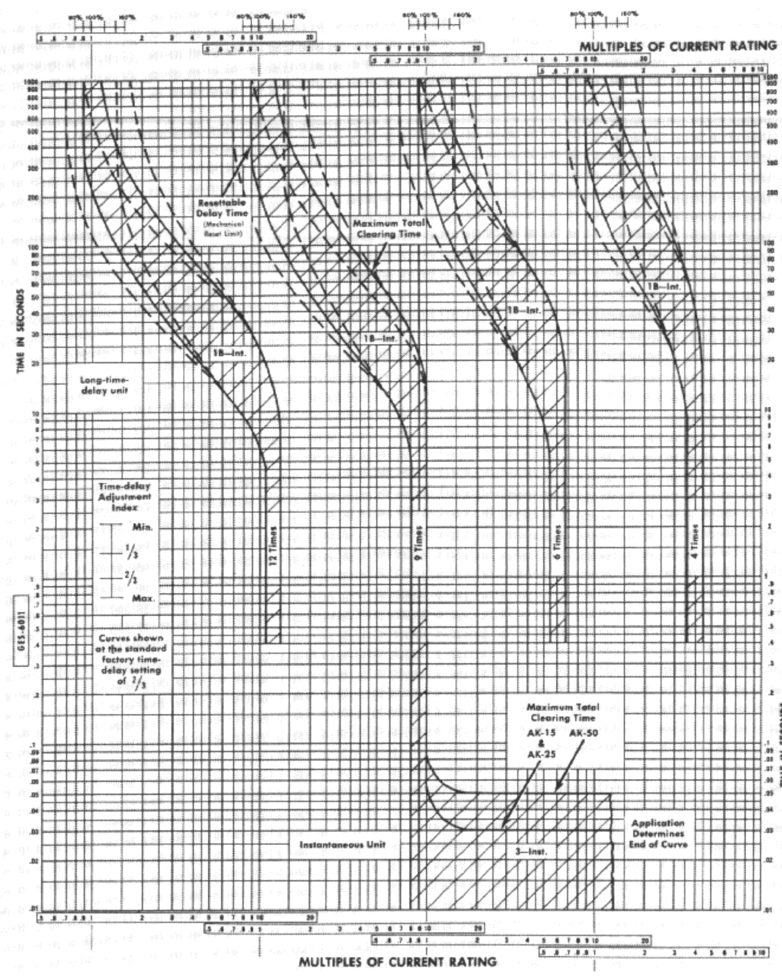


Fig. 41. EC-2 and EC-2A series trip device

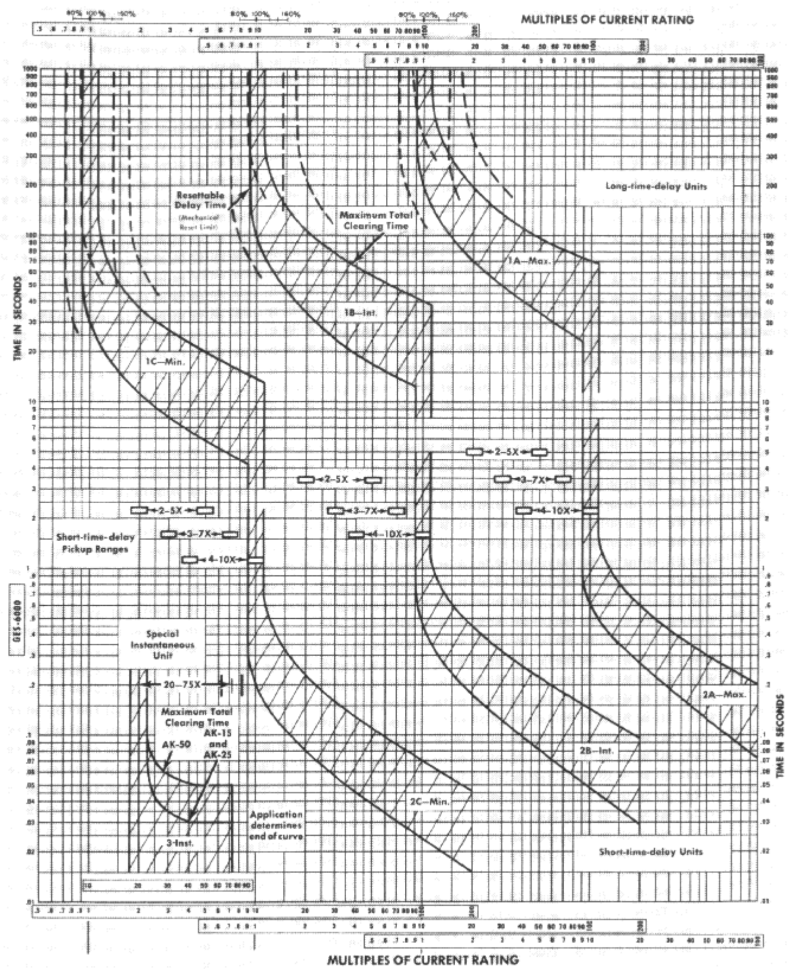


Fig. 42. EC-1 series trip device

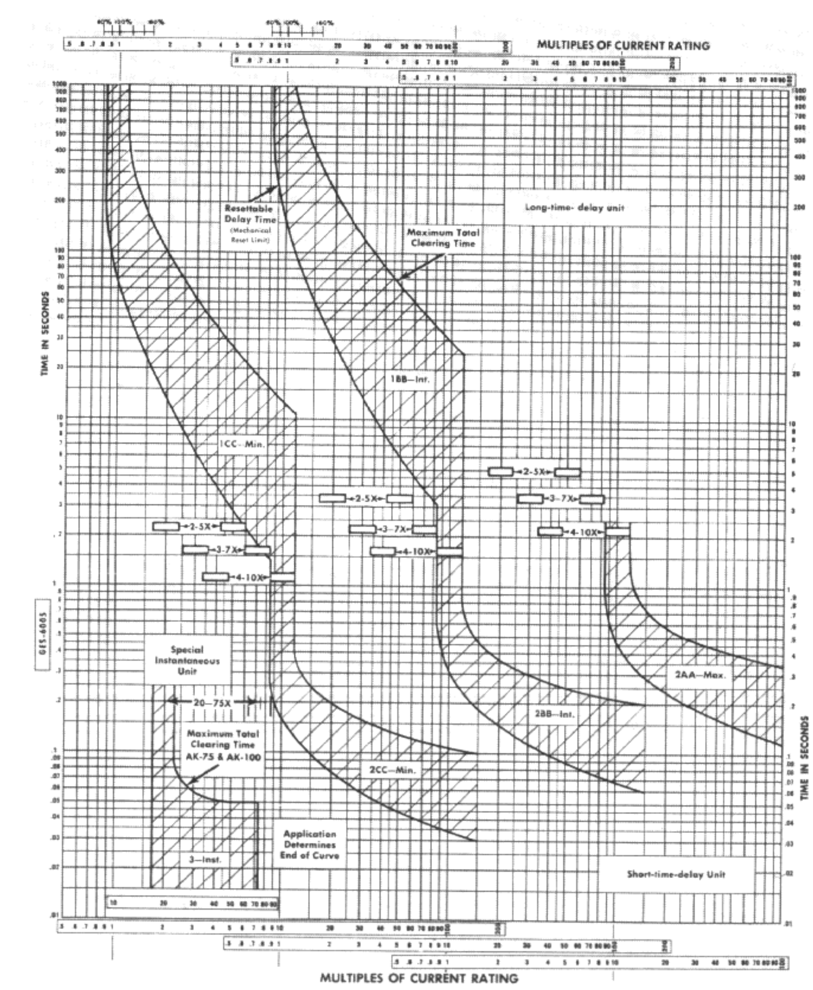


Fig. 43. EC-18 series trip device

Application Information

BREAKER ACCESSORIES

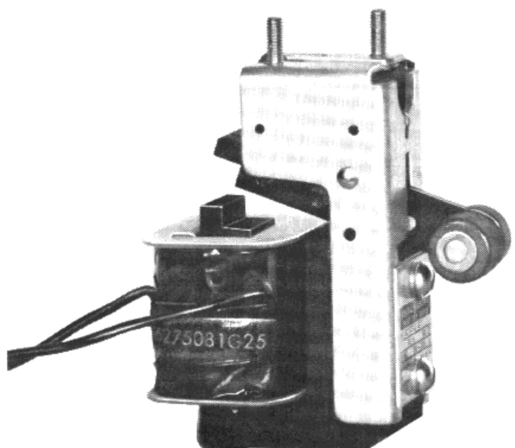


Fig. 44.

Shunt trip device, standard on electrically-operated breakers and optional on manual types, features a hinged armature that trips the breaker instantaneously when its coil is energized from a voltage source. Intended for remote electrical tripping from a control switch or push-button station, the device may also be used in conjunction with protective relays for automatic tripping.

