APPLICATION MANUAL

overcurrent protection for distribution systems

- Distribution Fuse Cutouts
- Distribution Fuse Links
- Oil Circuit Reclosers
- Circuit Breaker Relays

Properly Applied and Co-ordinated They Will:

Reduce Operating Expenses

Decrease Number and Duration of Power-Service Outages

Increase Consumer Good Will and

Stimulate Utilization of Electric Power

GENERAL ELECTRIC

PRICE $1.50

CONTENTS

OVERCURRENT PROTECTION FOR DISTRIBUTION SYSTEMS

Acknowledgement for the preparation of this revision is extended to the Electric Utility Engineering Operation and especially G. G. Auer

I. GENERAL PRINCIPLES

Co-ordination when applied to overcurrent protective devices means their arrangement in series along a distribution circuit so that they function to clear faults from the lines in accordance with a prearranged sequence of operation. Fuse cutouts or automatic circuit reclosers or relays might be used separately but the benefits obtained by combining these devices exceeds that which can be provided by either one alone.

VALUE OF MAIN-LINE SECTIONALIZING

Sectionalizing the main feeder and long branches is imperative on that portion beyond the zone of protection of the relay or recloser at the substation. Most distribution feeders extend beyond this protective orbit of the substation equipment. Further sectionalizing improves service continuity. Reclosing equipment is much more effective in improving service continuity for the whole system when employed at line sectionalizing points than when used at branch junctions. Generally, the increased revenue and consumer goodwill resulting from the better service continuity will justify single-element fuse cutouts. However, reclosers provide such a reduction in the time and automotive mileage for service restoration that they are a necessity on long rural circuits and generally, where available ratings permit, can be justified on urban and suburban feeders.

VALUE OF BRANCH PROTECTION

It is of paramount importance to isolate faults on branch and sub-branch lines which are one-half mile or more in length (or even shorter ones which are troublesome), thereby maintaining service on the rest of the circuit and indicating the fault location. Anything which limits such branch protection is apt to impair service continuity on the system as a whole. A major reduction in outage time and restoration expense is provided by the use of low cost, single-element fuse cutouts or sectionalizers in branches.

BASIC CONSIDERATIONS IN CIRCUIT PROTECTION

Distribution system protection involves two basic considerations. The first is to design and maintain the circuits so as to incur a minimum number of line faults. The other is to minimize the effects of faults that do occur.

TEMPORARY FAULT PROTECTION

Temporary faults are handled best by automatic opening and reclosing. If maximum benefits are to be obtained, the entire feeder circuit must be covered by automatic reclosing equipment, such as power circuit breakers with reclosing relays or automatic circuit reclosers. That is, all parts of the feeder circuit must be within the protective zone of the reclosing device. If the station recloser or breaker relays do not reach to the remote ends of the circuit, they should be supplemented by reclosers out on the line.

PERMANENT FAULT PROTECTION

Permanent faults simply require that the faulted line section be automatically disconnected from the remainder of the circuit so that a minimum number of consumers are affected. This isolation of permanent faults can be accomplished with single-shot cutouts. Furthermore, several single-shot cutouts can be used in series and at less cost than other sectionalizing devices. Isolation of permanent faults can also be accomplished by automatic reclosers or sectionalizers, but at greater first cost.

The effects of faults can be minimized by: (a) eliminating prolonged outages caused by temporary faults, and (b) limiting the extent of outages - that is, the number of consumers affected and the duration of interruption caused by permanent faults.

COMBINATION OF PERMANENT AND TEMPORARY FAULT PROTECTION

If all faults were of a permanent nature, low-cost single-shot cutouts would be the best solution for line sectionalizing. If all faults were temporary, automatic reclosing devices capable of covering the entire circuit would be the best solution.

However, in actual practice there are both types of faults to contend with and the problem becomes one of selecting the type of device, or combination of devices, that provide best over-all results on a given feeder. Proper consideration must be given to such factors as importance of service, total number of faults per year, ratio of temporary to total faults, cost of service trips, and annual charge on investment.

II. SELECTION OF OVERCURRENT PROTECTIVE EQUIPMENT

In order to see how a well coordinated system of overcurrent protective equipment is established, start with a one-line diagram of a distribution circuit. (See Fig. 1.)

At the left is the substation which steps down the voltage from transmission or subtransmission level to distribution level. The distribution system starts at this point. A substation may have a number of radial feeders radiating from it, but for simplicity only a single-phase feeder is shown extending to the right from the substation. At various points along the feeder, branch lines are tapped off, and in some cases, sub-branches are tapped from these branches. There are, of course, loads (residences, small commercial establishments, or farms, etc.) all along the feeder branches, and sub-branches. Only a few of these loads have been shown.

It is general practice to install a fuse on the primary (incoming) line side of all distribution transformers, as shown in Fig. 1. This may be a transformer internal fuse or an external fuse installed in a cutout. Figure 1, then, is the basic system to which overcurrent protective equipment must be added to assure good service continuity.

In order to properly apply overcurrent protective equipment to this system, it is necessary to know by calculation the highest and lowest (maximum three-phase and minimum line-to-ground, or line-to-line) values of short-circuit currents which can flow if a fault occurs: (1) where the feeder leaves the substation, (2) at each branch junction point, and (3) at each sub-branch junction point.

It is also necessary to know the minimum (line-to-ground) short-circuit current which would flow if a fault occurred at the extreme end of any of the branches or sub-branches. See Appendix for methods of calculating these short-circuit currents.

Referring to Fig. 1, automatic circuit reclosing devices should be applied to protect the entire circuit against temporary faults. In order to provide this protection, a recloser, or a power circuit breaker equipped with overcurrent and reclosing relays, should be installed on the main feeder at the substation.

In applying reclosers to do this job, certain factors must be considered:

1. The voltage rating of the recloser must be high enough to meet the requirements of the system.

2. Load current, or the amount of current which will flow at the point of installation under full-load conditions, should not exceed the value of current which the manufacturer has rated the recloser to carry continuously (continuous-current rating). Recloser ratings are usually selected to be about 20 to 30 percent higher than peak-load current at the point of installation. This allows for normal load growth.

3. The highest value of short-circuit current which will flow through the recloser and which the recloser must successfully interrupt should not be greater than the highest value of current which the recloser is rated to interrupt (interrupting rating).

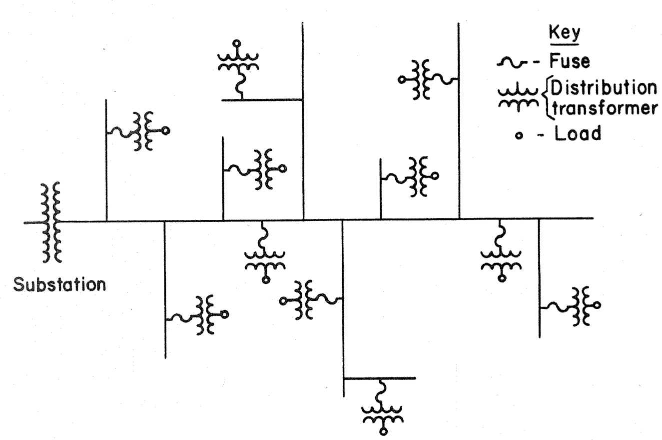


Fig. 1. One-line diagram of a distribution circuit

CLEARING TEMPORARY FAULTS

Referring to Fig. 2, a recloser or breaker with reclosing relays will be located at point A which meets the three application principles mentioned earlier. This device will be depended on to clear temporary faults occurring anywhere within its protective zone on the feeder, branches, or sub-branches (shown by dotted line). This protective zone extends to the point where the minimum available short-circuit current, as determined by calculation, is equal to the smallest value of current which will cause the recloser or breaker to operate. The value of current required to operate the recloser or relay is called "minimum pickup current". By Recloser Standards, this is equal to twice the continuous-current rating of the recloser, plus its tolerance. A fault anywhere beyond this zone will not draw sufficient current to cause recloser or relayed breaker A to operate. Recloser B, which has a lower minimum pickup current rating, should be installed inside of Zone A, thus resulting in so-called overlapping protection.

It will be noted that second recloser B is placed on the source side (side nearest source of power) of branch 5 so that it will protect the extreme end of this branch from temporary faults which occur beyond zone A. We will assume that a fault on the feeder or any branch or sub-branch beyond (to the right of) B will cause enough current to flow to operate the recloser at B. Every point on the circuit is now protected against temporary faults because the entire circuit is within the protective zone A or B. Obviously, if every piece of the circuit, particularly extreme ends, is not within the protective zone of these protective devices, another recloser would be installed farther out on the line to include those extreme ends.

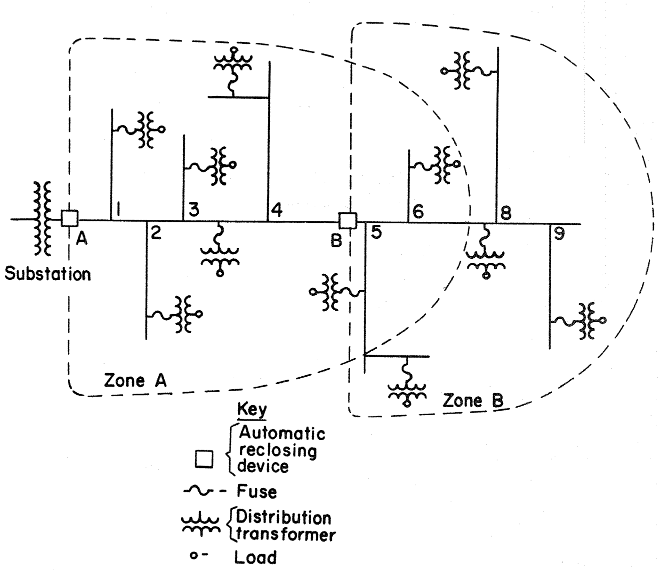


Fig. 2. Distribution circuit with protective device

CLEARING PERMANENT FAULTS

The first requirement for good overcurrent practice is to protect the circuit against temporary or transient faults. The second and third requirements are to confine permanent faults to the shortest practical section of line, and to make permanent faults easy to locate.

ISOLATION BY RECLOSER

If a permanent fault occurs anywhere on the system beyond a recloser, this device will operate once, twice, or three times instantaneously (depending upon adjustment), in an attempt to clear the fault. However, since a permanent fault will still be on the line at the end of these instantaneous operations, it must be cleared by some other means. For this reason, the recloser is provided with one, two, or three time-delay operations (depending upon adjustment). These additional operations are purposely slower (time-delay operations) to provide co-ordination with fuses or allow the fault to "self-clear". After the fourth opening, if the fault is still on the line, the recloser will lock open.

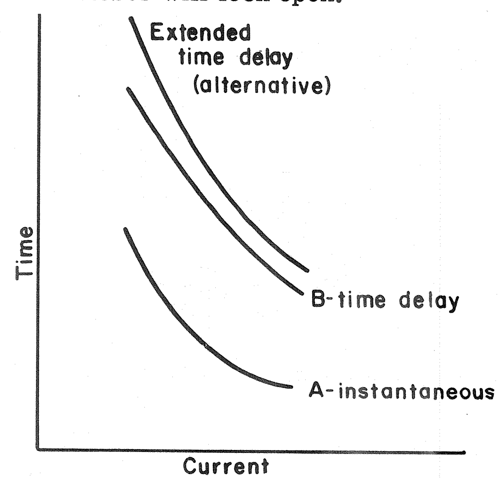


Fig. 3. Tripping characteristic for conventional automatic circuit recloser

Referring to Fig. 3, Curve A represents the instantaneous tripping characteristic with respect to time and current for the first and second opening of a conventional automatic circuit recloser. Curve B represents the tripping characteristics for the third and fourth openings. Following the fourth trip on time-delay, the recloser will lock out and must be manually reclosed after the cause of the fault has been removed.

ISOLATION BY FUSES

A permanent fault on a branch or sub-branch line should not be allowed to cause a recloser located on the main line to lock open, since a fault on a relatively unimportant sub-branch could shut down the entire circuit, in addition to being extremely difficult to locate. Therefore, some means must be employed to confine permanent faults to the branch or sub-branch on which they occur.

The method by which permanent faults can effectively be dealt with is illustrated in Fig. 4.

A fuse cutout is installed at each branch or sub-branch junction to confine permanent faults to the branch or sub-branch on which they occur; i.e., fuses 1, 2, 3, 4, etc.

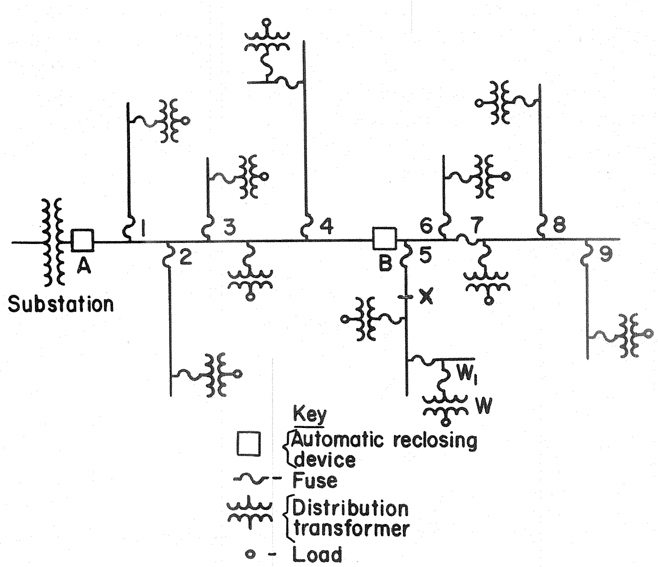


Fig. 4. Method for dealing with permanent faults

The fuse cutout to be installed at a particular location must be of sufficient rating to meet the voltage requirements of the circuit. Its continuous-current rating must be equal to, or greater than, the full-load current at the point of installation. Its interrupting rating must be high enough so that it will successfully open the circuit for any permanent fault occurring beyond it. This may be checked by comparing the interrupting rating of the cutout with the maximum calculated short-circuit current available at the point on the system where the cutout is to be installed.

When correct ratings of fuse links are applied, based upon magnitudes of calculated short-circuit current available and properly coordinated with reclosers, they should not be blown or even damaged by a temporary fault beyond it; i.e., the recloser should open the circuit one, two or three times dependent upon adjustment on instantaneous operations without the fuse link being damaged. On a permanent fault, the fuse link on the source side of the fault should blow and the circuit opened during the third or fourth (time-delay) operation of the recloser. Hence, the fault will be isolated by the fuse and the recloser will reset automatically, restoring service everywhere except beyond the blown fuse. The reclosers should never lock out on a permanent fault beyond the fuse if it has been properly coordinated with the recloser. (See coordination charts 8 to 26 inclusive.)

RECLOSER-FUSE COORDINATION

Figure 5 shows the time-current characteristic curves of the automatic circuit recloser similar to those shown in Fig. 3. On these curves, the time-current characteristics of a fuse C is superimposed. It will be noted that fuse curve C is made up of two parts: the upper portion of the curve (low-current range) represents the total clearing time curve, and the lower portion (high-current range) represents the melting curve for the fuse. The intersection points of the fuse curves, with the recloser curves A and B, define the limits between which coordination will be expected. Basically, this is correct within the interest of simplicity. However, to accurately establish intersection points a and b, and to prepare coordination charts (see section containing coordination charts 8 through 26 inclusive), it is necessary that the characteristic curves of both recloser and fuse be shifted or modified to take into account alternate heating and cooling of the fusible element as the recloser goes through its sequence of operations.