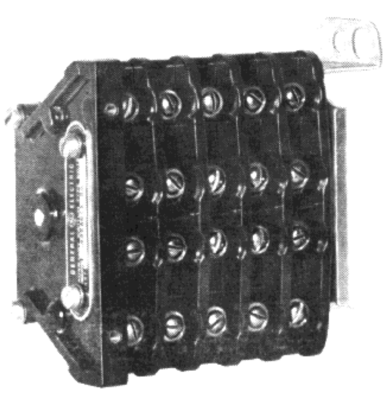


Fig. 45.

Auxiliary switches are devices with a rotary drum that provide necessary contacts of the "a" and "b" type to provide control in secondary circuits. Contacts operate as follows: "a" is closed when breaker is closed, "b" is open when breaker is closed. Standard arrangements comprise four contacts (two stages), or ten contacts (five stages). While alternate arrangements can be provided, two "a" and "b" switches are normally furnished on the four-contact switch with five of both types provided on a ten-contact switch. Special combinations of "a" and "b" contacts are available.

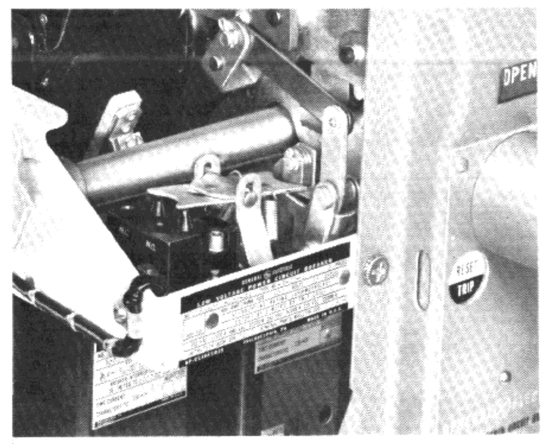


Fig. 46.

Bell alarm device, used to close a bell circuit or other signaling device indicating automatic breaker tripping, is actuated by opening of the breaker. Used also for interlocking purposes, a lockout device is added to the alarm circuit to mechanically lock the breaker at "open" when the device is actuated.

Current-closing rating of the contacts is 30 amperes at any voltage listed with 10 ampere continuous current-carrying capacity and inductive interrupting ratings as indicated.

TABLE XI

Volts D-C	
125	250
2.5A	0.9A

Volts A-C		
115	230	460
30A	15A	7A

TABLE XIII

Voltage Operating Range Volts	Volts	Amperes Inrush	Amperes Sustained
28–60	48 dc	4.5	4.5
70–140	125 dc	1.9	1.9
140–280	250 dc	1.0	1.0
95–125	115—60 cy	12.3	10.8
190–250	230—60 cy	6.9	5.7
380–500	460—60 cy	3.4	3.1
475–625	575—60 cy	2.8	2.5
175–225	208—60 cy	5.2	4.5
315–410	380—60 cy	2.9	2.6

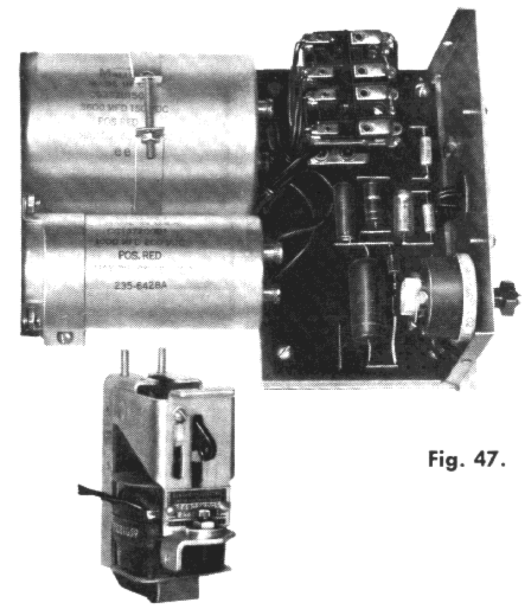


Fig. 47.

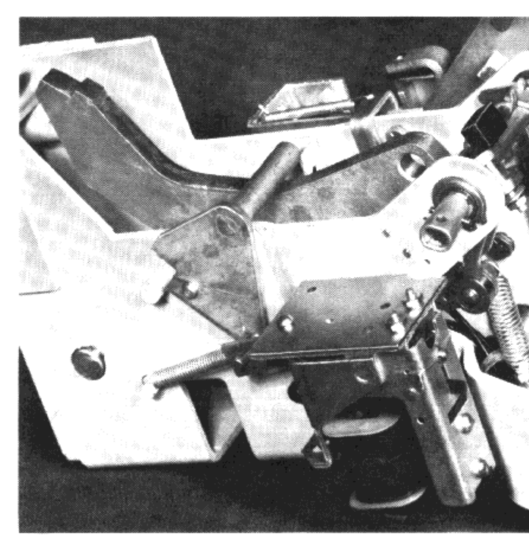


Fig. 48.

Electric lock-out device to cross-interlock two or more breakers, or to prevent closing a circuit breaker manually or electrically until certain control-circuit conditions exist. The device prevents the breaker from being closed either manually or electrically unless the coil is energized, but it will not trip the breaker if the coil is deenergized while the breaker is closed.

TABLE XII Undervoltage trip devices in AK-2 breakers are available in instantaneous form (left) and with time delay unit (right).

Volts d-c	Non-Inductive	Inductive	Volts a-c	Non-Inductive	Inductive
125	11A△5	6.25A△5	115	75A△5	15A△5
250	2A	1.75A	230	50A△5	10A△5
			460	25A△5	5A

△Limited to 20A continuous rating of switch on all breakers and to 5A continuous rating of No. 16 wire on drawout breakers.

Application Information

A-C POWER SYSTEM APPLICATION

The application tables on the following pages list the proper low-voltage power circuit breakers for load center applications. The power circuit breakers have been co-ordinated with transformer and system capacities — electrically, thermally, and mechanically.

BASIS FOR APPLICATION TABLES

Application tables are based on the following:

1. A three-phase bolted fault at the low-voltage terminals of the substation;
2. Transformer impedances listed in table;
3. Only source of power to the secondary is the substation transformer;
4. Total connected motor kva does not exceed 50 percent of transformer rating on 208Y/120-volt and 100 percent of transformer rating on 240-, 480-, and 600-volt systems;
5. The motor contribution is taken as 2.0 times the normal current of the transformer at 208Y/120 volts and 4.0 times normal at 240, 480, and 600 volts;
6. Coil sizes are listed for a circuit breaker applied at its maximum interrupting rating at the specified circuit voltage. Smaller coils may be used if available short-circuit current is less;
7. Tabulated values of short circuit current are in terms of RMS **symmetrical amperes** per NEMA Standard SG-3.

SUBSTATION ELECTRICAL ARRANGEMENT

Substations are available in a selective, fully rated, or cascaded arrangement. Care should be taken to specify the arrangement that provides the balance of selectivity and protection required by the power system.

SELECTIVELY CO-ORDINATED SUBSTATIONS

A selectively coordinated substation uses fully rated breakers with long-time and short-time trip characteristics (LS) to delay the opening of the main circuit breaker until the faulted feeder has had an opportunity to clear. This provides service continuity for all but the faulted circuit.

Selectivity may be carried a step further in the substation by specifying selective feeder circuit breakers that incorporate long-time and short-time characteristics (LS) to allow downstream devices to clear faults within their area.

A refinement of the selective feeder incorporates the long-time, short-time with high-set instantaneous characteristics (LSI) to provide selectivity without sacrificing instantaneous fault protection. Further, this combination of trip characteristics permits application of the breaker up to its interrupting rating with instantaneous trips. This is called the Zone-Selective arrangement and is often desirable when the load-center feeder serves a motor control center.

FULLY RATED SUBSTATIONS

Fully rated arrangements use fully rated breakers with long-time and instantaneous trip characteristics (LI) on both main and feeder circuit breakers. The main circuit breaker may, or may not, trip for a feeder fault—depending on fault magnitude.

CASCADED SUBSTATIONS

Cascaded arrangements allow feeder breakers to be applied on circuits that are subject to fault currents in excess of the normal published interrupting rating of the breakers.

Under the cascade system a short circuit on the feeder circuit may trip the main breaker. NEMA standards state that the operation of breakers in excess of their interrupting rating (as in cascade) is limited to one operation after which inspection, maintenance or complete replacement may be required. It is further recommended that all feeders applied in cascade be power operated from a remote location.

EXAMPLES

The tables make it easy to select the proper G-E breakers for use with each system. For instance, using a fully rated system, a 1000-kva, 480-volt load-center unit substation with a primary source having a 150 mva maximum available short-circuit capacity, requires an AK-50 main breaker with AK-25 feeder breakers.

Should either the main circuit breaker, or feeder circuit breakers be equipped with selective trips, the appropriate breakers may be found under the columns headed Main-Selective, and Feeder-Selective or Zone-Selective. The main circuit breaker is the same size whether fully rated (LI) or selective (LS). However, the frame sizes of feeder breakers will depend upon whether they are applied as fully rated (LI), selective (LS) or zone selective (LSI).

Further, the tables indicate the main (LI) and cascaded feeder breakers (LI) for cascaded systems with a wide range of primary available short-circuit capacities and transformer sizes.