Figure 6 shows what occurs when the current flowing through the fuse link is interrupted periodically. The Oscillogram shows typical recloser operation. The first time the recloser opens and closes due to fault or overload, the action is instan-

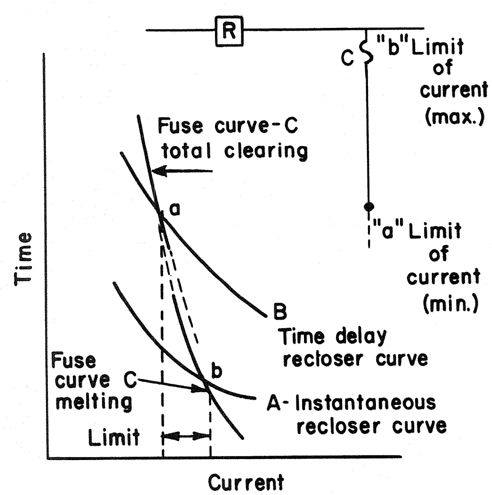


Fig. 5. Time-current characteristic curves of recloser of Fig. 3 superimposed on fuse curve C

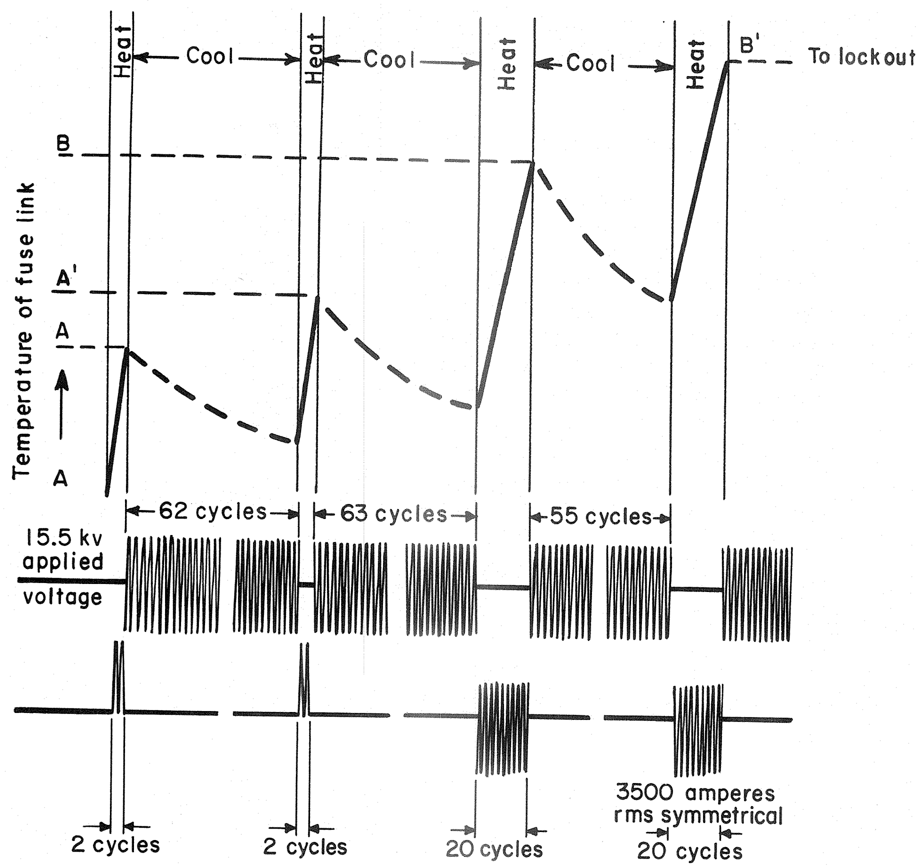


Fig. 6. Fuse link heating and cooling

taneous, requiring only two cycles. The second action is also two cycles, while the third action is delayed to 20 cycles, as is the fourth. Then the recloser locks itself open.

For example, if the fuse link is to be protected for two instantaneous openings, it is necessary to compare the heat input to the fuse during these two instantaneous recloser openings. The recloser-fuse coordination must be such that during instantaneous operation the fuse link is not damaged thermally.

Curve A' Fig. 7 is the sum of two instantaneous openings (A) and is compared with the fuse damage curve which is 75 percent of the melting-time curve of the fuse (see page 35 for methods of adding factors for instantaneous openings and temperature correction).

This will establish the high current limit of satisfactory coordination indicated by intersection point b'. To establish the low current limit of successful coordination, the total heat input to the fuse represented by curve B' (which is equal to the sum of two instantaneous (A) plus two time-delay (B) openings) is compared with the total clearing-time curve of the fuse. The point of intersection is indicated by a'.

For example, to establish how coordination is achieved, between the limits of a' and b', refer to Fig. 4 (branch 5 and recloser B) and also to Fig. 7. It is assumed that fuse number 5 beyond recloser B

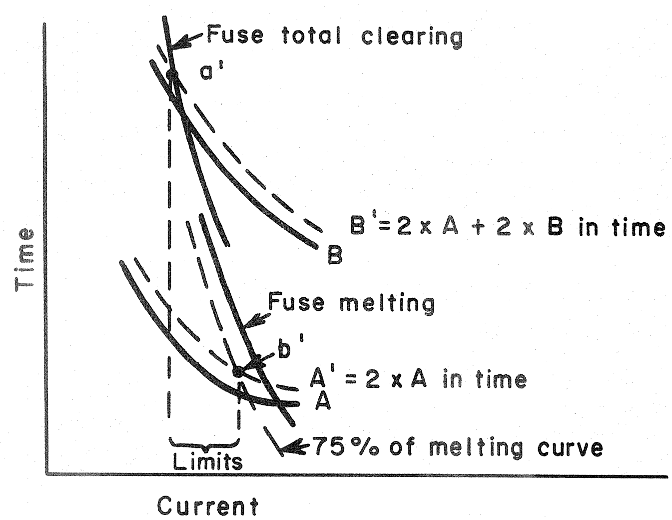


Fig. 7. Recloser-fuse coordination (fuse corrected for heating and cooling)

must be protected against blowing or being damaged during two instantaneous operations of the recloser in the event of a transient fault at X. If the maximum calculated short-circuit current at the fuse location does not exceed the magnitude of current indicated by b', the fuse will be protected during transient faults. For any magnitude of short-circuit current less than b' but greater than a' (see Fig. 7), the recloser will trip on its instantaneous characteristic once or twice to clear the fault before the fuse melting characteristic is approached. However, if the fault at X is permanent, the fuse at 5 should blow before the recloser B locks out. If the minimum (line-to-ground) calculated short-circuit current available at the end of branch 5 is greater than the current indicated by a', the fuse will blow (see Fig. 7) before the time-delay characteristic of the recloser is approached. (See coordination charts 8 to 26 inclusive.)

RECLOSER SEQUENCE AND TIMING

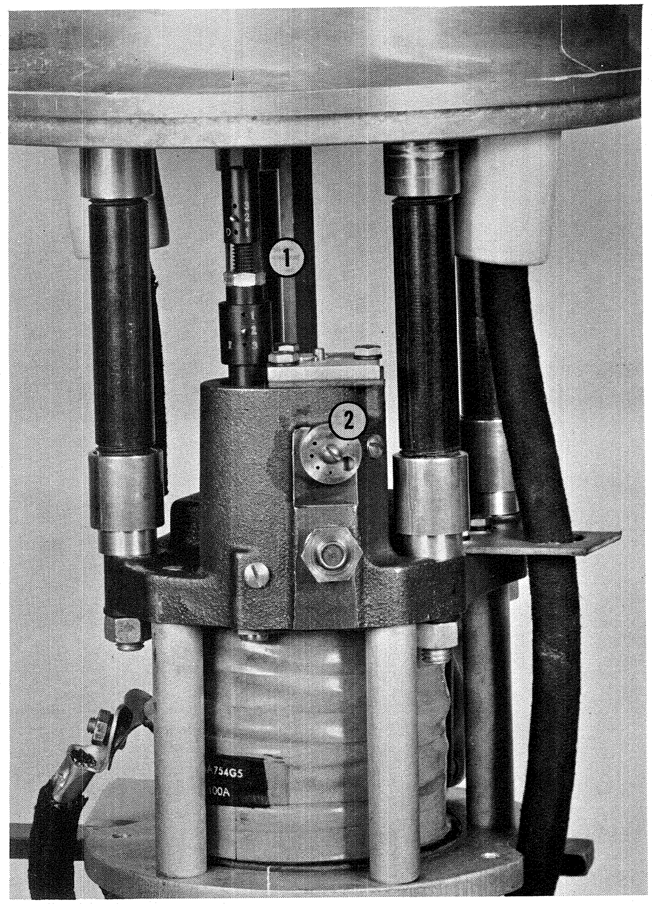
Questions are often presented as to the relative merits of various recloser operating sequences and time curves. The answer is dependent on circuit conditions defined by substation transformer protection, isoceronic level, and other protective devices used in conjunction with reclosers.

TWO-INSTANTANEOUS AND TWO TIME-DELAY OPERATION

The two instantaneous and two time-delay sequence of operations are the most popular and are considered adequate to provide a high degree of protection against both transient and permanent faults. The practice of standardizing on one particular sequence of operation for the entire distribution system was justified when sequence and/or time-curve change necessitated a time-consuming service shop operation and the necessity for adding new parts. Now that adjustable sequence and time features are available merely by dial and pin change (Fig. 8) the sequence and time curves can be determined by the specifications of the system and not by a condition of enforced uniformity. Thus, greater flexibility and more reliable service can be achieved for individual feeders.

THREE-INSTANTANEOUS AND ONE TIME-DELAY OPERATION

Conditions might be such that substation transformer high-side fusing is restrictive due to other considerations in subtransmission line protection, hence providing an advantage to three instantaneous and one time-delay recloser operations. This sequence reduces the fuse heating time during the clearing of permanent faults on the distribution system, consequently eliminating or reducing the possibility of unnecessary high-side fuse blowing when small-rated (less than 150 percent) links are applied.



While factory-calibrated to match distribution needs, the operating sequence and time cycle can be readily changed in the field as follows:

1. Move a pin to change the number of operations before the recloser locks open.

2. Turn a wheel to advance or retard the time of each operation.

Fig. 8. Adjustment of Type HR-1-50-3

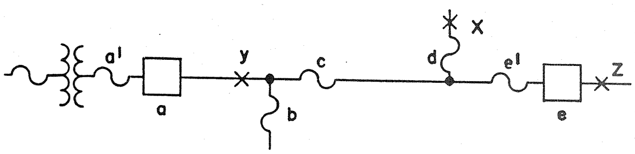
ONE-INSTANTANEOUS AND THREE TIME-DELAY OPERATION

This combination is used in those areas where branch or main line fuse blowing is considered a problem, where coordination with sectionalizers is required, or where certain reliance is placed on faults being self-clearing. This appears to be based more on personal preference sequence rather than on any substantiating evidence justifying its application.

HOLD CLOSED SEQUENCE

The so-called conventional sequence of operation of automatic circuit reclosers will make two instantaneous trip operations and then two time-delayed trip operations prior to lock-out. In addition to this sequence of operations, the G.E. recloser is exclusive in that it can be adjusted to, or ordered from the factory, with a different sequence of operations known as the "hold-closed" function. The characteristic curves will be similar to that shown in Fig. 3 except the time-delay curve B will be entire eliminated.

With this function, the operating sequence of the recloser consists of two instantaneous openings plus hold-closed, followed by automatic resetting as soon as the fault is removed. This sequence of operations permits the recloser to be readily coordinated with fuses installed at sectionalizing points on the main feeder between and beyond reclosers and at branch junctions.



Recloser (a) and fuse (a^1) are located on the same pole. Recloser (e) and fuse (e^1) are located on the same pole. Fuses (a^1) and (e^1) can be used as air-break disconnects when working on the line. Recloser (a) is coordinated with fuse a^1, b, c, d, and e^1 so:

(1) Recloser (a) operates instantaneously two or more times to clear all nonpersistent faults on the feeder to recloser (e) and to the ends of all branches such as (b) and (d) without damaging the fuse such as (a^1), (b), (c), (d), or (e^1).

(2) In case of a persistent fault at x, recloser (a) operates instantaneously two times and then holds closed until fuse (d) clears without damaging fuse (c). Then recloser (a) automatically resets to its normal operating position.

(3) In case of a persistent fault at Y, the operation would be as in (2) except fuse (a^1) would blow instead of fuse (d).

(4) In case of a maximum persistent fault at z which causes both reclosers (a) and (e) to operate, both reclosers would hold closed (without any hunting) so fuse (e^1) will blow. Then both reclosers will reset automatically.

Fig. 9. How instantaneous plus hold-closed recloser-fuse coordination operates

When a fault occurs beyond a fuse, the recloser will operate either once or twice instantaneously to protect the fuse and, if the fault is then removed, the recloser will automatically reset for additional operations. However, if the fault remains after these two operations, the recloser holds closed until the proper fuse blows and thus isolates the fault. Then the recloser resets automatically. Where there is no fuse between the recloser and the fault, the fuse at the recloser installation clears the fault. That is, at every recloser location there is installed a fuse cutout with a fuse link rating that will coordinate with other fuses on the system.

With this method the overlapping fuse-recloser coordination is obtained by having the recloser open instantaneously without partially melting the fuse in order to clear nonpersistent faults and depends on the recloser holding closed for an indefinite period to permit the fuses on the load side to clear and isolate persistent faults, after which the recloser resets automatically. As the recloser never locks open, a fuse, located at the recloser installation, must be provided to clear persistent faults just beyond the recloser. (See coordination charts 14, 15, 16 and 18.)

TABLE I

COMPARISON OF INSTANTANEOUS PLUS HOLD-CLOSED WITH INSTANTANEOUS PLUS TIME DELAY RECLOSERS

	Advantages of Instantaneous Plus Time-delay Reclosers	Advantages of Instantaneous Plus Hold-closed Reclosers
1. Economies	Recloser protects section of circuit just beyond it without requiring a fuse cutout at the recloser installation.	Permits use of fuse cutouts at some sectionalizing points, instead of reclosers with equivalent benefits.
2. Inrush currents following prolonged outages	Time-delay opening aids in picking up inrush currents.	Recloser holds closed and depends on fuse to withstand inrush currents. Fuses seldom, if ever, have been blown by inrush currents. Once inrush current dies out, recloser resets automatically.
3. Co-ordination with source side fuse at substation	Inverse time-delay curve permits co-ordination with source side fuses.	Fuse at recloser generally can co-ordinate with smaller source side fuse because of similarity of characteristics.
4. Co-ordination with load side fuses	Will co-ordinate with 2 to 4 ratings of fuses over a moderate range of fault currents.	Generally permits co-ordination with more ratings of fuses over a wide range of fault currents.

INTERRUPTING CAPACITY OF RECLOSERS

It has been noted that some confusion exists in the interpretation of interrupting capacity of reclosers. American and NEMA standards both recognize four different classes of reclosers, for example: the Distribution Class, Power Class I, Power Class II, and Power Class III. The Distribution Class recloser will have a maximum interrupting rating of 1250 symmetrical amperes, but, as noted in the Standards Tables, the interrupting capacity is actually limited to a maximum of 25 times the coil rating, or 1250 amperes, whichever is the lowest. The maximum rating of the Power Class I recloser is 2000 amperes for the 50-to-100 ampere units, but reduced in steps to 1000 amperes for the 25-ampere coil rating (40 times coil rating). The Power Class II recloser is 4000 amperes maximum for the 70-to-280-ampere rating but reduced to 1500 amperes for the 25-ampere coil rating (60 times coil rating). Similarly, Power Class III reclosers have a maximum rating of 8000 amperes for the 140-to-560 ampere coil rating, but are reduced to 6000 amperes for the 100-ampere coil rating (60 times coil rating). Thus, it is to be noted that when speaking of an interrupting capacity of a particular recloser, one must identify the coil and frame size used and establish the proper rating to that coil and frame size. This is a very important consideration as there are many applications where a large (100-, 200-, or 560-ampere) frame size recloser is required to meet maximum interrupting requirements, but a small coil size is needed for distance coverage. If this is the case, it is advisable to check the maximum interrupting capacity of the unit as established by the small coil rating to be sure it meets circuit requirements. In many cases, due to lack of familiarity with these rules, reliability and equipment performance is often jeopardized.

RECLOSER-RELAY COORDINATION

At substations where the available short-circuit current at the distribution feeder bus is 250 MVA or more, the feeder circuits are usually provided with circuit breakers and inverse-time overcurrent relays. (Refer to A in Fig. 4.) The relays of each feeder should be adjusted so that they can protect the circuit to a point beyond the first recloser in the main feeder (refer to B in Fig. 4), but with enough time delay to be selective with the recloser during any or all of the operations within the complete recloser cycle.

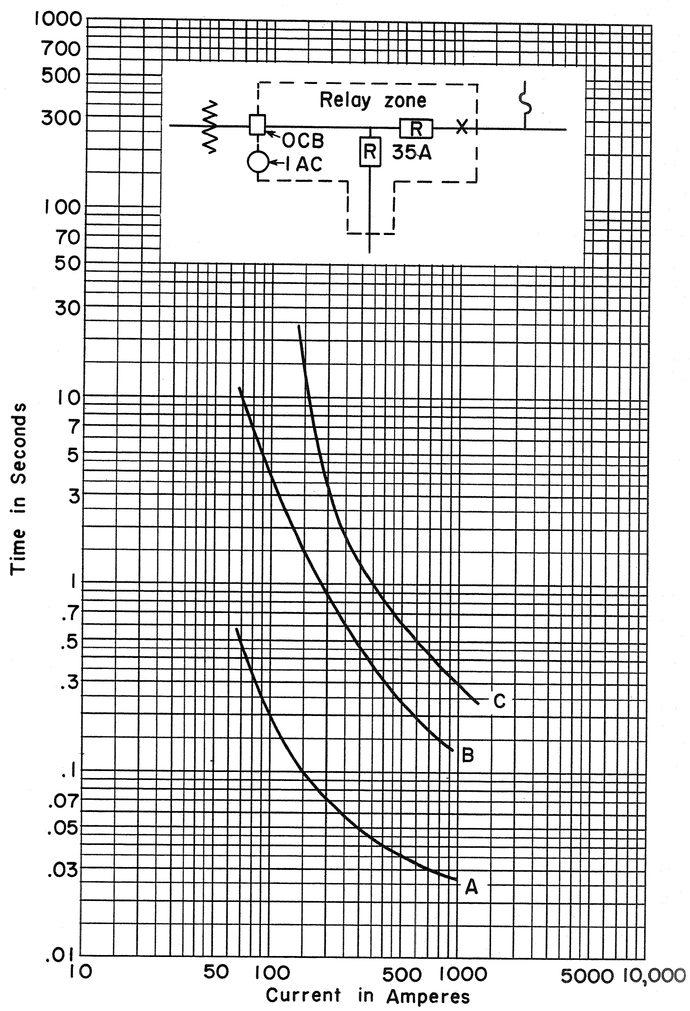
An important factor in obtaining this selectivity is the re-set time of the overcurrent relays. If, having started to operate when a fault occurs beyond recloser B, an overcurrent relay does not have time to completely reset after the recloser trips and before it recloses (an interval of approximately one second) the relay may "inch" its way toward tripping during successive recloser operations. In other words, it is not sufficient merely to make the relay time only slightly longer than the recloser time.

It is a good "rule of thumb" that there will be a possible lack of selectivity if the operating time of the relay at any current is less than twice the time-delay characteristic of the recloser. The basis of this rule, and the method of calculating the selectivity, will become evident by considering an example.

First, it should be known how to use available data for calculating the relay response under conditions of possibly incomplete resetting. The angular velocity of the rotor of an inverse-time relay for a given multiple of pick-up current is substantially constant throughout the travel from the reset (i.e., completely open) position to the position where the contacts close. Therefore, if it is known (from the time-current curves) how long it takes a relay to close its contacts at a given multiple of pickup and with a given time-dial adjustment, it can be estimated what portion of the total travel toward the contact-closed position the rotor will move in any given time. Similarly, the resetting velocity of the relay rotor is substantially constant throughout its travel. If the re-set time from the contact closed position is known for any given time-delay adjustment, the re-set time for any portion of the total travel can be determined. The re-set time for the longest travel (when the longest time-delay adjustment is used) is generally given for each type of relay. The re-set time for the number 10 time-dial setting is approximately six seconds for an inverse Type IAC relay, and approximately 60 seconds for either a very inverse or an extremely inverse Type IAC relay.

The foregoing information may be applied to an example by referring to Fig. 10. Curves A and B are the upper curves of the band of variation for the instantaneous and time-delay characteristics of a 35-ampere recloser. Curve C is the time-current curve of the very inverse Type IAC relay set on the number 1.0 time-dial adjustment and 4-ampere tap (160-ampere primary with 200/5 current transformers). Assume that it is desired to check the selectivity for a fault current of 500 amperes. It is assumed that the fault will persist through all of the reclosures. To be selective, the IAC relay must not trip its breaker for a fault beyond the recloser.

The operating times of the relay and recloser for this example are:



A. Time-current characteristic of one instantaneous recloser opening

B. Time-current characteristic of one extended time-delay recloser opening

C. Time-current characteristic of the IAC relay

Fig. 10. Relay-recloser coordination

Recloser:

Instantaneous - 0.036 second
Time-delay - 0.25

Relay:

Pick-up - 0.65 second
Re-set - (1.0/10) (60) = 6.0 second

The percent of total travel of the IAC relay during the various recloser operations is as follows, where plus means travel in the contact-closing direction and minus means travel in the re-set direction:

Recloser Operation	Percent of Total Relay Travel
First instantaneous trip (0.036/.65)	(100) = + 5.5
Open for one second (1/6)	(100) = -16.7

It is apparent from this that the IAC will completely reset while the recloser is open following each instantaneous opening.

Recloser Operation	Percent of Travel Relay Travel
First time delay trip (0.25/0.65)	(100) = +38.5
Open for one second (1/6)	(100) = -16.7
Second time-delay trip (0.25/0.65)	(100) = +38.5

From this analysis, it appears that the relay will have a net travel of 60.3 percent of the total travel toward the contact-closed position.

From the foregoing, it is seen that the relay travel lacks approximately 40 percent (or 0.4 x 0.65 = 0.24 second) of that necessary for the relay to close its contacts and trip its breaker. On the basis of these figures, the IAC will be selective. A 0.15- to 0.2-second margin is generally considered desirable to guard against variations from published characteristics, errors in reading curves, etc.

SUBSTATION PROTECTION

RECLOSERS

If automatic circuit reclosers are used at the substation as feeder breakers, it is necessary to select the proper size to meet the following conditions:

1. The interrupting capacity of the recloser should be greater than the maximum calculated fault current available on the bus.

2. The load current rating (coil rating) of the recloser should be greater than the peak load current of the circuit. It is recommended that the coil rating of the recloser be of sufficient size to allow for normal load growth and be relatively free from

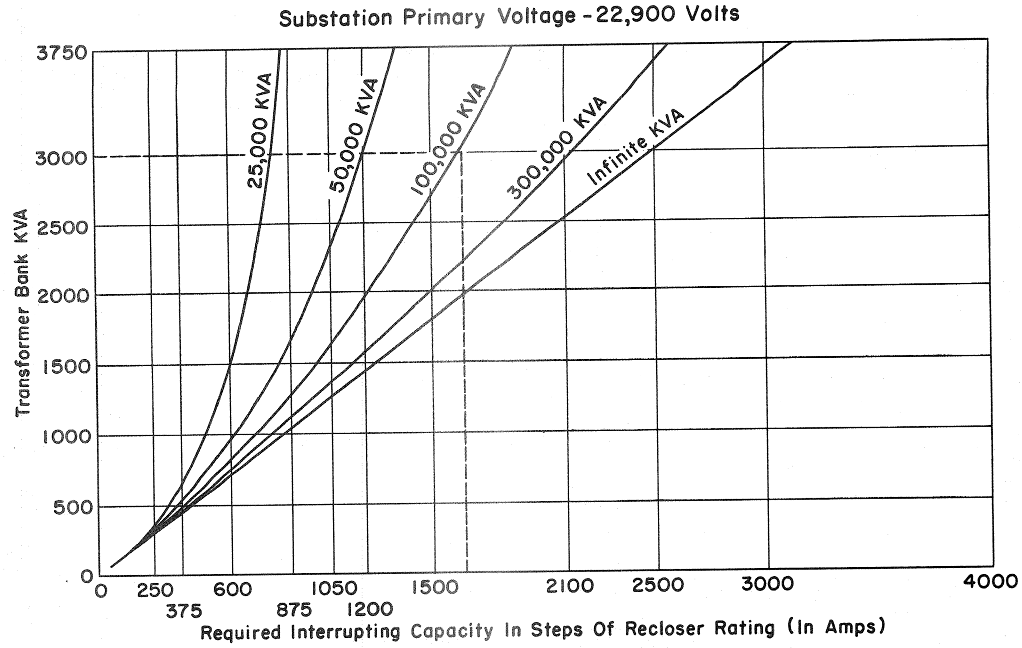


Chart A

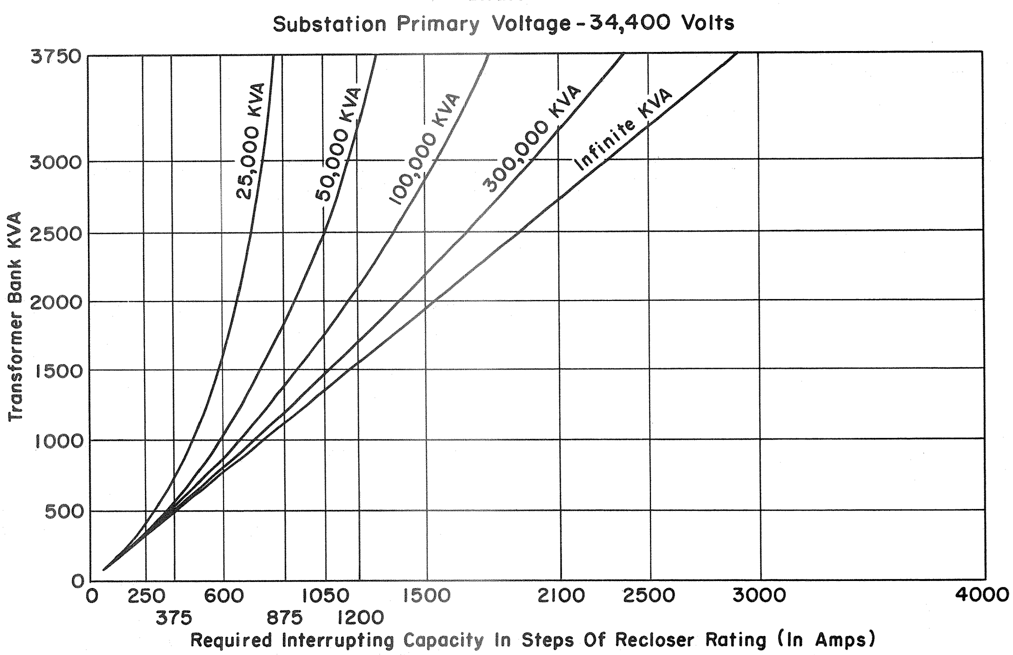


Chart B

Fig. 11. Application of reclosers in substations

unnecessary tripping due to inrush current following a prolonged outage. The margin between peak load on the circuit and the recloser rating is usually about 30 percent.

3. The minimum pick-up current of the recloser is two times (2X) its coil rating. This determines its zone of protection as established by the minimum calculated fault current in the circuit. The minimum pick-up rating should reach beyond the first line recloser sectionalizing point; i.e., overlapping protection must be provided between the station recloser and the first line recloser. If overlapping protection cannot be obtained when satisfying requirement (1) above, it will be necessary to relocate the first line recloser in order to have it fall within the station recloser protective zone.

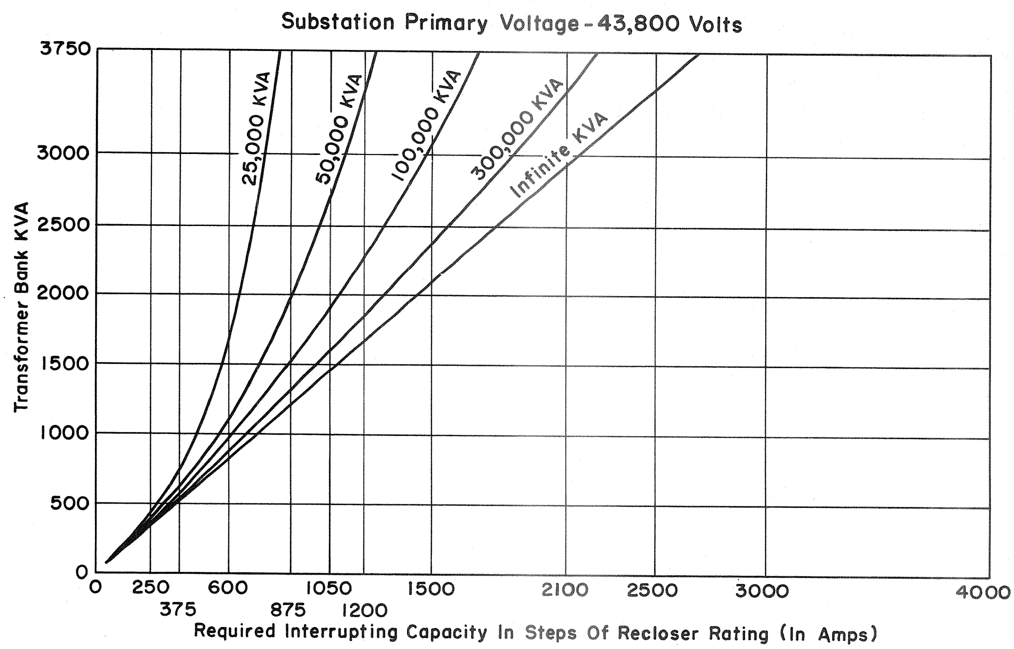


Chart C

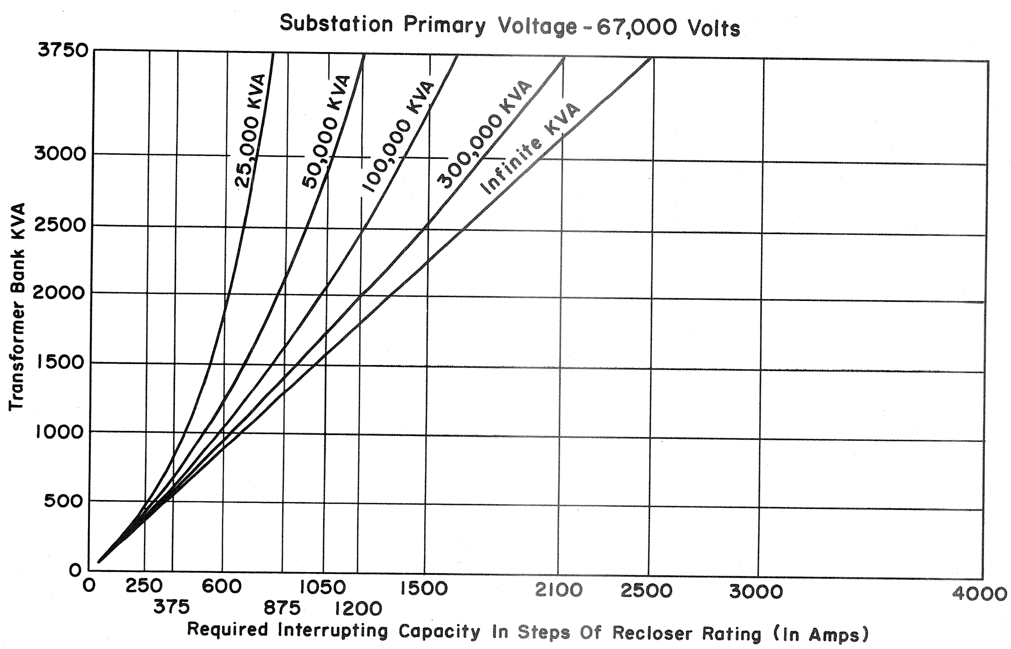


Chart D

Fig. 11. Application of reclosers in substations (Cont'd)

To Select Substation Reclosers

1. Determine required recloser interrupting capacity from appropriate chart.

2. Determine recloser continuous current rating from consideration of transformer full-load capacity and number of outgoing feeders. Continuous current rating should at least equal the normal load current. It is preferable to select a rating approximately 1/3 higher than the load current to allow for future growth.

3. Recloser selected must provide continuous current determined in step (2) and have an interrupting capacity equal to or more than value indicated on chart.

Example: Chart A indicates recloser interrupting capacity for station with a 3000 KVA transformer bank, 12,470 volts secondary, and with 22,900 volts primary supplied from a system having an available short circuit capacity of 100,000 KVA. Dotted lines show minimum interrupting capacity required to be approximately 1640 amperes. Proper recloser may now be selected as outlined in step (3).

TABLE II

RECLOSER APPLICATION TABLE

TRANS. BANK KVA	PRIMARY SHORT CIRCUIT KVA AVAILABLE	MAXIMUM SHORT CIRCUIT CURRENT AT 12,470 VOLTS (RECLOSER IC MUST BE EQUAL TO OR GREATER THAN THIS VALUE)			
		PRIMARY VOLTAGE OF SUBSTATION			
		22,900	34,400	43,800	67,000
500	50,000	357	332	309	290
	100,000	387	357	331	308
	300,000	407	374	345	322
	Infinite	422	387	356	331
1000	50,000	618	580	544	515
	100,000	714	662	617	579
	300,000	800	736	680	635
	Infinite	843	773	712	662
1500	50,000	822	777	732	696
	100,000	1000	933	869	819
	300,000	1165	1077	994	927
	Infinite	1270	1165	1070	994
2000	50,000	973	927	878	839
	100,000	1230	1160	1085	1025
	300,000	1490	1382	1280	1200
	Infinite	1680	1545	1420	1320
2500	50,000	1110	1055	1010	968
	100,000	1460	1368	1290	1220
	300,000	1850	1710	1590	1490
	Infinite	2110	1935	1790	1660
3000	50,000	1210	1160	1110	1070
	100,000	1640	1550	1460	1390
	300,000	2140	1990	1860	1740
	Infinite	2540	2320	2140	1990
3750	50,000	1340	1290	1240	1200
	100,000	1880	1785	1700	1620
	300,000	2580	2400	2240	2110
	Infinite	3160	2900	2680	2490

NOTES:

(1) This table based on Standard Transformer Impedance as follows:

High Voltage Rating	Transformer Impedance
22,900	5.5%
34,400	6.0%
43,800	6.5%
67,000	7.0%

(3) To determine maximum short circuit current for other than listed primary short circuit KVA available, use the following formula:

$$\text{MAXIMUM FAULT CURRENT} = \frac{(\text{Listed Fault Current for Infinite Primary}) \times (\text{Transformer Impedance in \%})}{(\text{Transformer Impedance in \%}) + \dfrac{(\text{Substation Bank KVA} \times 100)}{(\text{New Primary short circuit KVA})}}$$

EXAMPLE: Find max. short circuit current at 12:47 KV for 22.9 KV, 3000 KVA substation with 75,000 KVA available at 22.9 KV. From the table with infinite 22.9 KV system, 12.47 KV fault current would be 2540 amps.

$$\text{New Fault Current with 75,000 KVA available} = \frac{(2540)\quad(5.5)}{(5.5 + \dfrac{3000 \times 100)}{75,000}} = 1470 \text{ amps.}$$

LINE PROTECTION

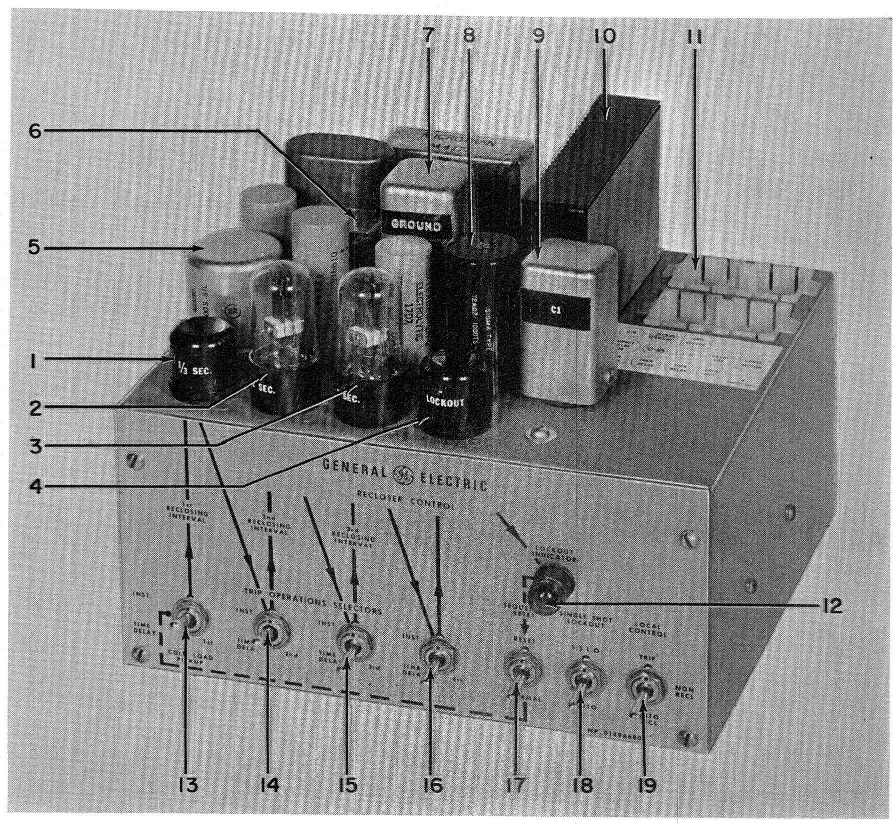
LINE RECLOSERS

The rating of line reclosers will be established on the same basis as the station recloser; i.e., it must have an interrupting capability sufficient to clear maximum three-phase fault current at its location, have sufficient load current capability and overlap the next line recloser in the circuit. When the last line recloser has been selected, a review of the circuit should indicate every piece of line, even to the most remote lateral, falling within the protective zone of some recloser. This insures complete protection against any transient fault causing a sustained outage.