CONTINUOUS CURRENT

The breaker types listed under the system headings satisfy the requirements for interrupting capacity. They may not be large enough to satisfy the requirements for continuous current rating, in which case, the next larger type should be used.

Table XIV—Summary of Breaker Types, Ratings

G-E Breaker Type	Voltage Rating 60 Cycles A-c	Interrupting Rating in Amperes, RMS Symmetrical		Overcurrent Trip Device Rating					Short-time Rating Symmetrical Amperes	Short Circuit Limit for 2-step Cascade Operation Amperes RMS Symmetrical
		With Inst. Trips	Without Inst. Trips	Min. with Instantaneous Characteristic	Min. with 2C Short-time Characteristic	Min. with 2B Short-time Characteristic	Min. with 2A Short-time Characteristic	Max. Breaker Rating		
AK-15		14,000	9,000	15	100	125	150	225	9,000	25,000
AK-25		22,000	22,000	40	175	200	250	600	22,000	42,000
AK-50	600	42,000	42,000	200	350	400	500	1600	42,000	85,000
AKT-50		42,000	42,000	200	350	400	500	2000	42,000	85,000
AK-75		65,000	65,000	2000	2000	2000	2000	3000	65,000	85,000
AK-100		85,000	85,000	2000	2000	2000	2000	4000	85,000	85,000
AK-15		22,000	9,000	20	100	125	150	225	9,000	42,000
AK-25		30,000	22,000	100	175	200	250	600	22,000	60,000
AK-50	480	50,000	50,000	400	350	400	500	1600	50,000	85,000
AKT-50		50,000	50,000	400	330	400	500	2000	50,000	85,000
AK-75		65,000	65,000	2000	2000	2000	2000	3000	65,000	85,000
AK-100		85,000	85,000	2000	2000	2000	2000	4000	85,000	85,000
AK-15		25,000	9,000	30	100	125	150	225	9,000	50,000
AK-25		42,000	22,000	150	175	200	250	600	22,000	85,000
AK-50	240	65,000	50,000	600	350	400	500	1600	50,000	100,000
AKT-50		65,000	50,000	600	350	400	500	2000	50,000	100,000
AK-75		85,000	65,000	2000	2000	2000	2000	3000	65,000	130,000
AK-100		130,000	85,000	2000	2000	2000	2000	4000	85,000	130,000

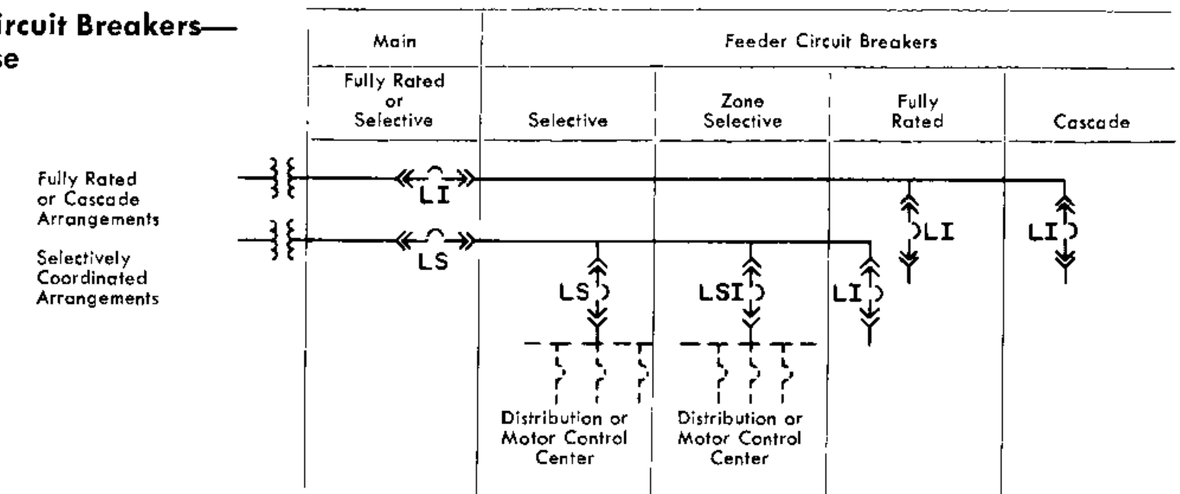
STANDARD CONTINUOUS CURRENT RATINGS

G-E Breaker Type	Continuous Current Ratings (Observe minimum limits set by application tables above and on pages 25-28)
AK-15	15, 20, 30, 40, 50, 70, 90, 100, 125, 150, 175, 200, 225
AK-25	40, 50, 70, 90, 100, 125, 150, 175, 200, 225, 250, 300, 350, 400, 500, 600
AK-50	200, 225, 250, 300, 350, 400, 500, 600, 800, 1000, 1200, 1600
AK-T5	2000
AK-75	2000, 2500, 3000
AK-100	2000, 2500, 3000, 4000

Application Information

A-C POWER SYSTEM APPLICATION

TABLE XV—Low-voltage Power Circuit Breakers—208 Volts, Three-phase



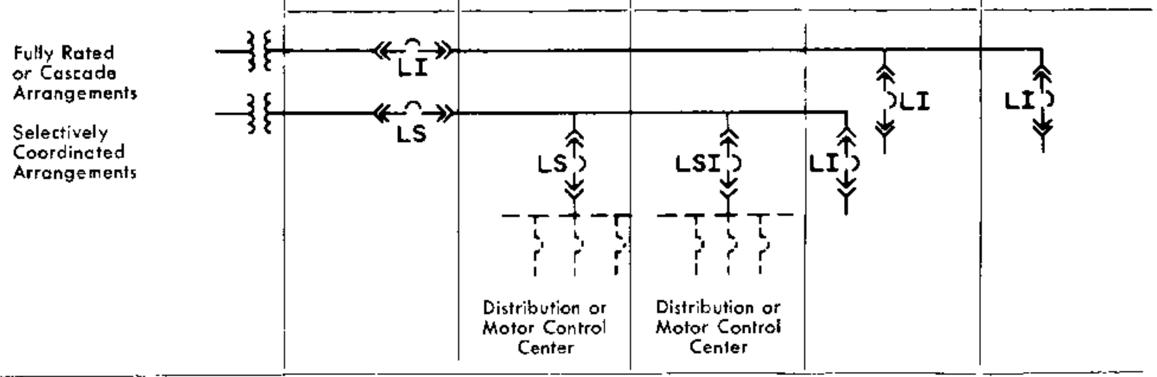
Transformer Rating 3-phase Kva and Impedance Percent	Maximum Short-circuit Mva Available From Primary System	Normal-load Continuous Current Amp	Short-circuit Current RMS Symmetrical Amp: Trans-former Alone	50% Motor Load	Combined	Long-time Instantaneous or Long-time Short-time: Breaker	Long-time Short-time: Breaker	Coil Size	Long-time Short-time Instantaneous: Breaker	Coil Size	Long-time Instantaneous: Breaker	Coil Size	Long-time Instantaneous: Breaker	Coil Size
						Minimum* Breaker and Coil Size Recommended								
300 **4.5%	50 100 150 250 500 750 Unlimited	833	16300 17300 17700 18000 18300 18400 18500	1700	18000 19000 19400 19700 20000 20000 20200	AK-50	AK-25	175	AK-15	100	AK-15	30	AK-15 is fully rated	30
500 **4.5%	50 100 150 250 500 750 Unlimited	1388	25300 27800 28700 29500 30200 30400 30800	2800	28000 29600 31500 32300 33000 33200 33600	AK-50	AK-50	350	AK-25	175	AK-25	150	AK-15	30
750 5.75%	50 100 150 250 500 750 Unlimited	2080	28700 32000 33300 34400 35200 35600 36200	4200	32900 36200 37500 38600 39400 39800 40400	AK-75	AK-50	350	AK-25	175	AK-25	150	AK-25	30
	50		35800		41400				AK-25	175	AK-25	150		
	100 150		41100 43200		46700 48800		AK-50	350	AK-50	350	AK-50	350	AK-15	30
1000 5.75%	250 500 750 Unlimited	2780	45100 46600 47300 48200	5600	50700 52200 52900 53800	AK-75	AK-75	2000					AK-25	150
	50		47600		55900		AK-75	2000	AK-50	350	AK-50	350		
1500 5.75%	100 150 250 500 750 Unlimited	4160	57500 61700 65600 68800 69900 72400	8300	65800 70000 73900 77100 78200 80700	No main breaker available	AK-100	2000	AK-75	2000	AK-75	2000	Cascade not possible since no main breaker available	

* If larger trip coils are required, see Table XIV—page 24.
L = Long-time delay trip (overload tripping).
S = Short-time delay trip (selective fault tripping).
I = Instantaneous trip (high fault fast tripping).
**Minimum impedance.