HEAVY-DUTY POWER CIRCUIT RECLOSER CONTROL

The functions of pickup, sequencing, and reclosing intervals are performed by electromechanical relays. Tripping and time-current functions are accomplished by static components. No batteries or electronic tubes are used. The complete unit can be electrically and physically disconnected by removal of two connecting plugs.

The nameplate of the recloser control shown in Fig. 12 depicts a typical automatic operating sesequence. Eleven pre-selections, made either by switches,pluggable units, or simple adjustment, are available to establish the automatic sequence. An explanation of each selection is listed below.



1. First reclosing plug
2. Second reclosing plug
3. Third reclosing plug
4. Lockout plug
5. Undervoltage relay
6. Sequence relay (extended coordination)
7. Ground plug
8. Pickup relay
9. Phase curve plug
10. Phase board
11. Connecting plugs
12. Lockout indicator light
13. First trip operation selector switch
14. Second trip operation selector switch
15. Third trip operation selector switch
16. Fourth trip operation selector switch
17. Sequence reset
18. Single-shot lockout
19. Local control

Fig. 12. Nameplate of recloser control, depicting typical operating sequence

PHASE-CURRENT PICKUP

Phase pickup is 200 percent of phase continuous current. Continuous current ratings are 100, 140, 200, 280, 400 and 560 amperes, and are selected by the choice of plug-in resistors which fit into fuse-type clips on the control panel (separate from the recloser control unit and not illustrated).*

TYPE OF TRIP OPERATION

The type of trip operation for each of the four possible trip operations is determined by the position of the TRIP OPERATIONS SELECTORS (13), (14), (15), and (16), Fig. 12. These switches select either instantaneous (INST. position) or time-delay (TIME DELAY position) trip operations.

SHAPE OF TIME-CURRENT CURVE

The shape of the time-current curve is determined by the phase curve plug (9), Fig. 12. Three time-delay curves, designated B, C, and D are available, each with three instantaneous curves, designated 1, 2, and 3, available in conjunction with each time-delay curve. Typical curves are shown in Fig. 13.

RECLOSING INTERVAL

Reclosing intervals are determined by the fixed-time thermal time-delay relays which are plugged in sockets (1), (2), (3), and (4), Fig. 12. Time-delay intervals of 1/3, 2, 5, 10, 15, 20, 30, 45, 60, 90, 120, 180, and infinite seconds are available. The 1/3-second interval is the instantaneous plug, and the infinite second interval applies to the lockout plug.

NUMBER OF OPERATIONS TO LOCKOUT

Position of the lockout plug determines the number of operations to lockout. In its normal position (4), Fig. 12, the lockout plug allows four trip operations. In position (1), it allows one trip operation; in position (2), two trip operations; and in position (3), three trip operations. When the recloser sequence has progressed to lockout (whatever the number of trip operations to lockout), the lockout indicator lamp (12) will light.

COLD-LOAD PICKUP

Cold-load pickup is accomplished by positioning the first trip operation selector switch (13), Fig. 1, in the TIME DELAY or COLD-LOAD PICKUP position. This provides load pickup capability without sacrificing overcurrent protection.

SINGLE-SHOT LOCKOUT

If only one trip operation is required, the SINGLE-SHOT LOCKOUT switch (18), Fig. 12, when placed in the S.S.L.O. position will lock out the recloser on the first opening operation. Visual indication of lockout is provided by the LOCKOUT INDICATOR light (12). This switch may also be used effectively with the COLD-LOAD PICKUP switch (13) to "shoot-the-line," or re-establish a circuit on a single operation.

When single-shot lockout is not required, the switch is left in the AUTO (automatic) position.

RESET INTERVAL

If a fault on the power system is of a temporary nature, and is cleared before the recloser has progressed to lockout, the control will reset itself automatically. The reset time interval to accomplish this is adjustable by means of a time dial located on the inside of the recloser control box. The reset time range is from 0 to 4-1/2 minutes, with a time dial setting of 2 being equal to one minute. The standard reset time adjustment is one minute. (Note: When the zone-limiting coordination feature is included as an accessory, the standard reset time adjustment is three minutes.) The minimum adjustment needs only to be slightly longer than the longest single expected time delay.

SEQUENCE RESET

The sequence may be reset manually (usually from the lockout position, as indicated by the lockout light) by placing the SEQUENCE RESET switch (17), Fig. 12, in the RESET position. This switch is spring-returned. Holding the switch in the RESET position for a few cycles is sufficient to reset the sequencing relay. Release of the switch initiates the closing circuit to close the recloser, and returns the switch to its NORMAL position.

LOCAL CONTROL

Local control through electrical operation of the recloser may be accomplished with the LOCAL CONTROL switch (19), Fig. 12. Placing this switch in the TRIP position will trip the recloser. Releasing the switch will spring-return it to the NON-RECL (non-reclosing) position. Returning the switch to the AUTO RECL (automatic reclosing) position activates

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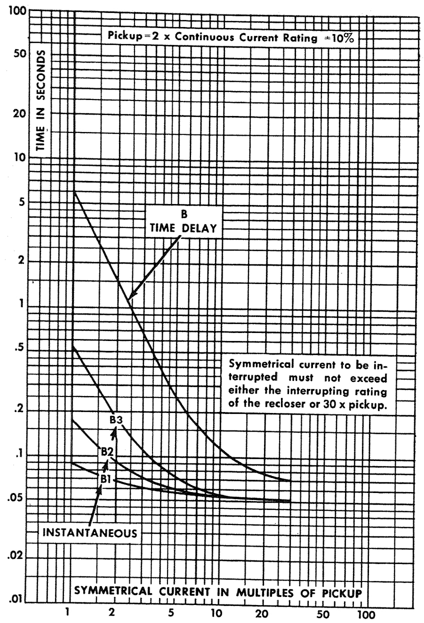
* Pickup values with the application of this device. Those given above are for a typical application.



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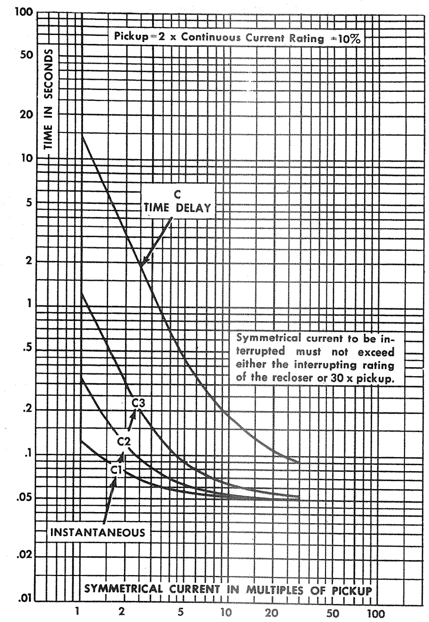

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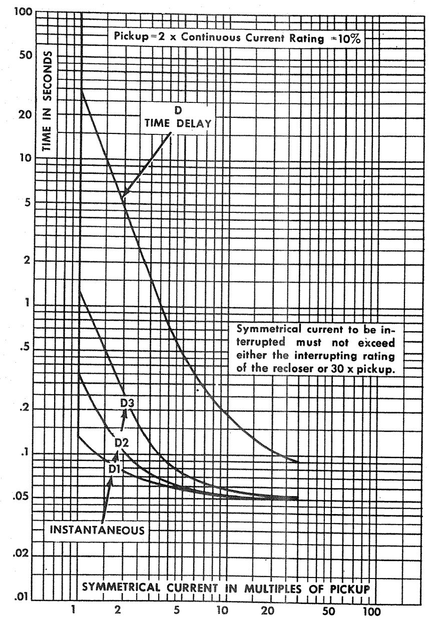
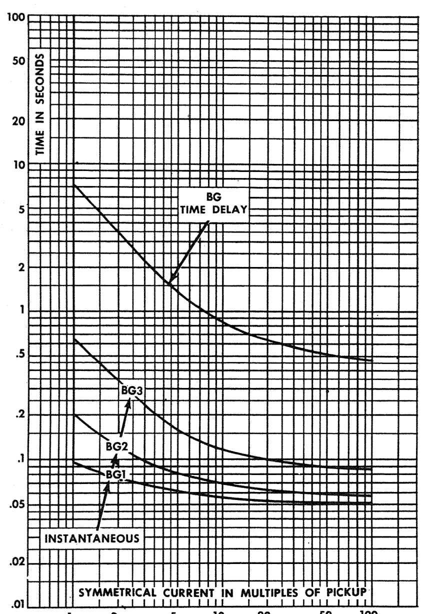


GES-6403

*Phase trip clearing time-current characteristic curves for Type OR three-phase reclosers with automatic recloser control.**



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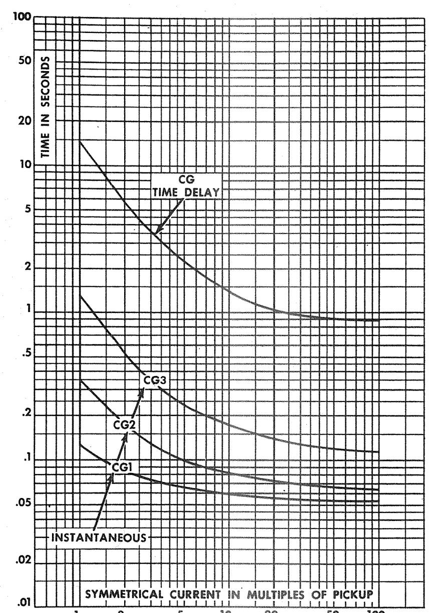

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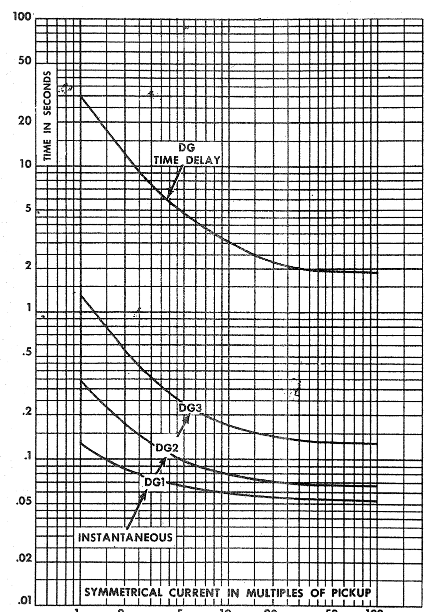


GES-6406

Ground-fault trip clearing time-current characteristic curves for Type OR three-phase reclosers with automatic recloser control.†

* TIME DELAY curves are average curves with ±10% time tolerance for times above 0.1 seconds. INSTANTANEOUS curves are maximum curves. Minimum curves are 25% lower in time for times above 0.1 seconds and include allowance for current asymmetry. (At 25C.)

† TIME DELAY curves are average curves with ±10% time tolerance. INSTANTANEOUS curves are maximum curves. Minimum curves are 25% lower in time for times above 0.1 seconds and include allowance for current asymmetry. (At 25C.)

Fig. 13. Typical operating characteristics for automatic recloser control

automatic sequencing. Any time delay associated with the reclosing interval will occur as in the automatic sequence. Thus, the complete reclosing sequence, except for the time-current tripping function, can be accomplished with the LOCAL CONTROL switch.

GROUND-CURRENT PICKUP (Optional Accessory)

Ground-current pickup is selected by the choice of a plug-in resistor (inserted in a clip mounted on the control panel, and located beside the phase-pickup resistors). The ground-pickup resistor is a single resistor, slightly smaller than the three resistors for phase pickup. Available pickup values are 50, 70, 100, 140, 200, 280, 400, and 560 amperes.*

Selection of the phase-trip sequence also determines the ground trip sequence, and selection of the shape of the phase-trip curves also selects the shape of the ground-trip curves. For example (refer to Fig. 12), if curve C-C3 were selected for phase trip, curve CG-CG3 would be the ground trip.

* Pickup values vary with the application of this device. Those given above are for a typical application.

III. APPLICATION OF FUSE CUTOUTS AND FUSE LINKS

ASYMMETRICAL RATINGS VS SYMMETRICAL CALCULATIONS

The current interrupting ratings are the maximum RMS symmetrical or asymmetrical current values in amperes which the cutout will interrupt at the rated voltage. This is the prescribed basis of rating in the American Standards C37.42-1962 for fuses above 600 volts.

The symmetrical short-circuit current is that obtained by dividing the circuit voltage by the impedance. In determining the asymmetrical short-circuit current available at an intended location, allowance should be made for the increase in the RMS value of the first loop of current caused by transient d-c offset which is a function of the ratio of the reactance to the resistance of the circuit.

It usually is the practice of utility engineers to neglect the asymmetrical valves of short circuit current in applying fuse cutouts on distribution systems. However, this practice can lead to serious consequences unless greater appreciation is given to the X/R ratio as a function of the cutout location to the source of generation.

As a guide in application, the AIEE has proposed the use of multiplying factors to be applied to calculated symmetrical short-circuit currents in order to include the d-c offset. They propose:-

FOR FUSES

a. A multiplying factor of 1.2 for circuits 15,000 and below, with an X/R ratio of 4 or less, and

b. A multiplying factor of 1.6 for all other circuits.

X/R ratios and correct multiplying factors to determine the asymmetrical currents on distribution systems have been investigated. Except for a few hundred feet from the substation the X/R ratio of distribution circuits will not exceed 4, and thus the multiplying factor would be 1.2.

On industrial applications at large plants fed by their own generators or substations, overcurrent protective equipment is subjected to more severe circuit conditions because of the concentration of power on short feeders with large conductors. Studies have indicated that the X/R ratio is likely to be higher than on utility distribution circuits and thus the d-c offset of the asymmetrical current will be greater, necessitating the use of the 1.6 multiplying factor.

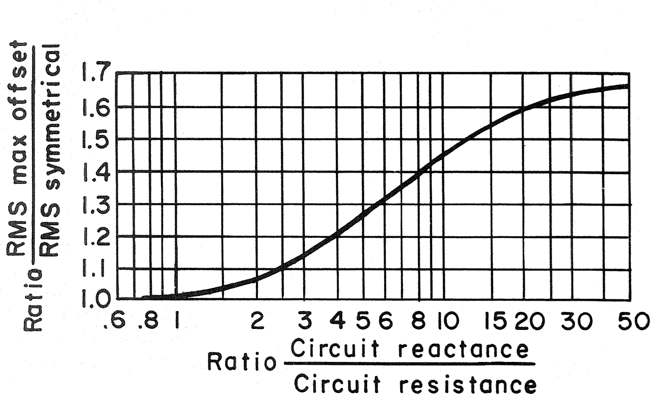
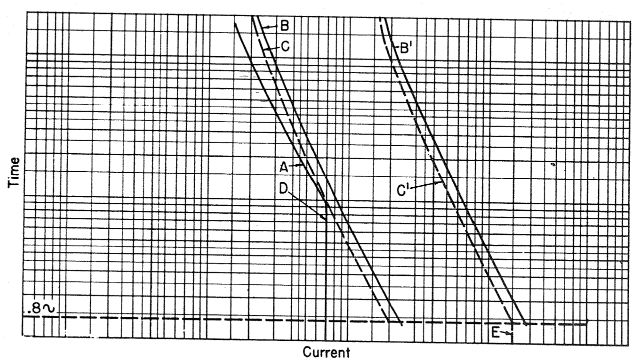


Fig. 14. The values from this curve can be used in calculating the maximum RMS value of the first half-cycle of fault current

FUSE LINK-TO-LINK COORDINATION

Fuse link to fuse link coordination and the method of preparation of the charts is illustrated in Fig. 15. For example, curve A might represent fuse link (8) in Fig. 16 and curves B or C fuse link I. The maximum short-circuit current at the primary terminals of the transformer, which fuse (8) is protecting, must not exceed the current D or E, in order to have assurance fuse (8) will always clear without partially melting fuse I. The rating of fuse



A–Published total clearing time-current curve of protecting fuse link plotted to maximum values so all manufacturing variables will be minus and thus out of the range of comparison with curves to the right.

B and B'–Published melting time-current curves of protected fuse links plotted to minimum values so all manufacturing variables will be plus and thus out of the range of comparison with curves to the left.

C and C'–Curves for 75 per cent of the time of curves B or B', respectively, to provide for such operating variables as preheating by load and to avoid melting of the fusible wire but not the strain wire of the fuse link.

D–Maximum current to which fuse link of curve A will protect fuse link of curve B. Current at which curve A crosses curve C.

E–Maximum current to which fuse link of curve A will protect fuse link of curve B'. Current at which Curve C' crosses 0.8-cycle line indicating that it will be melted at this and higher currents before a smaller fuse link can protect it.

Values D and E are those given in coordination chart, 1 through 7.

Fig. 15. "Fuse link protects fuse link" comparison of curves made in preparation of coordination charts 1 to 7 inclusive. (Under section containing coordination charts)

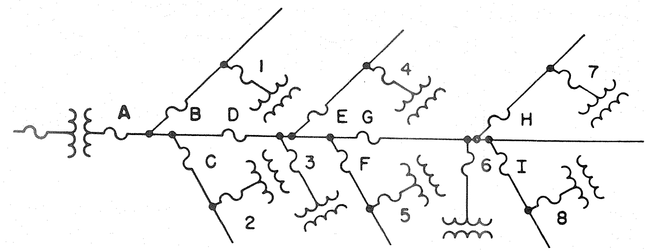


Fig. 16. Distribution circuit coordinated with fuses

I might have to be increased in order to carry the normal full load current. Also a check should be made to make sure the minimum short-circuit current at the end of the branch will cause fuse I to melt as each protective device must provide protection for all faults either out to the end of the line or to where the next overcurrent device takes over the protective job.

CONVERSION TO "K" OR "T" STANDARD FUSE LINKS

American Standards C37.43-1962 for universal cable-type fuse links for distribution cutouts provides electrical as well as mechanical interchangeability. Each continuous current rating of all manufacturer's K and T fuse links has similar time-current characteristics at 300, 10 and 0.1 seconds, i.e., within a permissible band of 20 percent at 300 and 0.1 seconds and 50 percent at 10 seconds. The knee or bend in the curves, occurring at about 10 seconds, varies with different ratings of links especially where common terminals and flexible cables are employed for a range of sizes. Thus the 50 percent band is necessary and since it does not detrimentally affect the coordination between ratings, it is allowed by the standard.

While the continuous current ratings of all K and T fuse links have similar time-current characteristics, the actual continuous current-carrying abilities are not similarl. Fuse links employing fusible elements with low-melting temperatures had to be de-rated in order to correspond with the actual continuous current-carrying ability of links having high-melting temperatures. In order to use these de-rated links to provide equal protection to equipment as the superseded ("N" rated) links, a continuous overcurrent rating is given which corresponds to the equivalent superseded link. Some ratings can carry lightly more current continuously which is recognized in these special ratings by some makers. However, where equivalent ratings are applied, conversion for equipment protection involves choosing the overcurrent rating of the types "K" or "T" link to replace the corresponding "N" link.

The Standards prescribe both "K" fast and "T" slow lines of fuse links having speed ratios, between the 0.1 second and 300 or 600 second minimum melting currents, of from 6 to 8.1 and from 10 to 13 respectively. The "N" rated links in general have speed ratios closer to the "K" fast links. "T" rated links are used to coordinate with the slow characteristics of service-entrance breakers or to permit substation breakers to open once ahead of the links especially where high fault currents are available. Generally it is wise to make an experimental coordination study on one or two representative circuits to determine which series will best meet the requirements of a system. Future growth should be considered in such a study to avoid costly changes later.

American Standards provide for interchangeability of all types and makes of fuse links, which meet the Standards, so by "Rules of Thumb," each rating in the "Preferred" or in the "Intermediate-Non-Preferred" series will protect the next higher rating in the same series up to current values of 13 times the lower rating for "K" (fast) or 24 times the lower rating for "T" (slow) links. The Standards do not define the arcing time, merely giving a straight line curve which is the maximum for all manufacturers. This curve was used to check the "Rules of Thumb" coordination between ratings. Actual test data shows the arcing time-current curves to be an inverted "V" shape. This permits coordination to high values since the total clearing time curves do not bend to the right at higher currents as they do when the straight line arcing curve is used. Also the standards prescribe only the maximum permissible band of variation. Most manufacturer's limits fall well within this band thereby contributing further to closer coordination than is possible by the "Rules of Thumb."

The advantages of the electrical and mechanical interchangeability between different makes of "K" and "T" fuse links can be capitalized by providing a duplicate source of supply in case of a production failure for the standardized line. Generally, one or two additional types and makes of links have time-current characteristics close enough to those of the standardized link to permit interchangeable use in an emergency although they might restrict the coordination if used generally.

Conversion from "N" rated to the Standard "K" or "T" fuse links for sectionalizing can be done on a rating for continuous overcurrent rating basis where engineering studies have established the procedure and any limitations for specific ratings. Such recommended procedures have been prepared which provide for changing all fuse links at the relatively few sectionalizing points on the primary lines and then changing the multitudinous transformer fuses as they blow.

RELATIVE COMPARISON OF "K" AND "T" FUSE LINKS

It appears reasonable to examine some of the pertinent aspects of coordination using K or T links based upon present-day circuit protection practices and design. Where concern is expressed regarding conversion procedure, a step-by-step method illustrates how to arrive at a standardized fuse coordination program.

"K" VS "T" IN SYSTEM PROTECTION

Let us examine the relative merits of the K (fast) and T (slow) links in the interest of improving service continuity and simplifying coordination problems.

RELAY-FUSE COORDINATION

Starting at the source end of a feeder, the primary line fuse will be called upon to coordinate with the overcurrent relay on a substation breaker. As shown in Fig. 17 characteristics of the T or slow

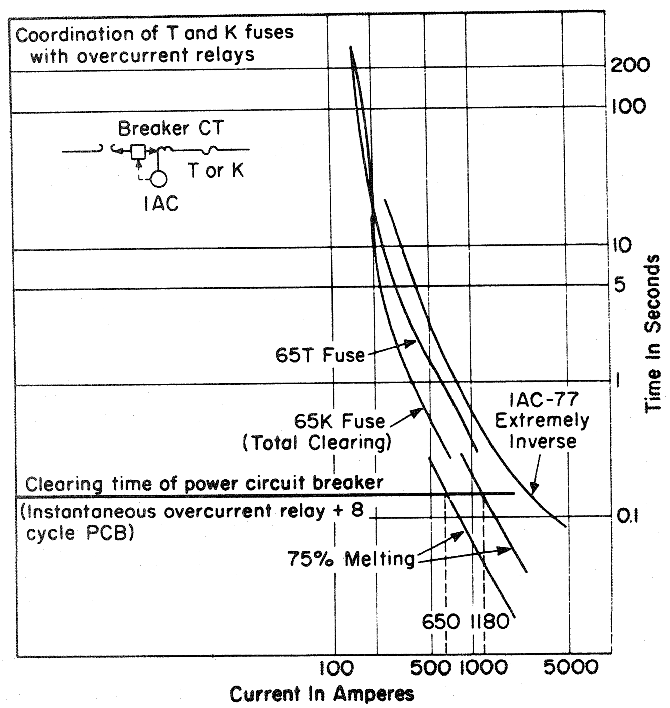


Fig. 17. Coordination of Type T and Type K fuses with overcurrent relays

link afford better coordination with the instantaneous breaker opening characteristics than does the K, or "fast" link.

In the example shown, the instantaneous overcurrent attachment in the relay will protect the 65-ampere T fuse from damage by transient faults up to 1180 amperes, whereas the 65-ampere K fuse is protected up to only 650 amperes. This advantage which the type T has over the type K provides for wider application of the T link on systems with growing values of available short-circuit current and greater benefits in protection against unnecessary outages due to transient faults. However, the use of T fuses with old inverse relays may present some coordination problems, especially where the overcurrent protection on the high side of the substation restricts the inverse time setting of the relay on the load side. Best coordination with T links is obtained with the more modern very inverse and extremely inverse relays.

RECLOSER-FUSE COORDINATION

Coordination between oil-circuit reclosers and T or K fuses is illustrated in Fig. 18. The range in amperes over which a fuse will coordinate with a recloser is a measure of the usefulness of the combination. In each case the T, or "slow," link has a wider range of coordination of approximately 525 amperes, while the K, or "fast," link has a range of only 370 amperes for this particular combination of a 35-ampere recloser and a 25-ampere fuse.

From this, it can be seen that the slow, or T, link coordinated with reclosers will provide a broad field of application on systems with relatively high magnitudes of short-circuit currents.

CONDUCTOR PROTECTION

The effectiveness of the T and K fuses in clearing lines before 4/0 wire is damaged is illustrated in Fig. 19. It will be noted that a larger ampere rated K link provides the same degree of line protection as a lower rated T link. However, the higher rated K fuse has the advantage of providing the possibility of more sectionalizing locations in series without exceeding conductor damage limits.

CIRCUIT COVERAGE

A problem which arises when applying fuse protection to a feeder is "How far out will the fuse protect?" Because of line impedance, a fault on the far end of a long line draws considerably less current than a fault at the cutout location. If a small fuse were used for the lower magnitudes of fault current

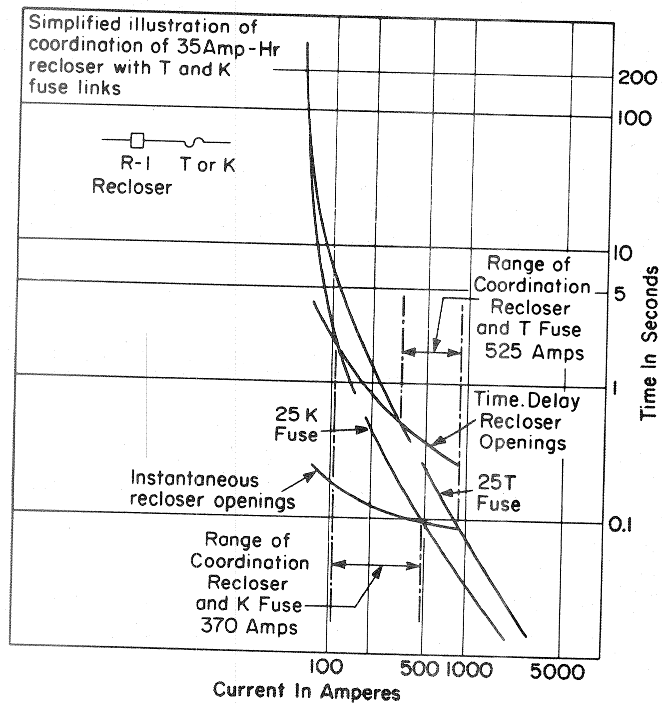


Fig. 18. Coordination of Type 35 AMP-HR recloser with Type T and Type K fuse links

at the end of the line it protects, it might not coordinate properly with other high-side protective devices at the higher magnitudes of current experienced with a fault at the fuse location.

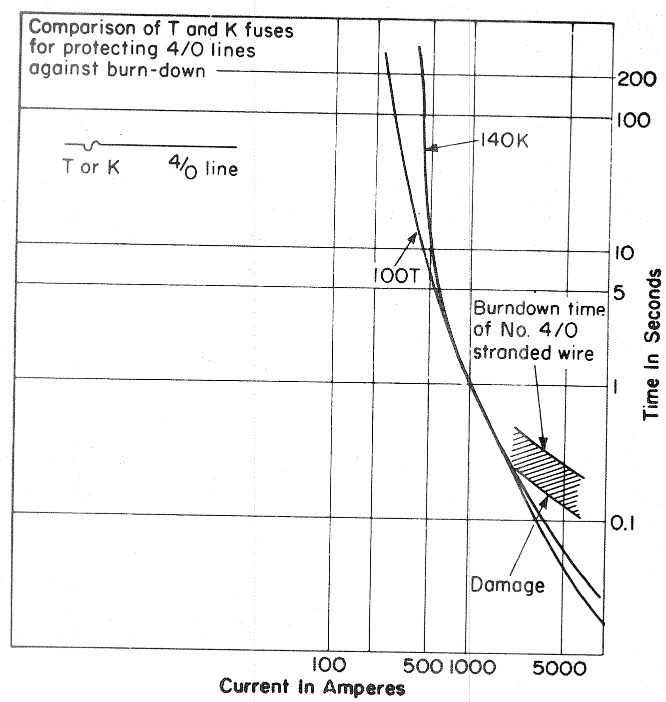


Fig. 19. Comparison of Type T and Type K fuses for protection of 4/0 lines against burn-down

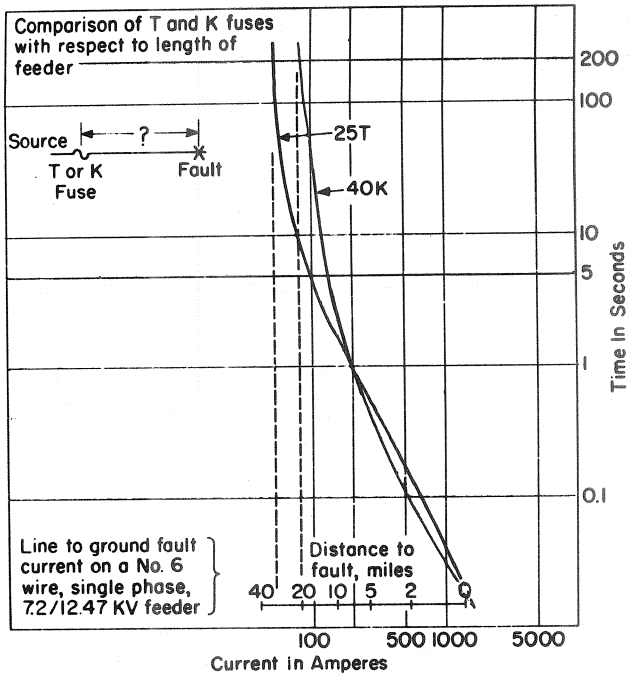


Fig. 20. Comparison of Type T and Type K fuses with respect to length of feeder

A comparison of the distance that a T and a K fuse will protect is shown in Fig. 20. A 25-ampere T and a 40-ampere K link were selected since they have approximately the same maximum short circuit current capability at 0.035 seconds; i.e., 1600 amperes. It will be noted that at the low current range of the fuses, the K has a minimum melting value of about 80 amperes, while the T link has a minimum melting of 52 amperes. In terms of mileage on a 7.2/12.47-kv system with number 6 conductor, this represents about 15 miles difference. Recognizing that no fuse would be applied to cover the range of 1600 to 52 amperes, the figure does, however, indicate the advantage of the slow T link over the fast K link in line mile coverage.

TRANSFORMER PROTECTION

Coordination of a T or K branch fuse with the high voltage internal fuse in a self-protected distribution transformer is shown in Fig. 21. For this application the K, or "fast," fuse characteristic more nearly parallels the transformer internal fuse curve and hence allows more sectionalizing points on the source side than does the T-type link.

In the protection of conventional distribution transformers, Fig. 22 indicates that the K link will operate faster than the slow link to remove a faulty transformer from the system. Furthermore, the K link has the advantage of being able to protect greater lengths of secondary circuit than does an equivalent T rated link. This can be seen in Fig. 22 where the K link crosses the ASA transformer safe loading curve at a lower current value than does the T link. However, where residential loads are being increased due to installation of room coolers and other large motor-operated appliances, the installation of service entrance time-lag fuses or time-delayed service entrance breakers on the consumers' premises does create a serious coordination problem with the transformer primary fuse. In this case, the T link does have a definite advantage over the K link in being able to stay above any time-lag characteristic.

SUMMATION OF "K" VS "T" FUSE LINKS

In the interest of stock simplification and the prevention of having coordination destroyed by a lineman using the wrong type fuse, it is definitely advantageous for a system operator to standardize on only one type of fuse.