Application Information

A-C POWER SYSTEM APPLICATION

TABLE XVI—Low-voltage Power Circuit Breakers—240 Volts, Three-phase



Transformer Rating 3-phase Kva and Impedance Percent	Maximum Short-circuit Mva Available From Primary System	Normal-load Continuous Current Amp	Short-circuit Current RMS Symmetrical Amp: Transformer Alone	Short-circuit Current RMS Symmetrical Amp: 100% Motor Load	Short-circuit Current RMS Symmetrical Amp: Combined	Main (Fully Rated or Selective; Long-time Instantaneous or Long-time Short-time): Breaker	Feeder Circuit Breakers, Selective (Long-time Short-time): Breaker	Coil Size	Feeder Circuit Breakers, Zone Selective (Long-time Short-time Instantaneous): Breaker	Coil Size	Feeder Circuit Breakers, Fully Rated (Long-time Instantaneous): Breaker	Coil Size	Feeder Circuit Breakers, Cascade (Long-time Instantaneous): Breaker	Coil Size
300 **4.5%	50	722	14200	2900	17100	AK-50	AK-25	175	AK-15	100	AK-15	30	AK-15 is fully rated	30
	100		15000		17900									
	150		15400		18300									
	250		15600		18500									
	500		15800		18700									
	750		15900		18800									
	Unlimited		16000		18900									
500 **4.5%	50	1203	21900	4800	26700	AK-50	AK-50	350	AK-25	175	AK-25	150	AK-15	30
	100		24000		28800									
	150		24900		29700									
	250		25600		30400									
	500		26100		30900									
	750		26300		31100									
	Unlimited		26700		31500									
750 5.75%	50	1804	24900	7200	32100	AK-75	AK-50	350	AK-25	175	AK-25	150	AK-15	30
	100		27800		35000									
	150		28900		36100									
	250		29800		37000									
	500		30600		37800									
	750		30800		38000									
	Unlimited		31400		38600									
1000 5.75%	50	2406	31100	9600	40700	AK-75	AK-50	350	AK-25	175	AK-25	150	AK-15	30
	100		35700		45300				AK-50	350	AK-50	600		
	150		37500		47100									
					48700									
	250		39100		50100		AK-75	2000					AK-25	150
	500		40500		50600									
	750		41000		51500									
	Unlimited		41900											
1500 5.75%	50	3609	41300	14400	55700	AK-100	AK-75	2000	AK-50	350	AK-50	600	AK-25	150
	100		49800		64200									
	150		53500		67900		AK-100	2000	AK-75	2000	AK-75	2000		
	250		56900		71300									
	500		59700		74100									
	750		60600		75000									
	Unlimited		62800		77200									

Minimum* Breaker and Coil Size Recommended

* If larger trip coils are required, see Table XIV—page 24.
L = Long-time delay trip (overload tripping).
S = Short-time delay trip (selective fault tripping).
I = Instantaneous trip (high fault fast tripping).
**Minimum impedance.

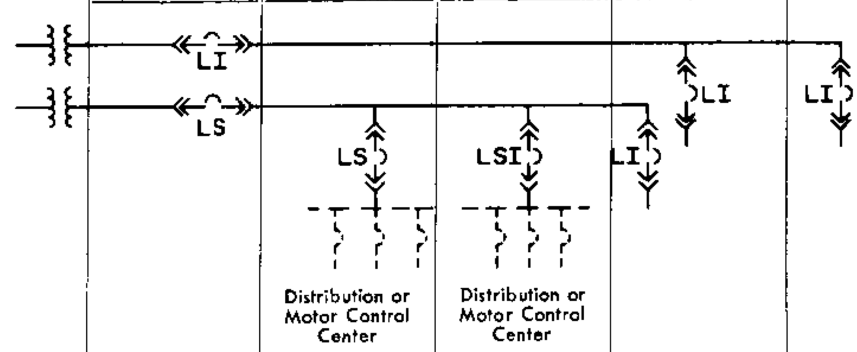
Application Information

A-C POWER SYSTEM APPLICATION

TABLE XVII—Low-voltage Power Circuit Breakers— 480 Volts, Three-phase

Fully Rated or Cascade Arrangements

Selectively Coordinated Arrangements



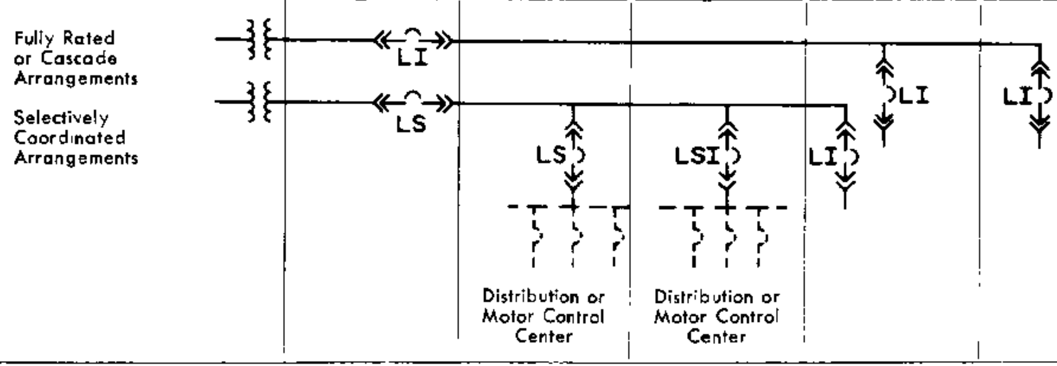
Transformer Rating 3-phase Kva and Impedance Percent	Maximum Short-circuit Mva Available From Primary System	Normal-load Continuous Current Amp	Short-circuit Current RMS Symmetrical Amp			Main: Fully Rated or Selective	Feeder Circuit Breakers: Selective		Feeder Circuit Breakers: Zone Selective		Feeder Circuit Breakers: Fully Rated		Feeder Circuit Breakers: Cascade	
						Long-time Instantaneous or Long-time Short-time	Long-time Short-time		Long-time Short-time Instantaneous		Long-time Instantaneous		Long-time Instantaneous	
						Minimum* Breaker and Coil Size Recommended								
			Trans-former Alone	100% Motor Load	Combined	Breaker	Breaker	Coil Size	Breaker	Coil Size	Breaker	Coil Size	Breaker	Coil Size
300 **4.5%	50	361	7100	1400	8500	AK-25	AK-15	100	AK-15	100	AK-15	20	AK-15 is fully rated	20
	100		7500		8900									
	150		7700		9100		AK-25	175						
	250		7800		9200									
	500		7900		9300									
	750		7900		9300									
	Unlimited		8000		9400									
500 **4.5%	50	601	10900	2400	13300	AK-50	AK-25	175	AK-15	100	AK-15	20	AK-15 is fully rated	20
	100		12000		14400									
	150		12400		14800									
	250		12800		15200									
	500		13100		15500									
	750		13200		15600									
	Unlimited		13400		15800									
750 5.75%	50	902	12500	3600	16100	AK-50	AK-25	175	AK-15	100	AK-15	20	AK-15 is fully rated	20
	100		13900		17500									
	150		14400		18000									
	250		14900		18500									
	500		15300		18900									
	750		15400		19000									
	Unlimited		15700		19300									
1000 5.75%	50	1203	15500	4800	20300	AK-50	AK-25	175	AK-15	100	AK-15	20		
	100		17800		22600		AK-50	350	AK-25	175	AK-25	100	AK-15	20
	150		18800		23600									
	250		19600		24400									
	500		20200		25000									
	750		20500		25300									
	Unlimited		20900		25700									
1500 5.75%	50	1804	20600	7200	27800	AK-75	AK-50	350	AK-25	175	AK-25	100	AK-15	20
	100		24900		32100				AK-50	350	AK-50	400		
	150		26700		33900									
	250		28400		35600									
	500		29800		37000									
	750		30300		37500									
	Unlimited		31400		38600									
2000 5.75%	50	2406	24700	9600	34300	AK-75	AK-50	350	AK-50	350	AK-50	400	AK-15	20
	100		31100		40700									
	150		34000		43600								AK-25	100
	250		36700		46300									
	500		39100		48700									
	750		40000		49600									
	Unlimited		41900		51500		AK-75	2000	AK-75	2000	AK-75	2000		
2500 5.75%	50	3008	28000	12000	40000	AK-100	AK-50	350	AK-50	350	AK-50	400		
	100		36400		48400									
	150		40500		52500		AK-75	2000	AK-75	2000	AK-75	2000	AK-25	100
	250		44500		56500									
	500		48100		60100								AK-50	400
	750		49500		61500									
	Unlimited		52300		64300									
3000 5.75%	50	3607	30700	14400	45100	AK-100	AK-50	350	AK-50	350	AK-50	400	AK-25	100
	100		41200		55600		AK-75	2000	AK-75	2000	AK-75	2000		
	150		46500		60900								AK-50	400
	250		51900		66300		AK-100	2000	AK-100	2000	AK-100	2000		
	500		56800		71200									
	750		58700		73100									
	Unlimited		62700		77100									

* If larger trip coils are required, see Table XIV—page 24.
L = Long-time delay trip (overload tripping).
S = Short-time delay trip (selective fault tripping).
I = Instantaneous trip (high fault fast tripping).
**Minimum impedance.

Application Information

A-C POWER SYSTEM APPLICATION

TABLE XVIII—Low-voltage Power Circuit Breakers—600 Volts, Three-phase



Transformer Rating 3-phase Kva and Impedance Percent	Maximum Short-circuit Mva Available From Primary System	Normal-load Continuous Current Amp	Short-circuit Current RMS Symmetrical Amp: Trans-former Alone	Short-circuit Current RMS Symmetrical Amp: 100% Motor Load	Short-circuit Current RMS Symmetrical Amp: Combined	Main (Fully Rated or Selective; Long-time Instantaneous or Long-time Short-time): Breaker	Feeder Selective (Long-time Short-time): Breaker	Coil Size	Feeder Zone Selective (Long-time Short-time Instantaneous): Breaker	Coil Size	Feeder Fully Rated (Long-time Instantaneous): Breaker	Coil Size	Feeder Cascade (Long-time Instantaneous): Breaker	Coil Size
						Minimum* Breaker and Coil Size Recommended								
300 **4.5%	50 100 150 250 500 750 Unlimited	289	5700 6000 6100 6200 6300 6400 6400	1200	6900 7200 7300 7900 7500 7600 7600	AK-25	AK-15	100	AK-15	100	AK-15	15	AK-15 is fully rated	15
500 **4.5%	50 100 150 250 500 750 Unlimited	481	8700 9600 10000 10200 10500 10500 10700	1900	10600 11500 11900 12100 12400 12400 12600	AK-25	AK-25	175	AK-15	100	AK-15	15	AK-15 is fully rated	15
750 5.75%	50 100	722	9900 11100	2900	12800 14000	AK-50	AK-25	175	AK-15	100	AK-15	15	AK-15 is fully rated	15
	150 250 500 750 Unlimited		11500 11900 12200 12300 12500		14400 14800 15100 15200 15400				AK-25	175	AK-25	40	AK-15	15
1000 5.75%	50 100 150 250 500 750 Unlimited	962	12500 14300 15000 15700 16200 16400 16800	3800	16300 18100 18800 19500 20000 20200 20600	AK-50	AK-25	175	AK-25	175	AK-25	40	AK-15	15
1500 5.75%	50	1444	16500	5800	22300	AK-50	AK-50	350	AK-50	350	AK-50	200	AK-15	15
	100 150 250 500 750 Unlimited		19900 21400 22700 23800 24200 25100		25700 27200 28500 29600 30000 30900								AK-25	40
2000 5.75%	50 100 150 250 500 750 Unlimited	1924	19700 24800 27200 29400 31200 32000 33500	7700	27400 32500 34900 37100 38900 39700 41200	AK-75	AK-50	350	AK-50	350	AK-50	200	AK-25	40
2500 5.75%	50 100 150	2406	22400 29200 32400	9600	32000 38800 42000	AK-75	AK-50	350	AK-50	350	AK-50	200	AK-25	40
	250 500 750 Unlimited		35700 38500 39600 41900		45300 48100 49200 51500		AK-75	2000	AK-75	200	AK-75	2000	AK-50	200
3000 5.75%	50	2886	24600	11500	36100	AK-75	AK-50	350	AK-50	350	AK-50	200	AK-25	40
	100 150 250 500 750 Unlimited		33000 37300 41600 45500 47000 50200		44500 48800 53100 57000 58500 61700		AK-75	2000	AK-75	2000	AK-75	2000	AK-50	200

* If larger trip coils are required, see Table XIV—page 24.
L = Long-time delay trip (overload tripping).
S = Short-time delay trip (selective fault tripping).
I = Instantaneous trip (high fault fast tripping).
**Minimum impedance.

Application Information

D-C POWER SYSTEM APPLICATION

D-C MACHINE CIRCUITS

D-c rotating machines are subject to burning of the commutator and brushes and to possible flashover on currents above the commutation limit, which is usually about 200 percent of the continuous rating. For this reason, it is necessary to disconnect such machines quickly from the circuit. Hence, power circuit breakers with instantaneous overcurrent trip devices, adjustable from 80 to 250 percent of the breaker rating, are generally recommended for d-c machines and feeders. For marine service, and such other applications where some sacrifice in machine protection is justified to ensure maximum continuity of service, the dual-magnetic trip, with inverse time tripping from 80 to 160 percent of the breaker rating, and instantaneous tripping at 8 to 12 times rating, can be used for d-c machines rated 250 volts and below.

For d-c generators and synchronous converters for general two-wire service, the recommended arrangements are shown in Fig. 49 and Fig. 52, with explanatory notes. Circuits to d-c motors should have the same arrangements as the d-c feeders.

For d-c, 3-wire machines, overcurrent protection is required in both sides of the armature, as shown in Fig. 51.

Time overcurrent protection is recommended for the neutral circuit, generally as part of an additional pole on the machine breaker. Usually the continuous rating of the machine neutral is approximately 25 percent of the full-load line current of the machine. This requires that the center pole on the 3-pole breaker shown in Fig. 51 be of lower capacity than the other poles, with calibration adjustable from 80 to 250 percent of the pole rating.

When two 2-wire generators are connected in series to supply power to a 3-wire system which gives a full-capacity neutral, a 3-pole breaker which has one pole in the positive lead, one in the negative, and the third in the common neutral circuit of the two generators is recommended. Each pole is provided with overcurrent protection, as shown in Fig. 52.

For very low-voltage d-c generators (of about 25 volts or less), such as are used for electrolytic service, it is usually not considered necessary to employ the high-current breakers which ordinarily would be required. For these machines, instantaneous overcurrent relays in the armature circuit (which function to reduce the generator field current) generally afford sufficient protection.

For excitors, it is not customary to furnish overcurrent protection. Sometimes, however, several exciters may be operated in parallel. In such cases, current-directional protection is recommended for each exciter. This should be of such a characteristic that it will trip its circuit breaker only on values of reverse current above those which may be caused by inductive action between the a-c machine armature and its field circuit, when a system disturbance occurs. Because the required settings of the current-directional device may be above the continuous-current rating of the breaker, it is generally necessary to provide separate reverse-current relays rather than direct-acting, reverse-current devices on the breakers. A two-pole nonautomatic breaker with a shunt-trip device, or a contactor, is required for each exciter for this application.

EQUALIZER CIRCUITS

Although knife switches can be used in the equalizer circuits of compound-wound machines, the use of power circuit breakers (as indicated in Fig. 50 to 52) usually offers advantages in switchgear, station layout, and operation. Because the equalizer circuit can in most applications be closed and opened simultaneously with the armature circuit, it is advantageous to use multipole breakers for combining both functions. The equalizer breaker poles need not be provided with overcurrent tripping, as the overcurrent protection to a machine must be provided in the armature circuit.

In two two-wire generators in series, the series fields of both generators are connected in the neutral side of each armature. A separate, two-pole equalizer breaker should be furnished for parallel operation, as illustrated in Fig. 52. This breaker (or double-pole switch, if switch is used) must be closed before the line breaker is closed, and opened after the line breaker trips.

Normally, the amount of current in an equalizer circuit is small, but this circuit must have a low resistance to be effective. It is recommended that the rating of the equalizer circuit and the devices be approximately one-third to one-half of the maximum or overload rating of the d-c machine.

REVERSE-CURRENT PROTECTION

For d-c generators and synchronous converters operating in parallel, or in parallel with another source, particularly in machines above 300 kw, it is desirable to provide current-directional or reverse-current devices on the circuit breakers to prevent abnormal interchange of current between the machines; also, to give more sensitive and faster internal-fault protection than is afforded by the overcurrent tripping devices. These reverse-current tripping devices (or separate reverse-current relays), used to trip the circuit breakers, are particularly recommended for d-c generators and synchronous converters which have time-overcurrent trip on the generator circuit breakers. The setting of these reverse-current devices should be as low as operating conditions will permit, but it must be high enough to prevent unnecessary tripping on normal values of regenerated load, or on slight interchange of current between the machines at light load. The setting of standard G-E reverse-current devices is 10 percent of the breaker rating.

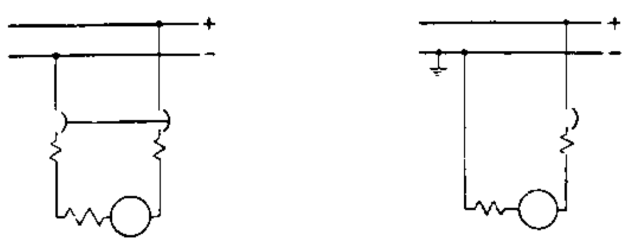
To give the best protection, each machine circuit breaker requires the same number of reverse-current tripping elements (whether devices on the breaker, or separate relays) in the armature circuits as there are overcurrent trips. In d-c, 3-wire machines, however, reverse-current protection is frequently provided in one side only, at some sacrifice in machine protection.

In some applications, protection from loss of driving power is necessary. In these cases, and in unattended (automatic) stations, current-directional relays rather than the reverse-current devices on the breakers themselves must be used to obtain the required degree of sensitivity. Such sensitive protection is liable to trip the machine under conditions of regenerated load, or of momentary interchanges of current among several machines that operate in parallel, and accordingly, these applications require special consideration.