The K (fast) fuse link provides the advantages of better protection against burning down lines, better coordination with the internal fuses of self-protected transformers, and allows greater coverage of secondary circuits where conventional transformers are used. The T (slow) link provides major benefits where coordination of circuit breakers and reclosers with fuses is used to prevent outage by temp-

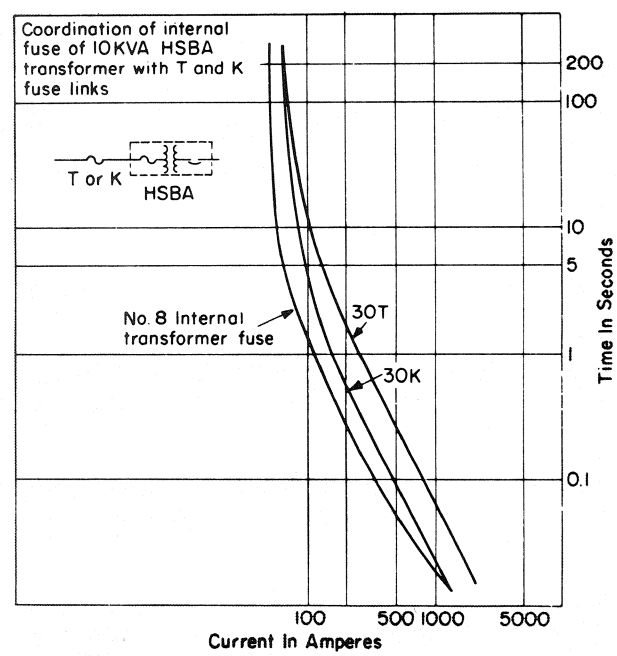


Fig. 21. Coordination of internal fuse of 10-kva Type HSBA transformer with Type T and Type K fuse links

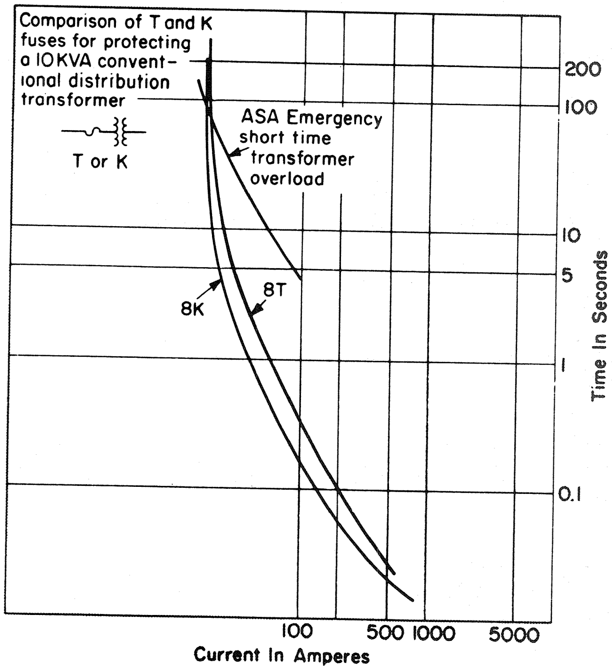


Fig. 22. Comparison of Type T and Type K fuses for protection of a conventional distribution transformer

orary faults, where greater distance coverage is required on the primary circuit, and in the protection of conventional distribution transformers where time-lag service entrance fuses or breakers are installed on the consumers' premises. Another advantage of the T link is its inherent ability to withstand lightning surge currents better than K links of the same rating.

CONVERSION PROCEDURES

The following step-by-step procedure provides a relatively simple and economical method for converting from G-E Universal cable-type N-rated (Model 9FIC Series) fuse links to American Standard (GE Model 9FIT Series) type T fuse links. Comparable load-carrying ability, overcurrent protection, and fuse-to-fuse coordination will be obtained. Although this procedure relates only to the N and T links, similar procedures have been prepared for conversion to K or T links when replacing any other manufacturer's links. This information is available upon request at any G-E Apparatus Sales Office.

Steps I, II and III will be used for line sectionalizing and equipment protection.

Steps II and III will be used for equipment protection only.

Step I CHANGE ALL MAIN LINE AND BRANCH FUSES AT THE SAME TIME ON ANY ONE FEEDER. REPLACE G-E N RATED FUSE LINKS WITH G-E TYPE T FUSE LINKS IN ACCORDANCE WITH TABLE III (FOR EXAMPLE, REPLACE 20N WITH 12T).

Exception:

Where actual currents exceed the maximum coordinating current values shown for the adjacent fuse link combinations in Table IV, a larger rating of protected link may be necessary. This will require coordination analysis of adjacent sectionalizing fuses.

Step II CHANGE EQUIPMENT FUSES AS THEY BLOW, OR WHEN EQUIPMENT IS SERVICED. REPLACE G-E N RATED FUSE LINKS WITH G-E TYPE T FUSE LINKS IN ACCORDANCE WITH TABLE III (FOR EXAMPLE, REPLACE 8N WITH 6T).

Exception:

If coordination is required to main line or branch fuses, and if actual currents at equipments exceed the maximum coordination current values shown for the adjacent fuse link combination in Table IV, a larger rating of protected link may be needed. This will require coordination analysis of adjacent branch or main line fuses.

Step III USE G-E MODEL 9FIT-SERIES FUSE LINKS FOR ALL FUTURE REQUIREMENTS.

"N" rated fuses may be used at equipments after main line or branch fuses have been changed as in Step I. Existing stocks of G-E N rated links may be used for replacing blown fuses at equipments.

PERTINENT COMMENTS

Coordination Chart 3 (see section "Coordination Charts) will be used in checking coordination of T fuse links in main line, branches, and equipments.

Coordination Chart 4 will be used in checking coordination of T links in the main line and branches with N-type links in the equipments.

Use of special fuse links with American Standard Fuse Links such as G-E Hi-Surge Links, in the 5- or 10-ampere series, may be used in place of the G-E type 6T or 8T fuse links, respectively, where lower rated fusing is desired to improve equipment protection.

TABLE III

GUIDE TO REPLACE G-E "N"-RATED FUSE LINKS COLUMN 1 WITH THE TYPE "T" FUSE LINKS IN COLUMN 2

N RATED FUSE LINKS	G-E EEI-NEMA Type *T* FUSE LINKS	
Current Rating RMS Amps.	EEI-NEMA Current Rating RMS Amps.	Over-current† Continuous Rating RMS Amps.
Col. 1	Col. 2	Col. 3
1N	(1N) X	. . .
2N	(2N) X	. . .
3N	(3N) X	. . .
5N	. . . . .	. . .
8N	6T	8
10N	8T	10
15N	10T	15
20N	12T	20
25N	15T	25
30N	20T	30
40N	25T	40
45N	30T	45
50N	40T	50
75N	50T	75
85N	65T	85
95N	80T	95
100N	100T	100 *
125N	140T	150
150N	140T	150
200N	200T	200 *

† General Electric "K" and "T" fuse links, because of their low melting point characteristics, can be operated continuously at currents in excess of American Standard current ratings without exceeding the maximum temperature rise of 30 C over 40 C ambient for cutouts. Note that G-E "K" and "T" links have overcurrent continuous ratings (Col. 3) same as the "N" ratings of the links shown opposite in Column 1, thus assuring equal continuous current-carrying ability.

X Present 1N, 2N and 3N ampere ratings of the 5 ampere series Hi-Surge Fuse Links meet American Standards for 1T, 2T and 3T ampere ratings, respectively. Hence, are recommended for applications requiring 1T, 2T, or 3T fuse links.

* No increase over American Standard ratings.

TABLE IV

Protected Link	Protecting Link	Amps.
25T	20T	88
30T	25T	160
40T	30T	115
65T	50T	160

In order to simplify stocking problems and to prevent loss of coordination due to the use of the wrong type of fuse link by a lineman, it is desirable for a system to be equipped with only one series of fuse link and preferably of only one manufacturer. As the new K and T links become more readily accepted, the present N link will gradually go out of production and eventually be discontinued.

In some applications the type K (fast) fuse link works best, while in others, better coordination is obtained with the type T (slow) fuse link. However, as circuits become more heavily loaded, feeders become shorter in length, and fuse ratings are correspondingly increased, the slow, or T, link provides better coordination with other automatic reclosing devices. However, the over-all advantages for a particular system must be analyzed individually to determine whether type K or T fuse links should be applied.

REDUCE UNNECESSARY PRIMARY FUSE BLOWING

On many distribution systems, the rate of primary-fuse blowing does not exceed 1 to 2 per cent per year. However, on other systems, a much higher rate of fuse blowing is experienced, much of which is unnecessary. The corrective measures to be described should be of assistance in attaining a low rate, where, in the majority of cases, fuses are blown to provide the beneficial overcurrent protection for which the cutout was installed.

DISTRIBUTION TRANSFORMER CAUSES OF PRIMARY FUSE BLOWING

1. Secondary short circuits within the zone of protection of the primary fuse or from the terminal flashovers of the transformer.

Secondary short circuits between the transformer and the NEC service fuses generally are not a frequent cause of unnecessary primary-fuse blowing. In the majority of cases the fuse blowing affords a desirable thermal protection to the transformer.

2. Lightning current and/or power short-circuit current which passes through the fuse during lightning flashovers of transformers or line.

Basically, when fuses blow at transformer installations or at sectionalizing points during lightning storms, they do so because:

a. Impulse currents passing through the fuse have sufficient magnitude and time duration to cause melting of the fuse link. (For instance, where the lightning discharge current has to pass through the fuse cutout to get to the lightning arrester and thence to ground), or

b. 60-cycle short-circuit current, accompanying lightning flashover at some low dielectric point of the line or of apparatus on the load side of the fuse, cause the fuse to melt even though no lightning current at all passes through the fuse.

SECTIONALIZING FUSES

Frequently it is rather difficult to determine whether fuse blowing at sectionalizing points is caused by impulse currents, or 60-cycle short-circuit currents. See (2) above.

Line flashover causing a 60-cycle short circuit is a predominate cause of fuse blowing on rural lines, where lightning protection at transformers, which are installed one, two or three per mile, leaves long intervening sections of the line unprotected. The use of automatic reclosing and resetting oil circuit reclosers, properly coordinated to protect branch and section fuses from blowing on temporary faults, is the best remedy for such unnecessary outages.

A considerable part of the sectionalizing fuse blowing by impulse currents can be avoided by installing distribution arresters one- or two-pole spans away from, and on either side of, the section fuse. Such practice assures that the arrester which is located in the path of the incoming wave will discharge to ground without necessitating passage of the lightning current through the section fuse to the arrester on the other side.

TRANSFORMER FUSES

Experience indicates that unnecessary blowing of transformer fuses can be reduced to the order of two per cent, or less, per year by adopting the following measures in lightning protection.

1. Installation of efficient distribution arresters at every transformer, recognizing the fact that older transformers require a better level of protection.

2. Connection of arresters on the line side of the distribution fuse cutout.

3. Interconnection, either solidly or gapped, of primary-arrester ground to secondary neutral.

4. Maintenance of a protectible insulation level, both inside and outside the transformer tank, particularly on the older transformers which may have improper lead spacings and low oil level.

Experience has frequently shown that until these essential measures are actually put into practice it may be an unwarranted sacrifice in overcurrent protection to arbitrarily increase the rating of primary-fuse links as a means of reducing fuse blowing.

SMALL PERCENTAGE OF RESIDUAL FUSE BLOWING

After eliminating the major causes of fuse blowing, the small amount of residual fuse blowing at transformer locations may be due to one or more of the following three causes:

1. Secondary short circuits occurring within the zone of protection of the primary fuse.

2. Lightning flashovers of older transformers, notwithstanding efforts to increase lead spacings, clearances, etc., and to provide the most efficient protection.

3. Some occasional cases of long-duration lightning discharges which persist over 2000 or 3000 microseconds and which saturate the transformer core, thus permitting some component of the surge to pass through the fuse and primary winding of the transformer.

The most effective remedy for fuse blowing by long-duration lightning discharges is to fuse all the lower-rated transformers with 5- or 10-ampere series Hi-surge fuse links which entail no sacrifice of overcurrent protection to the transformer. With such a practice it is well to appreciate that after the transformer core becomes saturated by the discharge, the d-c resistance of the primary winding limits the current which flows through the winding to ground. Thus, where identical fusing is used for say 3- and 5-kva transformers, the fuse links at the 5-kva transformers are more apt to be blown, because of the lower d-c resistance of the primary windings. The 60-cycle in-rush current, which immediately follows transformer saturation, is likely to be only a small fraction of the impulse-discharge current, and is thus only a contributory factor in causing fuse blowing.

BLOWING BY MAGNETIZING INRUSH CURRENTS

The I^2t in the 60-cycle magnetizing inrush current of General Electric distribution transformers is equivalent to approximately 10 to 12 times the normal full-load current of the transformer, flowing for 0.1 second. Using this ratio as a criterion, fusing practices of 1.5, or more times the full-load current of the transformer (with fuse links having a rating basis similar to the G-E Universal, cable-type design Types "N", "K", or "T" will not cause any fuse blowing from magnetizing inrush currents. However, some difficulty might be anticipated with fusing practices of the order of 1.3 or less times the full-load current of the transformer.

IV. EQUIPMENT PROTECTION

FUSING CAPACITORS APPLIED AT DISTRIBUTION VOLTAGES (2.4 KV THROUGH 13.8 KV)

Fusing practices on capacitor banks at distribution voltages (2400 to 13,800 volts) can logically be separated into two classes:

1. Group fusing capacitor banks normally pole mounted and located on the primary feeder. In this case only one fuse is used per phase, each of which protects two or more capacitor units that are located in that phase.

2. Individual fusing of large capacitor banks normally located at the distribution substation. Here, each capacitor unit is protected by its own individual fuse; back-up protection in the form of a circuit breaker or higher-rated fuse is normally provided to protect against bus faults ahead of the individual fuses. (On factory-built stack-rack-type assemblies the proper fuse is furnished by the manufacturer.)

PURPOSE OF FUSING

Basically, the reasons for fusing for either class are similar. These are:

1. To isolate a faulted bank or portion of a bank without interrupting service on the remainder of the circuit, thereby reducing the consumer or KVA-minutes outage on the whole system.

2. To clear a faulted capacitor from the circuit before gas generated by internal arcing bursts the capacitor case with the possibility of this impact damaging adjacent capacitor units or other equipment and endangering operating personnel.

3. To give indication as to the location of the fault in order that it may be easily corrected.

4. In the case of group fusing or back-up fusing of individually fused capacitor banks, the fuse cutout affords a convenient means of manually switching the capacitor banks, or section thereof, on and off the line in accordance with system KVAR requirements.

5. In the case of an individually fused capacitor bank, to isolate a faulted capacitor unit without measurably affecting the over-all operation of the bank. In this way, the remaining unfaulted units continue to deliver rated capacitor KVAR.

CONSIDERATIONS FOR CHOOSING PROPER FUSE

It is not possible to choose fuse links for capacitor protection merely by the continuous current rating.

There is a wide difference between makes and types of fuse links and fuses in the relation of the rating to the current at which they melt in 300 seconds and in their speed ratios, i.e., the ratio of their 0.1 to their 300-second melting currents. Thus to choose fuse links or fuses for capacitor applications it is necessary to compare their time-current characteristics in relation to the required characteristics for protection of capacitors. A complete discussion on the use of current-limiting fuses is outside the scope of this publication. For more information on, together with characteristic curves for, current-limiting power fuses, attention is called to publication GET-3039 entitled "Selection and Application of Power Fuses."

PREVENTING CAPACITOR UNIT CASE RUPTURE

When a capacitor dielectric fails, the resulting arc creates internal pressure from heat and a gas generated in the liquid dielectric of the unit. The pressure varies depending upon the amount of fault current to the failed unit and the time it is allowed to flow. This force can swell the sides of the capacitor case or rupture the case, that is, anything from opening a seam or bushing seal, to violent bursting endangering adjacent equipment. Thus protection against case rupture involves clearing the failed unit or the whole bank quickly enough to prevent disruptive pressures, for all circuits within the range of minimum to maximum calculated-fault currents available to a failed capacitor, as limited by line impedance and differences in power generation at the source. The fault resistance, or impedance, of a failed capacitor should be considered as zero. Case rupture can occur at low currents which persist for long periods. Thus, the total clearing time-current curves for the protecting fuse link should be totally to the left of the desired–10 percent, 50 percent or 90 percent–NEMA standard case bursting curves shown in NEMA publication No. CA-1-1955 (CAI-6.07) for the full range of available fault currents at the failed capacitor. (For coordinating use Curves 20A and 20B under Useful Curves.)

In the Safe Zone the fuse link must clear the circuit in 300 seconds at the minimum available fault current.

The 10 percent, 50 percent and 90 percent curves terminate with a vertical line at 4000 amperes for the 25 (or 15)-kvar units and 5000 amperes for the 50 and 100 kvar units. This indicates the maximum permissible available fault current for expulsion or oil-type fuse links up to which tests have shown the fuse link is capable of protecting the capacitor against violent rupture. With some of the higher-rated fuse links the maximum permissible current may be less than these values as indicated by the total clearing time-current curve of the link crossing the 10 percent or 50 percent curves. Where the available fault current exceeds the 4000 or 5000 amperes, or the lower values, indicated by the crossing of the curves, there are two alternatives which may be considered. First, the capacitor equipment can be connected floating-wye and group-fused with expulsion fuses since then the fault current is limited to approximately three times normal current. Second, current-limiting fuses, such as the General Electric type EJO, can be used for grounded-wye or delta equipments. In this case the maximum fuse rating is limited by the availability of sufficient short-circuit current to melt the fuse within 1/2 cycle. The continuous current rating of the current-limiting fuse should be chosen on the same basis as outlined for the expulsion fuse links. Do not apply these fuses at system voltages less than 70 percent of the voltage rating of the fuse.