Application Information

D-C POWER SYSTEM APPLICATION

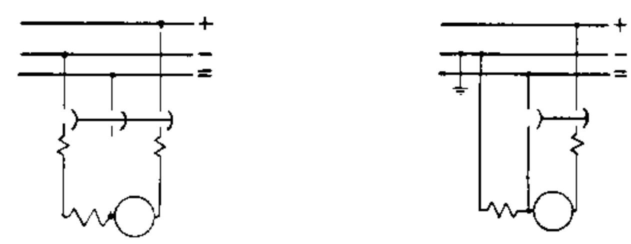
Direct-current Machine Circuits



(a) Ungrounded negative
One 2-pole breaker with two overcurrent trips

(b) Grounded negative
One 1-pole breaker with one overcurrent trip

Fig. 49. D-c, 2-wire, shunt-wound generator or synchronous converter, or compound-wound machine, for isolated operation



(a) Ungrounded negative
One 3-pole breaker with two overcurrent trips

(b) Grounded negative
One 2-pole breaker with one overcurrent trip

Fig. 50. D-c, 2-wire, compound-wound generator of synchronous converter, for parallel operation

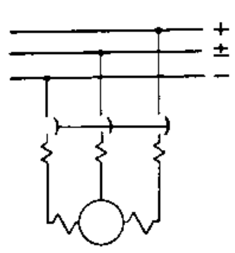


Fig. 51. D-c, 3-wire, shunt-wound generator or synchronous converter, or compound-wound machine, for isolated operation, grounded or ungrounded neutral

One 3-pole breaker with three* overcurrent trips (see Note A)

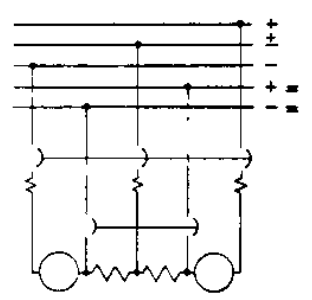


Fig. 52. D-c, 2-wire generators in series for 3-wire service, for parallel operation with other similar machines, grounded or ungrounded neutral

One 3-pole main and neutral breaker with three overcurrent trips and one 2-pole equalizer breaker with no overcurrent trips

Note A—For 3-wire, d-c machines, Fig. 51, a circuit-breaker pole with trip is shown in the neutral circuit. For 6-phase, 3-wire, d-c synchronous converters, some means must be provided additionally for disconnecting and segregating the transformer neutrals during the starting period (when the starting is done by means of taps in the low-voltage transformer windings).

* The overcurrent device on the breaker pole in the neutral circuit is usually of reduced capacity (25%), and should be calibrated for setting from 100 to 200 percent of the neutral pole rating.

D-C FEEDER CIRCUITS

Figs. 53 to 57, inclusive, show the required arrangements of breaker poles and overcurrent trip devices for the protection of feeder circuits on the various types of d-c systems. Since a majority of the feeder loads will be motors the recommendations for the protection of d-c machine circuits should be followed in selecting the overcurrent trip devices.

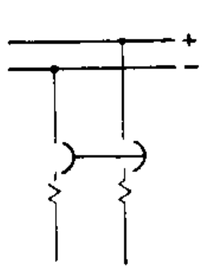


Fig. 53. Two-wire, ungrounded

† One 2-pole breaker with two overcurrent trips

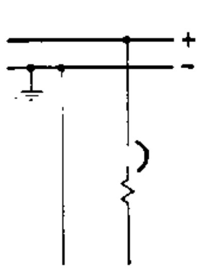


Fig. 54. Two-wire, grounded

¶ One 1-pole breaker with one overcurrent trip

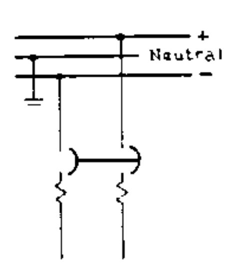


Fig. 55. Two-wire, connected to outside wires of three-wire grounded neutral circuit

One 2-pole breaker with two overcurrent trips

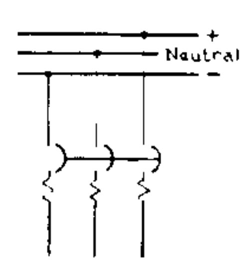


Fig. 56. Three-wire, ungrounded

One 3-pole breaker with three overcurrent trips

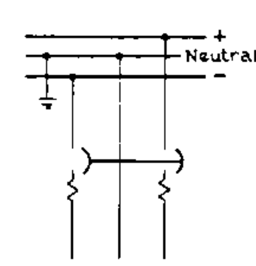


Fig. 57. Three-wire, grounded

¶ One 2-pole breaker with two overcurrent trips (one in each conductor, except neutral)

† Exception may be made for certain types of d-c feeders using single-pole circuit breakers.

¶ On incoming service lines, where the National Electrical Code applies, reference should be made to paragraph 2351a. If the switch or circuit breaker does not interrupt the grounded conductor, other means shall be provided in the service cabinet or on the switchboard for disconnecting the grounded conductor from the interior winding.

D-C APPLICATIONS (Cont'd)

UNDERVOLTAGE DEVICES

For d-c generators or synchronous converters which operate in parallel with another source, it is desirable to insure the disconnection of the machine from the system, both on normal and emergency shutdowns, in order that the machine cannot subsequently be subjected to voltage from the system source. For manually operated breakers this requires a direct-acting undervoltage device with its coil connected across the machine armature circuit. For synchronous converters or for motor-driven generators, the coil of the undervoltage device should be placed in series with the normally open auxiliary switch on the running breaker or field contactor, whichever closes last in the starting sequence. Also, for d-c machines equipped with overspeed or other protective devices, or a control switch for remote tripping, and without a reliable source of tripping power in the station (such as an operating or tripping storage battery).

FIELD DISCHARGE BREAKERS

These breakers are equipped with a field discharge clip using silver-alloy contacts. This clip is connected to the main-contact operating shaft and, therefore, operates independently of the breaker mechanism. The field-discharge clip closes BEFORE the main circuit is broken, thus assuring positive protection for field coils against high induced voltages when the breaker is opened either normally or by a protective device or relay. With the AKF breakers the field-discharge clips overlap the main contacts both opening and closing.

Double-pole field breakers are available as follows:

TABLE XIX

Type	D-c Voltage Rating	Continuous Amp Rating	Nominal Field Voltage Rating— D-c Volts
AKF-1B	250	600	125/250
AKF-2C	500	2000	250/375/500
AKF-2D	500	4000	250/375/500

OPERATING MECHANISMS

Power-circuit breaker operating mechanisms perform the function of closing and opening the breaker contacts in response either to a manual effort or an electrical signal. Basically, operating mechanisms fall into two categories.

a. Direct acting in which the closing force is furnished by an operator (manual) solenoid or motor (electrical).

b. Stored energy (both manual and electrical) in which an energy storing means is interposed between the control source and the breaker contacts.

In recent years, there has been a strong trend towards energy operating mechanisms because of the important advantages they offer. These include: increased safety of operation, prolonged contact and breaker life, wider breaker application, particularly selective tripping and motor starting, reduced maintenance and a reduction in control power requirements for electrical breakers.

General Electric Type AK circuit breakers utilize stored energy closing mechanisms. Models are available for either manual or electrical operation.

STORED ENERGY CLOSING

A spring-operated "stored energy" closing mechanism provides fast, constant-speed closing for either electrical or manual AK-2-15 and AK-2-25 power circuit breakers. This mechanism, an extension of the principle long used in large-sized AK breakers, provides a closing speed completely independent of the operator (manual) or the voltage level of the control power source (electrical).

A manually operated breaker uses an insulated plastic handle. To close the breaker, the handle is first rotated counter-clockwise through approximately 100 degrees. This resets the mechanism and partially stores energy in the closing spring. The handle is then rotated clockwise, completing the charging of the springs. As it approaches the normal rest position, the mechanism goes "over center," releasing energy to close the contacts. Upon receiving a tripping impulse, the breaker contacts are driven open at high speed by the same springs that are used for closing. A unique "rebound latch" which operates only during opening, prevents the contacts from rebounding in the closing direction.

Electrically operated models use an a-c or d-c solenoid to charge the closing spring and provide total closing time of less than 5 cycles from the instant the close button is energized. The solenoid is small, compact, has a low total-energy requirement, and affords greater accessibility for adjustment of overload trip devices. Electrically operated breakers are normally furnished without manual handles, but with a maintenance closing device.

The electrical stored energy closing mechanism utilizes energy stored in powerful closing springs to close the breaker contacts. A small universal motor, which can be operated from ac or dc, drives a gear reducer unit. The output of this unit charges the closing springs through a charging crank and cam.

In the charged position, the springs are positively blocked by the "advance of center" location of the charging crank with respect to the charging cam. When the closing switch is operated the motor quickly drives the crank over center, releasing the springs and closing the contacts. Once the springs are released, the contacts will close regardless of continuity of control power. This is important when breakers are accidentally closed in on a short circuit and the control power source is the main bus.

Recharging is done immediately after a closing operation at a low rate of energy input. This means low closing current—only 4 amp at 115 volts ac. The springs, therefore, are always charged and ready to close the breaker.