The recommended fuse ratings apply to G-E fuse links and have been selected on the following basis:

1. The continuous-current capability of the fuse link should be at least 165 percent of the nominal capacitor-bank current. (For delta and floating-wye banks this factor may be reduced to 150 percent if necessary.)

2. The total clearing characteristic of the fuse link must be coordinated with the capacitor "case-bursting" curves.

Tests have demonstrated that expulsion fuse links will not satisfactorily protect against violent rupture where the fault current through the capacitor is greater than 5000 amperes. The capacitor bank may

TABLE V

RECOMMENDED FUSING FOR GROUNDED-WYE AND DELTA CONNECTED CAPACITOR BANKS WHERE FAULT CURRENT DOES NOT EXCEED 5000 AMPERES

3-phase KVARS	2400 Volts		4160 Volts		4800 Volts		7200 Volts		12470 Volts		13200 Volts		13800 Volts	
	N/Oil	K/T	N/Oil	K/T	N/Oil	K/T	N/Oil	K/T	N/Oil	K/T	N/Oil	K/T	N/Oil	K/T
150	75	50	40	25	40	25	20	12	15	10	15	10	15	20
300	—	100‡/—	75	50	75	50	40	25	25	15	25	15	25	15
450			100	100/—	95/100	80/—	75	50	40	25	40	25	40	25
600			—	100‡/—	—	100‡/—	85/100	65	50	40	50	40	45	30
750							100	100/—	75	50	75	50	50	40
900							—	100‡/—	75	50	75	50	75	50
1050							—	100‡/—	85/100	65	75	50	75	50
1200									95/100	80/—	85/100	65	85/100	65
1350									100	100/—	100	100/—	95/100	80/—
1500									—	100‡/—	—	100‡/—	100	100/—
1650									—	100‡/—	—	100‡/—	—	100‡/—
1800									—	100‡/—	—	100‡/—	—	100‡/—

* Fault current should not exceed 5,000 amperes.

‡ Use low melting temperature fuse link such as G-E "K" or "T".

NOTE: For single-phase capacitor banks, multiply the single-phase kvar rating by 3 to obtain the equivalent 3-phase kvar rating, and multiply the single-phase voltage by 1.73 to obtain the equivalent 3-phase voltage rating. Select the fuse link recommended under the corresponding 3-phase kvar and 3-phase line-to-line voltage rating from the table for the grounded-wye or delta-connected banks.

TABLE VI

RECOMMENDED <u>FUSING</u> FOR FLOATING-WYE CONNECTED CAPACITOR BANKS$^{\phi}$

3-phase KVARS	4160 Volts		4800 Volts		7200 Volts		8320 Volts		12470 Volts		13200 Volts		13800 Volts	
	N/Oil	K/T	N/Oil	K/T	N/Oil	K/T	N/Oil	K/T	N/Oil	K/T	N/Oil	K/T	N/Oil	K/T
75	20	12	15	10	10	8		—		—		—		—
150	40/30	25	30	20	20	12	20	12	15	8	10	8	10	8
225	50	40	45/40	30	30	20	25	15	20	12	15	10	15	10
300	75/60	50	75/60	50	40	25	40	25	25	15	25	12	20	12
375	85/75	65	75	50	45/50	30	40	25	30	20	30	20	25	15
450	95/—	—	85/—	65	50†/60	40†	50	40	40	25	30	20	30	20
525			95/—	—	75/60	50	50†/60	40†	40	25	40	25	40	25
600					75	50	75	50	45/50	30	45/50	30	40	25
675					85/—	65	75	50	50	40	45/50	30	45/50	30
750					95/—	—	85/—	65	50†/60	40†	50	40	50	40
825					95/—	—	85/—	65	50†/60	40†	50†/60	40†	50†/60	40†
900							95/—	—	75	50	75/60	50	50†/60	40†
975									75	50	75	50	75	50
1050									75	50	75	50	75	50
1125									85/—	65	75	50	75	50
1200									85/—	65	75/—	65	75	50
1275									95/—	—	85/—	65	85/—	65
1350									95/—	—	95/—	—	85/—	65
1425											95/—	—	95/—	—
1500													95/—	—

ϕ Minimum fault current should blow fuse link within approximately 300 seconds.

† Should be used in 100-ampere cutout. Tests show that these links in 100-ampere cutout will carry the required current continuously.

be connected in a floating wye to limit short-circuit current to less than 5000 amperes.

For grounded-wye or delta-connected banks, satisfactory protection can be obtained with G-E Type EJO fuses up to a maximum size of 100 E at the 15-kv class and 150 E at the 2.5- and 5-kv class.

DISTRIBUTION TRANSFORMER PROTECTION

SELF-PROTECTED TRANSFORMERS

The incorporation of an internal line-protection fuse and an external mounted lightning arrester as an integral part of the transformer makes the self-protected transformer a completely self-contained unit with built-in over-current protection and direct mounted overvoltage protection.

The self-protected transformer has an internal line-protection fuse installed in the unit for the sole purpose of removing the transformer from the primary line in case of a fault within the transformer itself. The low voltage breaker protects the transformer against high overloads and faults originating on the secondary lines.

Internal Fuse Selection

The rating of the internal fuse is so selected by the transformer manufacturer that the fuse will not be damaged by the maximum tripping current of the breaker. There is another factor in the selection of this fuse which must be considered--the effect of surge currents due to lightning. The lightning arrester affords adequate protection to the transformer as far as the surge voltage is concerned, but in some cases surge currents may be of such type and duration as to blow a fuse.

Experience has shown that to keep this type of fuse-blowing to a minimum, a substantially larger fuse is necessary than would be required from the standpoint of coordination with the low voltage circuit breaker. The choice of fuse size is, therefore, dictated by a balance between the number of fuse blowings due to lightning, and unduly raising the level for the line fuse coordination.

In the early use of these transformers, some confusion was caused by the desires of individual operators to use fuses of ratings differing from those regularly supplied by the manufacturer. At present, the ratings of internal fuses provided by most manufacturers is approximately the same.

TABLE VII

GUIDE FOR <u>SWITCHING</u> G-E DISTRIBUTION CUTOUTS WITH CAPACITOR LOADS*

1. For load-break fuse cutouts without capacitor units individually fused see Table V or VI for maximum KVAR ratings† based on fusing to prevent capacitor case bursting, (except oil-filled cutouts–see tables below).

2. For load-break enclosed or open cutouts with capacitor units individually fused¶ cutouts will switch KVAR loads† up to that permissible with the maximum rating of fuse link or disconnecting blade (except oil-filled cutouts - see table below).

3. For fuse cutouts, expulsion (not load-break) or oil-filled types see table below which are based on limited switching ability of cutouts* with capacitor loads.

Type of G-E Cutout	CUTOUT RATINGS			MAXIMUM RATED CAPACITOR KVAR, 3-PHASE, 60-CYCLES, THAT CAN BE SWITCHED† (MAXIMUM FUSE LINK FOR GROUP FUSING, SEE TABLES XV AND XVI, MAY LIMIT KVAR RATING BELOW THESE VALUES)							
	Max Design Volts	Am-peres	Interrupting RMS Amperes	△ At 2400V Delta	△ At 4160V Delta or Ungrd. Wye	At 4160V Grd. Wye	△ At 4800V Delta or Ungrd. Wye	△ At 7200V Delta or Ungrd. Wye	At 8320V and 12470V Grd. Wye	At 13200V Delta and Ungrd. Wye or Grd. Wye	At 13800V Delta and Ungrd. Wye or Grd. Wye
ENCLOSED-TYPE EXPULSION CUTOUTS—Fuse Values—Disconnecting Values											
9F6D1 Series	5200	50	5000/8000	125/300	225/450	225/530	275/450	....	No	Cutout	Available
9F6D3 and -D5 Series	5200	100	5000/14,000	250/600	450/450	450/600	450/450	....	No	Cutout	Available
9F6D2 Series 9F6D4 and -D6 Series	7800 7800	50 100	4000/5000/8000 4000/14,000	125/300 250/600	225/450 450/450	225/530 450/600	275/450 450/450	Use Load Break Cutout	No No	Cutout	Available
9F16C76	5200	200	10,000/14,000	500/600	450/450	600/600	450/450	....	No	Cutout	Available
OPEN-TYPE EXPULSION CUTOUT—Fuse or Disconnecting Values											
Dropout Dropout	7800 15000	100 100	5000 4000	190 190	240 240	375 375	100 100	Use Load Break Cutout	....	....	....
OIL-FILLED CUTOUTS—Fuse or Disconnecting Values											
Pole, Pothead Subway or Metal Enclosed	5200 5200 5200 7800	100 200 300 100	5000 10000 10000 3750	250/460 500/770 750/750 250/460	450/800 900/1000 1000/1000 450/800	450/800 900/1200 1200/1200 450/800	500/925 1000/1000 1000/1000 500/925	....	Refer to G.E. Pittsfield	Cutout Cutout Cutout Cutout	Available Available Available Available

* Switching with air-break devices such as enclosed- or open-type fuse cutouts depends on the technique of the operator and the speed of opening of the devices. Thus the values in this table are given as a guide. Operating experience may indicate that experienced operators can successfully switch high KVAR values of capacitors on and off the line.
The tests from which the above values were derived were made on single-phase single bank basis, indoors, in still air. Thus these values are for switching single banks only and not for switching banks which are adjacent to other capacitors energized from the same lines. Clearing of the circuit was obtained on 100% of the tests and in no case did the arc rise more than one foot above the top of the cutout. Open-type cutouts successfully switched higher KVAR values than those in the table but with considerably higher rise of arc above the cutout.

† These values of 3-phase, 60-cycle capacitor KVAR can be switched are based on rated capacitor voltage and current with allowance for overloads encountered under average operation conditions and providing the bank regulation does not exceed 5%. (Bank regulation = $\frac{\text{Capacitor full load current}}{\text{Available short circuit current at point of installation.}}$)

For single-phase KVAR values, divide the above figures, for delta connected banks of the same voltage ratings, by 1.73. For example, the 3-phase value that can be switched with a certain cutout at 7200 volts delta is 160 KVAR. Therefore, the single-phase value at this voltage is 160 divided by 1.73, or 92 KVAR.

¶ When capacitor units are individually fused, higher rated back-up fuse links (at least 150 to 165% of load current) can be used. Thus cutouts with greater switching ability or with load-break ratings can be used to switch capacitor loads up to the full rating of the cutout—or for oil-filled cutouts as given in the table above.

△For switching, delta connection resembles ungrounded wye, whereas, for fusing (see Table V), delta connection resembles grounded wye.

Low Voltage Breaker with Household Fuses

From the viewpoint of fitting the transformer internal breaker performance curve into a coordination plan, it appears desirable (if not essential) to have a performance curve which parallels and lies between the internal fuse and the household fuse curves in the short-time region.

The tripping characteristics of the low voltage breaker are also adjusted to coordinate with the largest service entrance fuse, or similar device, which is likely to be used between the transformer and the load. For example, the low voltage breaker in a 3-kva self-protected transformer will allow a 60-ampere household fuse to blow before the transformer breaker trips when a fault occurs on the load side of the fuse. Since the internal fuse must be sufficiently high in current rating not to be damaged by current permitted by the breaker, it is apparent that the rating of the household fuse has a definite bearing on the rating of the internal fuse and the coordination level of the whole system. The higher the household fuse rating, the higher the breaker performance curve, and the higher the internal fuse rating required. This in turn may require a higher rating sectionalizing fuse, and so on up the line to the substation.

Coordination of Internal Fuse with Line-sectionalizing Fuse by Use of Charts

Although the coordination of internal secondary breakers and internal primary fuses offers no flexibility of choice by the user, the coordination of

TABLE VIII

DESIGNATION NUMBERS OF INTERNAL FUSES IN G-E TYPES HBA AND HSBA DISTRIBUTION TRANSFORMERS (WITH INTERNAL FUSES AND SECONDARY BREAKERS)

KVA	VOLTAGE RATING OF TRANSFORMER																			
	2400 VOLTS				4160 VOLTS			4800 VOLTS 2400 x 4800			4160 4800	7200 VOLTS 7620 VOLTS				11500 12000	13200 14400	11500 VOLTS 14400 VOLTS		
	FUSE DESIGNATION NUMBER△																			
Date Built	Prior 1940	1940 1955	1955 1956	1956 #	Prior 1940	1940 1955	1955 1956	Prior 1940	1940 1955	1955 1956	1956 #	Prior 1940	1940 1955	1955 1956	1956 #	Prior 1940	Prior 1940	1940 1955	1955 1956	1956 #
1½	6				4			3				3								
3	7	6	7	7	6	4	5	6	3	5	5	3	2	2	3	2	1	1	1	2
5	8	6	7	7	7	4	5	7	4	5	5	6	3◉	3	3	3	2	1	1	2
7½	9	8			8	5		7	5			7	4	4	5					3
10	9	8	9	9	9	6	7	8	5	7	8	7	4	4	6	4	4	3	3	4
15	11	10	10	10	10	8	8	9	7	8	8	8	5	5	6	6	5	4	4	4
25	12	10	11	11	11	8	9	9	8	9	9	8	6	7	7□	7	6	4	5	6
37½		12	13	14		9	11		9	11	12		7	9	10			5	7	8
50		13	14	14		10	12		10	12	12		8	10	10			7	8	8
75				34							14				32					30
100				35							33				32					31

* Voltages 4160 and 4800 and 2400 x 4800 were combined for the year 1956 under voltage class 4160 and 4800.

\# 1956 listings indicate fuses used in conjunction with new plus + breaker settings. Transformers manufactured July 1956 and later.

△The fuse designating number applies to fuses which are used in the primary leads inside of distribution transformers. It is not the current rating. Designating numbers 2 to 14 refer to Time-current Characteristic Curve 13 and numbers 30 to 35 refer to curve 13A, Useful Curves.

◉For transformers built between Jan. 1940 and Sept. 1945 fuse 2 was used (Serial numbers 6,000,000 to 7,660,000 approximately).

□No. 8 fuses used until March 1957 (Serial numbers C580000 to D108000).

NOTE: Approximate transformer serial numbers by dates of manufacture:
Prior to 1940—6,000,000 or less.
1940 to May 1955—6,000,000 to C-370,000
May 1955 to July 1956—C-370,000 to C-580,000. For 3, 5 and 7½ kva, serial numbers C-276,000 to C-723,000.
July 1956 and above—C-580,000 and above. For 3, 5 and 7½ kva, serial numbers C-723,000 and above.

internal primary fuses with line-sectionalizing fuses can be obtained by proper selection of the latter fuses. This coordination is imperative to reduce such maintenance expense as tracing faults causing blown sectionalizing fuses, indicating a line fault when the fault is actually in the transformer. Internal fuses, when properly coordinated, clear before sectionalizing fuse links are damaged.

Transformer internal fuses are installed at the factory and are given a designating number rather than an ampere rating. (See Table VIII Designation Number of Internal Fuses.) It is necessary to know which fuse link is in each transformer. With this information, and referring to Coordination Charts 5, 6, and 7 (see section on Coordination Charts), the proper external fuse rating can be selected which will coordinate with the transformer internal fuse.

PROTECTION OF CONVENTIONAL TRANSFORMERS

Most operating experience in the United States is based upon primary fusing at one ampere per kva of transformer rating at 2400 volts, one-half ampere at 4800 volts, and one-third ampere at 6900 volts (with "N" type fuse links designed to melt at 150 per cent of their rating within 300 seconds). In such practice, the primary fuse link will clear the transformer from the line quickly enough to protect the transformer from faults occurring at a reasonable distance out on the secondary lines.

In setting up transformer fusing practices, especially where higher fusing might appear to be advantageous, it is desirable to determine what effect fusing will have on the overcurrent protection of the transformer. This protection might best be measured in terms of the length of secondary line on which a fault will be cleared quickly enough to provide the degree of overcurrent protection to the transformer that is indicated by the ASA C-57 transformer safe-loading guide or in accordance with Table IX.

TABLE IX
SUGGESTED TRANSFORMER FUSING PRACTICE

Voltage Rating of Transformer or Bank									Suggested Fuses			
2400 1 Phase	2400 L to L 3 Phase †	4160 L to L 3 Phase †	4800 1 Phase	4800 L to L 3 Phase †	7200-7600 1 Phase	8320 L to L 3 Phase †	12,000-14,400 1 Phase	12,000†-14,400 L to L 3 Phase				
KVA Rating of Transformer or Bank									N	K	T	Hi Surge
....	....	....	....	....	3	....	3, 5	9	1	1	....	1V
....	....	....	....	....	5	....	....	15	2	2	....	2V
....	....	....	3	....	....	9	10	....	2	2	....	2X
....	....	....	....	....	....	....	....	....	3	3	....	3V
3	....	9	5	9	10	15	15	30	3	3	....	3X
....	....	....	....	....	....	....	....	....	5	6	6	3X
5	....	15	....	....	....	....	....	....	5	3	....	5X
....	....	....	10	15	15	30	25	45	5	6	6	5X
....	9	....	15	....	25	45	37½	75	8	6	6	8X
10	15	30	....	30	....	....	50	....	10	8	8	....
15	22½	45	25	45	37½	75	75	112½	15	10	10	....
....	50	....	37½	....	50	112½	100	150	20	12	12	....
25	45	75	50	75	75	150	....	225	25	15	15	....
....	....	....	....	112½	....	....	167	....	30	20	20	....
37½	75	112½	75	150	100	225	....	300	40	25	25	....
50	....	150	....	....	....	....	....	....	45	30	30	....
....	....	....	100	....	167	300	....	500	50	40	40	....
75	112½	225	....	225	....	500	....	....	75	50*	50*	....
....	....	....	....	300	....	....	....	....	85	60	60	....
100	150	300	167	....	....	....	....	....	85	65	65	....
....	225	....	....	....	....	....	....	....	100	80	80	....
167	....	500	....	....	....	....	....	....	100	100	100	....
....	300	....	....	500	....	....	....	....	125	100	100	....
....	500	....	....	....	....	....	....	....	150	140	140	....