Contacts require considerably more energy for closing under short circuit or overload conditions than under normal load. Each time the springs are charged, there is enough energy stored to close the contacts under full short-circuit conditions. Energy in excess of that required to close the breaker under a particular load is absorbed by the flywheel effect of the gear box, and is returned to the closing springs.

A second set of springs is used to open the contacts when the breaker receives a trip impulse.

A detachable ratchet handle, which can be slipped over the extension shaft of the gear box, is provided for maintenance operation.

Application Information

CONTROL-POWER REQUIREMENTS

Successful operation of electrical breakers is dependent on a reliable control-power source. The operating currents of the closing mechanisms and shunt trip coils together with control-circuit fuse ratings and operating voltage ranges are listed in Table XX.

Note: The following control-power transformers are recommended where only one breaker at a time is being closed.

AK-2-15, -25	3 KVA (All control voltages)
AK-2-50, AK-2-75, AK-2-100	½ KVA (All control voltages)

TABLE XX—Operating Currentsψ

Type of Breaker	Ampere Rating	Closing Mechanism: 115-volt, 60-cycle (Operating Range 95–125 V) — Operating Current in Amperes at Rated Volts	Ampere Rating of Fuse	Closing Mechanism: 230-volt, 60-cycle (Operating Range 190–250 V) — Operating Current in Amperes at Rated Volts	Ampere Rating of Fuse	Closing Mechanism: 125-volt, D-c (Operating Range 90–130 V) — Operating Current in Amperes at Rated Volts	Ampere Rating of Fuse	Closing Mechanism: 250-volt, D-c (Operating Range 180–260 V) — Operating Current in Amperes at Rated Volts	Ampere Rating of Fuse	Shunt Trip (Operating Current in Amp At Rated Volts; Min Recommended Fuse Rating for All Trip Circuits—30 Amp): 115 V 60-cycle Range 95–125 V	230 V 60-cycle Range 190–250 V	125 V D-c Range 70–140 V	250 V D-c Range 140–280 V
AK-2-15 AK-2-25	15–225 40–600	153/78φ	30	68/28φ	15	44/44φ	10	24/24φ	6	12.3/10.8φ	6.9/5.7φ	1.9/1.9φ	1.0/1.0φ
AK-2-50	200–1600	9/4φ	6	4/2.6φ	6	30/4φ	6	15/2φ	6	12.3/10.8φ	6.9/5.7φ	1.9/1.9φ	1.0/1.0φ
AK-2-75	2000–3000	9/4φ	6	4/2.6φ	6	30/4φ	6	15/2φ	6	12.3/10.8φ	6.9/5.7φ	1.9/1.9φ	1.0/1.0φ
AK-2-100	4000	9/4φ	10	4/3.2φ	10	30/5φ	10	15/2.5φ	10	12.3/10.8φ	6.9/5.7φ	1.9/1.9φ	1.0/1.0φ

ψ Values listed for operating currents are subject to change and should be used for estimating purposes only.
φ Inrush/sustained.

REPETITIVE DUTY

Circuit breakers are designed primarily to perform the function of circuit interruption under short-circuit conditions. Nevertheless modern circuit-breaker mechanisms are capable of many operations under full-load operation and inrush conditions such as encountered in motor starting applications. Industry standards have been established for the minimum performance which is indicated in Table XXI. With adequate maintenance G-E breakers can be expected to exceed the standards. Refer to Switchgear Marketing when questions arise with respect to specific applications.

TABLE XXI—Repetitive Duty and Normal Maintenance

Frame Size of Breaker	Circuit Breaker Designation Interrupting Rating, Amperes	Number of Operations: Number of Operations Between Servicing, Par. A	No Load Mechanical, Par. B, E, F, G, H, and I	Full Load Nonfault, Par. C, E, F, G, H, and J	Full Load Fault, Par. C, E, F, G, H, I, and K	Inrush Nonfault, Par. D, E, F, G, H, and J	Inrush Fault, Par. D, E, F, G, H, I, and K
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
225	15,000	2500	50,000	5000	4000	3500	2500
600	25,000	1750	35,000	3500	2800	2500	1750
1600	50,000	500	10,000	1000	800	750	500
3000	75,000	250	5,000	500	400	....	....
4000	100,000	250	5,000	500	400	....	....

NOTES FOR TABLE XXI

Power-operated circuit breakers, when operating under usual service conditions, shall be capable of operating the number of times specified in the above table. The operating conditions and the permissible effect of such operations upon the breaker are given in the following lettered paragraphs. For each column, all paragraphs listed in the column heading must be given consideration.

This standard applies to all parts of a circuit breaker that function during normal operation. It does not apply to other parts, such as overcurrent tripping devices, that function only during infrequent abnormal circuit conditions.

SERVICING

A. Servicing shall consist of adjusting, cleaning, lubricating, tightening, etc. as recommended by the manufacturers. The operations listed are on the basis of servicing at intervals of six months or less.

CIRCUIT CONDITIONS

B. When closing and opening no load.

C. When closing and opening currents up to the continuous current rating of the circuit breaker at voltages up to the maximum design voltage and at 80 percent power factor or higher.

D. When closing currents up to 600 percent and opening currents up to 100 percent (80 percent power factor or higher) of the continuous current rating of the circuit breaker at voltages up to the maximum design voltage.

OPERATING CONDITIONS

E. With rated control voltage applied.

F. Frequency of operation not to exceed 20 in 10 minutes or 30 in one hour. Rectifiers or other auxiliary devices may further limit the frequency of operations.

G. Servicing at no greater intervals than shown in Column 2 of the table.

CONDITION OF THE CIRCUIT BREAKER AFTER THE OPERATIONS SHOWN IN THE TABLE

H. No parts shall have been replaced except as qualified by par. K.

I. Circuit breaker shall be in a condition to meet all of its current, voltage and interrupting ratings.

J. The circuit breaker shall be in a condition to meet all its current and voltage ratings but not necessarily its interrupting rating.

OPERATION UNDER FAULT CONDITIONS

K. If a fault operation occurs before the completion of the permissible operations, it is not to be inferred that the breaker can meet its interrupting rating or complete its number of operations without servicing and making replacements if necessary.

Guide form specifications

GENERAL SPECIFICATIONS

The individually mounted low-voltage power circuit breaker shall consist of an electrically and mechanically trip-free circuit breaker element and a suitable mounting enclosure (except for dead front units). The circuit breaker element shall be equipped with direct acting dual-magnetic overcurrent tripping devices, a manual or electrical operating mechanism, multiple finger type contact structure provided with arc quenchers. It shall include interpole barriers, mechanical push-button trip, position indicator and provisions for up to three padlocks to lock the breaker in a trip-free position. The manual or electrical closing mechanism shall be the stored energy type to provide "quick make, quick break" operation.

The circuit breaker enclosure shall be code gage steel or cast iron (explosion proof) and shall be phosphate coated, primed and finished with synthetic-alkyd paint.

Enclosures shall be of the NEMA type specified and shall not require pull boxes for making connections. Circuit breaker elements shall be drawout or easily removable types.

DETAILED SPECIFICATIONS

Fill in	This specification covers .. low voltage power circuit breakers rated
Number	Breakers rated
Fill in	Amperes maximum frame size
Rating	Amperes RMS symmetrical interrupting capacity.
	..... Volts (AC . Cycles) (DC)
	Amperes trip coil rating
Cross out one	Dual magnetic overcurrent trips to provide (long time delay) (selective) instantaneous characteristic
	(Manual) (Electrical) stored energy operating mechanism
Cross out accessories not required	Breaker accessories (shunt trip) (undervoltage trip instantaneous) (undervoltage trip, time delay) (overcurrent bell alarm) (lockout device) (auxiliary switch)
Cross out six	Enclosure to be (dead front switchboard) (skeleton drawout) (general purpose, NEMA type 1) (semi-dust-tight, NEMA type 1A) (weatherproof NEMA Type 3) (dust-tight, water-tight, NEMA Types 4 and 5) (explosion-proof, NEMA Type 7)
Cross out one	The breaker shall be suitable for 3-phase (3-wire) (4-wire) service
Cross out if not required	Means shall be provided for connecting to a busway stub
Fill in number and size of cables	Cable lugs are to be supplied for . . . # . . .... cables per phase

TABLE XXII

INDOOR AKD-5	Max. NUMBER PER STACK	HEIGHT	DEPTH	WIDTH
AKU-2A-25	4	91¾"	60"	20"
AKU-2A-50	3	91¾"	60"	27"
•AK -2A-75	1*	91¾"	60"	30"
•AK -2A-100	1*	91¾"	60"	38"

TABLE XXIII

OUTDOOR AKD-5	Max. NUMBER PER STACK	HEIGHT	DEPTH	WIDTH
AKU-2A-25	4	114½"	108½"	20"
AKU-2A-50	3	114½"	108½"	27"
•AK -2A-75	1*	114½"	108½"	30"
•AK -2A-100	1*	114½"	108½"	38"

(*) With separately mounted fuses

THE FOLLOWING FOUR-STEP PROCEDURE WILL SERVE AS A GUIDE IN SELECTING A FUSED BREAKER:

1. Calculate the available short-circuit current at the point of application in terms of rms symmetrical amperes. (If the calculated available short-circuit current is below 200,000 amperes no further consideration need be given to this point.)
2. Determine the continuous current rating of the breaker on the basis of established practices considering the characteristics of the load and the protection to be provided for conductors.
3. Select the trip device characteristics based on the load characteristics and the type of protection to be provided.
4. Determine the rating of the fuse which co-ordinated with the trip rating and characteristics selected (see co-ordination tables).

Fused circuit breakers shall be stored-energy closing mechanisms, racking mechanisms, mechanical interlocks, three over-current trip devices and read-mounted current limiting fuses in series. All low-voltage power circuit breakers shall be equipped with an open fuse lockout device that is visible from the front of the breaker and capable of indicating which fuses are blown, tripping all three phases of the breaker upon the fuse blowing and preventing the circuit breaker from being reclosed on a single phase condition.

The circuit breaker shall be of the drawout type capable of being racked to the disconnect position with the door closed. Interlocks will be provided to prevent connecting or disconnecting the circuit breaker unless the breaker is open. The breaker shall be prevented from being closed during any racking operation. A test position shall be provided to permit operating the breaker while it is disconnected from the power circuit. Current limiting fuses shall be readily accessible for maintenance without removing the circuit breaker from the equipment.

Each switchgear section shall be factory-assembled with stored-energy closing of fused-drawout circuit breaker equipment with all components integrally mounted on a drawout tray listed as follows:

....main secondary breaker(s),
... .amperes continuous current,
.. . . amperes interrupting capacity
at . .... .V: a-c (manually, electrically) operated, with CLF current limiting fuses.

.. .. feeder breaker(s),
.... amperes continuous current,
.... .. amperes interrupting capacity
at ..... V a-c (manually, electrically) operated, with CLF current limiting fuses.

Power Sensor Guide Form Specifications

The overcurrent trip devices to be furnished with type AK stored energy power circuit breakers shall be of three phase construction and employ solid-state components in their design to afford a combination of long time, short time (optional) and instantaneous tripping characteristics. The power circuit breaker and integral solid-state trip device shall be self-contained to include necessary power supply, transformers and tapped current level sensing transformers. An external source of power shall not be required to trip the power circuit breaker under fault or overload conditions.

The combination of current sensor tap and long time-delay pickup setting shall result in a minimum adjustability of 40% to 130%. Three time delay bands —minimum, intermediate and maximum—shall be provided for the long time-delay adjustment. The short time band pickup (optional) shall be 2 to 5 times or 4 to 10 times the trip setting. Definite set adjustments shall be provided within the fixed range of the short time characteristic selected. The short time-delay characteristic shall be adjustable to three time bands—minimum, intermediate and maximum.

The instantaneous pickup adjustment shall be adjustable in fixed steps from 4 to 12 times the trip rating set value. No time delay shall be introduced before power circuit breaker tripping.

Ground fault tripping shall be available by employing a separate set of current sensors connected to detect ground fault currents. For three-phase three-wire systems, three current sensors are employed. On four-wire systems, a fourth current sensor located in the neutral conductor shall be furnished, which takes into account normal neutral currents. Separate circuitry shall be provided in the solid-state unit to receive this signal. Ground fault pickup value shall be adjustable in fixed steps with ranges of 100-400 amperes, 300-1200 amperes and 750-3000 amperes and with time delays of .06 seconds adjustable in 5 steps to .30 seconds.

For wide selection and field adjustment of the solid-state trip device current level sensing transformers shall be tapped so that numerous trip rating set values may be easily changed in the field.

All three phases shall be adjustable in the field without dis-assembly of components by locating one positioning knob which inserts fixed resistors into the solid-state circuitry. The fixed resistors shall provide repeatable accuracy of adjustments. Hole plates with clear markings shall provide rapid and precise identification of the various settings. The solid-state trip device unit shall be free from aging or shifting characteristics due to changes in ambient temperature from −20°C to +55°C. The solid-state circuitry shall not be affected by external magnetic fields and conversely shall not generate interference to external electronic equipment. To assure that the solid-state overcurrent trip device is within calibration as a part of periodic maintenance program, field testing shall be possible on the solid-state trip unit while mounted on the de-energized breaker. Testing shall confirm that the tripping points fall within the characteristic curve. Also it should be possible to check the trip circuit of the breaker. The solid-state trip unit shall be the same for all frame size power circuit breakers. By removing a disconnect plug it may be isolated and removed from the breaker after loosening one mounting bolt.

BREAKER IDENTIFICATION

The following means should be used to specify a power circuit breaker with Power Sensor solid-state trips.

1. Identify the breaker according to frame size. (See table, page 18.) Breakers with Power Sensor designated AK-3 15, 25, 50, 75 or 100.
2. Specify long time-delay trip rating. (See Table VIII, page 18.) Note trip settings and time bands are adjustable in the field.
3. Select desired combination of characteristics such as long time-delay and instantaneous, long time-delay and short time-delay and ground fault protection with characteristics. (See Table VIII, page 18.)

EXAMPLES

A. To select a 400 amp feeder breaker 480v a-c with long time-delay and instantaneous tripping, specify AK-3-25 with 400 amp trip rating; Power Sensor with long time-delay and instantaneous.

B. To select a main breaker for a selective system rated 2000 amp 480v a-c and include ground fault protection specify AK-3-75 with 2000 amp trip rating; Power Sensor long time-delay, short time-delay and 3-wire ground fault protection. (See Table VIII.) Short time-delay pickup is available in two ranges 2-5X or 4-10X. Specify range required.

Application Information

CIRCUIT BREAKER ACCESSORIES

G-E power circuit breakers are available with a wide range of auxiliary devices, some of which have been discussed in earlier sections. The application of these not discussed is relatively simple and will depend on the specific requirements for each breaker. Included are:

Auxiliary switch	4 contact 10 contact
Undervoltage trip	Instantaneous time delay

Overcurrent bell alarm
Overcurrent lockout
Shunt trip (electrical)
Reverse current trip
Selective trip
Neutral connector (general-purpose enclosed breakers)

MOUNTINGS AND ENCLOSURES

The most popular means of applying low-voltage power circuit breakers is in equipments such as load-center unit substations or separate drawout switchgear. Arrangements and variations of breaker are almost endless as each equipment is custom applied to a given requirement. Further details on these equipments can be found in GEA-3592R "Load-center Unit Substations."

Breakers are also frequently applied as individual units and as such are available with the following enclosures.

Dead-front Switchboard

Breaker is not enclosed except for arc quenchers. Dead-front steel plate can be furnished as an accessory.

Skeleton Drawout Breaker Units

Complete one-high drawout unit consisting of skeleton drawout housing and removable drawout breaker element. Housing can be stacked to form section of a standard 90-in.-high enclosure.

General-purpose Enclosure, NEMA Type 1

Breaker is mounted in a steel enclosure. For indoor use only. AK-15, -25, -50 are wall mounted with an easily removable breaker element. AK-75, -100 is floor mounted with stationary breaker elements. Cover plates provided. Terminal or bus bar connectors furnished as required.

Semi-dust-tight Enclosure, NEMA Type 1A

Enclosure and mounting similar to general-purpose enclosure, with addition of a gasket around the cover and escutcheon.

Weatherproof, NEMA Type 3

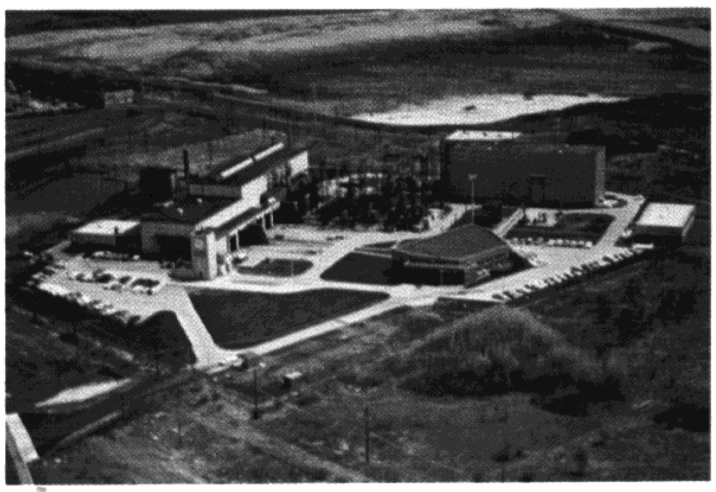
Breaker is mounted in a weatherproof steel enclosure including terminal connectors. AK-15, -25, -50 breaker elements are of easily removable type. AK-75, -100 are stationary mounted.

Dust-tight, Watertight, NEMA Types 4 and 5

Breaker is mounted in a heavy-duty steel enclosure with gasketed door including terminal connectors. AK-25, -50 are of easily removable type.

Explosion-proof, NEMA Type 7

Breaker is mounted in a heavy-duty cast-iron enclosure, including terminal connectors. Suitable for Class 1, Group D hazardous location.



General Electric low voltage power circuit breakers are tested at the Company's High Power Laboratory in Philadelphia.

LOW VOLTAGE SWITCHGEAR DEPARTMENT
PHILADELPHIA, PENNSYLVANIA 19142

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