* In 100-amp cutouts.

† Transformers connected in either wye or delta.

CAUTION: This fusing table is based on a fusing practice of 2.4 times the transformer full load current. This fusing practice makes no guarantee that the transformer will not be damaged due to overloading or short-circuit currents.

PROTECTION AGAINST CONDUCTOR BURNDOWN

Extensive outages and hazards to life and property can result from primary lines being burned down by flashover, tree branches falling on line, etc. Insulated conductors anchor the arc at one point and thus are most susceptible to being burned down. With bare conductors, except on multi-grounded neutral circuits, the motorizing action of the current flux of an arc always tends to propel the arc along the line away from the power source until the arc elongates sufficiently to automatically extinguish itself. However, if the arc encounters some insulated object, the arc will stop traveling and may cause line burndown.

With bare conductors, on multi-grounded neutral circuits, the motorizing effect occurs only on the phase wire since current may flow both ways in the neutral. When the arc is extended by traveling along the phase wire, it is extinguished but may be re-established across the original path. Generally the neutral wire is burned down.

With tree branches falling on bare conductors the arc may travel away and clear itself, but generally the arc will be re-established at the original point, continuing this procedure until the line burns down or the branch falls off the line. Limbs of soft spongy wood are more likely to burn clear than hard wood. However, one-half inch diameter branches of any wood which cause a flashover are apt to burn the lines down unless the fault is cleared quickly enough. Overcurrent protective devices at branch or line sectionalizing points in the primary lines aid in preventing line burndown and limit the damage to conductors. To permit determining the degree of such protection afforded by a particular device against burning down the line, Curve 18 GET-1713A has been made available. These data are for insulated conductors (5-inch spacing) and are thus very conservative for bare conductors. By superimposing Curve 18 on the total clearing-time current curves for the protective device, it will be possible to determine the degree of protection afforded.

V. HELPFUL SUGGESTIONS FOR USING TIME-CURRENT CHARACTERISTIC CURVES OF FUSE LINKS, OIL CIRCUIT RECLOSERS AND RELAYS

GENERAL

The time-current characteristic curves of over-current protective devices provide the means by which the sequence of operation can be determined when the devices are connected in series. American Standards have adopted on a uniform log-log coordinate sheet (obtainable from Kueffel and Esser, New York City under Number 336E) so as to facilitate ready comparison of all published data. The curves are all plotted on the standard size of transparent paper to permit readily superimposing one sheet over another. (Paper changes size with changes in atmospheric moisture so the scales of the curves may not coincide exactly over the full sheet. In using the curves be sure the scales coincide exactly in the portion where the comparison is being made.) These transparent curves are not provided with this publication but can be readily obtained by contacting your nearest General Electric representative and referring to the GET or GES listed under Useful Curves.

The time-current curves for fuses have two characteristics, namely: melting time, which is the time required to melt and to cause the fusible section to be severed; and the total clearing time, which is the time to melt the fusible section plus the time arcing persists until the circuit is cleared. Since the melting time-current curves of fuses will always be compared with curves to the left they are plotted to minimum test points so the minor amount of variation that cannot be eliminated in the manufacture, is to the right. Conversely, total clearing time-current curves of fuses are always compared with curves to their right so they are plotted to maximum test points making the variations to the left. Thus, as illustrated in Fig. 23, the manufacturing variables have been included in the plotting of the curves so no further consideration of these variables is necessary in using the fuse curves. This procedure in plotting is in accordance with American Standards.

The test data for the curves for fuses is based on starting at the ambient temperature of 25 C when the fuse is subjected to the excessive current. The fuses will melt about 15 percent faster after having carried full load. Also the fusible section of most modern distribution fuse links is comprised of a strain wire and a fusible wire in parallel which melt progressively, requiring a maximum of 10 percent allowance with G-E fuse links to prevent melting only the fusible wire and leaving the strain wire intact. Therefore, a factor of minus 25 percent in the time to melt is recommended for these operat-

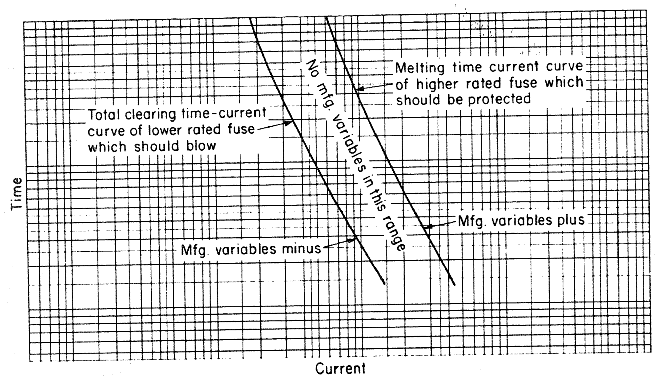


Fig. 23. Shows how plotting of fuse curves eliminates manufacturing variables from the range of comparison

ing variables, which can be included when comparing the curves by shifting the relation of the time scales, as will be described later.

The time-current curves for oil circuit reclosers show two characteristics: the instantaneous and the time-delay opening cycles. The time-delay operation can be either a standard time-delay or an extended time-delay operation.

The time-current curves (instantaneous, standard and extended time-delay) for each frame size (50, 100, 200 amperes) of HR reclosers and curves B, C, and D for the OR and VIR reclosers can be produced in template form for extensive coordination studies with all fuse links. These transparent templates can then be used with the time-current characteristic curves of overcurrent protective devices such as fuses and relays for making coordination studies or preparing coordination charts.

Whenever there is more than one operation of the recloser the curve would represent the total time for all openings. This can be obtained by shifting the templates upward in time (i.e., for two instantaneous operations, the time comparison of the recloser template when superimposed on the fuse curve sheet would be doubled).

The time-current curves for relays show the time to close the contacts thus energizing the means for tripping the breaker. The curves are plotted to average values with a variation of plus or minus 10 percent, which can be factored, plus any additional allowance considered advisable, by shifting the relation of the scales of the curves, as will be described later.

Logarithmic scales are used for plotting the time-current curves. This makes possible a distinct separation of the fuse link curves in the high-current as well as the low-current range as is illustrated in Fig. 24. This is important in securing the accuracy necessary in order to provide a dependable sequence of operation of fuses or other protective devices connected in series.

Multiplying or dividing the time and/or current values of one curve with respect to another is aided by the use of logarithmic scales. Just as with a slide rule, if 1 on the time scale of one curve sheet is placed over say 2 on the time scale of a second curve sheet, all of the values on the time scale of the second curve sheet will be exactly two times the coinciding values on curve sheet one, as illustrated in Fig. 25.

Thus, if the time values for curves on curve sheet number one are read on the scale of curve sheet number two, this would have the effect of multiplying the time of curve sheet number one by two. Such shifting of the time and/or current scales permits numerous short cuts to avoid replotting in comparing the published curves for operating conditions not directly covered by the curves as published.

(1) TO INCLUDE A FACTOR FOR VARIABLES

To include a factor for variables place one curve sheet over the other so the current scales coincide and shift the time scales so the 1-second line on the curve sheet to which the factor is to be applied coincides with 1-second minus the factor – or with 1-second plus the factor – on the other curve sheet. For example: In applying the 25 percent factor to the melting time of the fuse link curves for operat-

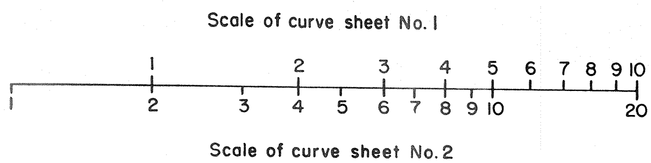


Fig. 25. Showing how shifting the relation of log arithmic scales on two curves sheets multiplies the values

ing variables place the curve sheets so the current scales line up exactly and so the 1-second line on the sheet for melting time-current curves coincides with the 0.75-second line on the sheet for total clearing time-current curves (or so 4 on the melting time coincides with 3 on the total clearing time) as illustrated in Fig. 26. Compare the curves on the two sheets reading the time values on the total clearing time-current scale.

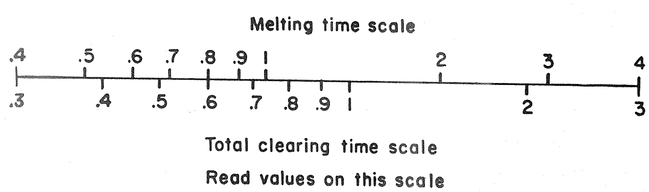
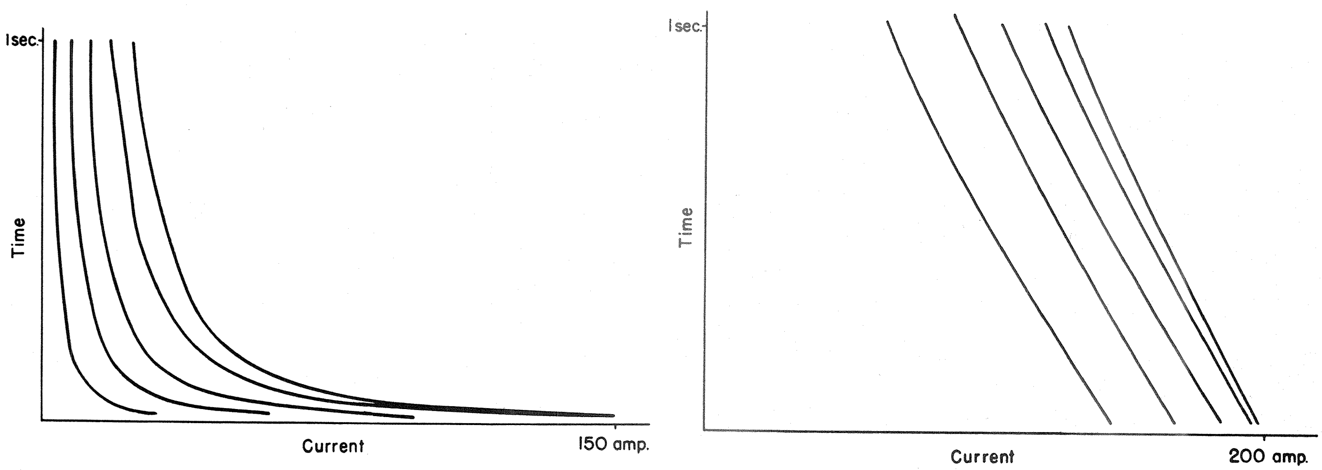


Fig. 26.

(2) TO MULTIPLY OR DIVIDE TIME OR CURRENT

To multiply or divide the time or current values of a curve, say, for including the time for all of the opening cycles of a reclosing device, place the curve sheets so that the scale to be multiplied is underneath and the current scales of both sheets coincide. The one-second time value on the scale to be multiplied must coincide with the multiplier value on the



(a) Fuse curves plotted to arithmetic scale

(b) Fuse curves plotted to logarithmic scales

Fig. 24. Comparison of curves for identical fuse links showing the bunching of the curves in the high current and with the arithmetic scales and the distinct separation with the logarithmic scales

time scale of the top sheet. Read all values on the top scale.

For example, to compare the total-clearing time curve of a protecting two-element reclosing cutout with the melting-time characteristic of the protected single-element fuse, proceed as follows: place the curve sheets so the current scales coincide and shift the time scales so the 1-second line on the sheet for the total clearing time-current curves coincides with the 2-second line on the sheet for the melting time-current curves. Read the time values from the melting time scale.

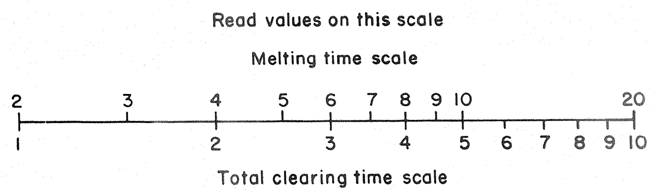


Fig. 27.

(3) TO COMBINE THE INCLUSION OF A FACTOR WITH MULTIPLICATION

To combine the inclusion of a factor of (1) and a multiplying operation (2) proceed as follows: Place the curve sheets so that the curves to be multiplied are underneath and the current scales of both sheets coincide. Add (or subtract) the factor to (from) unity. This value on the time scale of the bottom sheet must coincide with the multiplier value on the time scale of the top sheet. Thus, in the examples of (1) and (2) shift the time scales so the line for the 2-seconds melting time coincide with the line for 0.75 seconds total clearing time instead of the 1-second total clearing time line as directed in (2).

(4) TO FACTOR TRANSFORMATION RATIOS

To factor transformation ratios place the curve sheet so the time scales coincide exactly – or are shifted as in (1), (2), or (3). If it is desired to read the currents in terms of primary voltage, place the primary fuse curves on top and read on this scale. For secondary currents, place the secondary fuse curves on top and read on this scale. Shift the current scales so the 1-ampere line on the curve sheet for the higher voltage device coincides with the current line for the higher value of the transformation ratio (the 10 of a 10-to-1 ratio) on the curve sheet for the lower-voltage device. (The transformation ratio is given in terms of voltage and the current is greater for the lower voltage.) For example, to check the coordination of secondary and primary fuses on a 6900/230-volt transformer, 30-to-1 transformation ratio, place

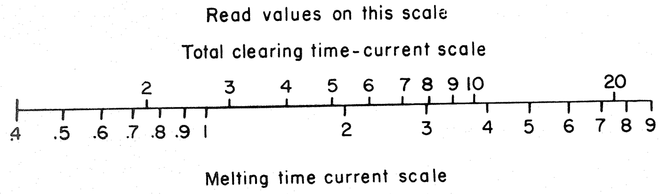


Fig. 28.

the curve sheet so the time scales coincide correctly and shift the current scales so the 1-ampere line of the curve sheet for the 6900-volt primary fuse is over the 30-ampere line of the curve sheet for the 230-volt secondary fuse. Read the current values in terms of the desired voltage by using the corresponding current scale. This is shown in Fig. 29.

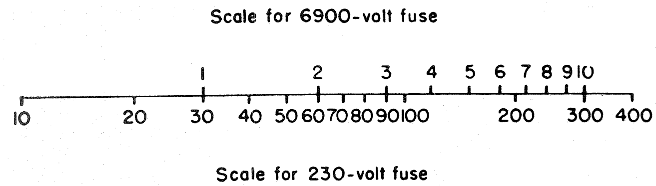


Fig. 29.

(5) TO COMPARE CURVES WHEN CURRENT IS GIVEN AS A MULTIPLE OF FULL-LOAD OR MINIMUM CLOSING CURRENT

To compare curves where values on the one curve are given in terms of a multiple of minimum closing or full load or some other current, place the curve sheet so the time scales coincide and so the line marked 1 on the curve sheet with the scale marked "Multiple of (some) Current" coincides with the line on the other curve sheet for the actual current of which the other curve is a multiple. For example, in checking the coordination of a relay set to close at 250 amperes, using relay curves 9, 9.1, 10, 10.1, or 10.2 under "Useful Curves," place the line for 1 times the minimum closing current on the relay curve sheet so it coincides with the 250-ampere line on the fuse link curve sheet curve 4 (under "Useful Curves") and have the time scales line up exactly, as shown in Fig. 30.

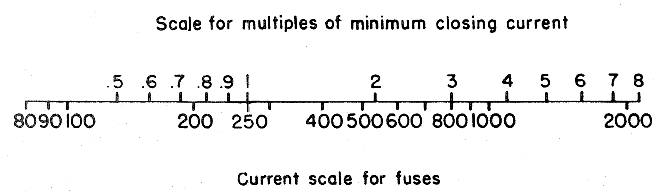


Fig. 30.

(6) TO FACTOR THE COOLING EFFECT OF FUSE LINKS WHILE RECLOSING DEVICES ARE OPEN

Where fuse links are subjected to alternate heating and cooling periods, such as occurs when in series with reclosing circuit-interrupting devices, it is necessary to correct the melting, or total clearing time-current curves to compensate for the heat lost during all of the cooling periods while the reclosing device is open. The following procedure involves using a formula to calculate the additional "correction time" a given current must be applied to compensate for this heat loss, as illustrated in Fig. 31. While not absolutely accurate, this procedure has been checked by laboratory tests and at least 5 years of operating experience by several utilities on which not one case of incorrect operation has been reported.

$$\text{Correction Time} = \frac{(I^2_{300})\,(T_d)}{I_p^2}$$

Where I_{300} = The current in amperes at 300 seconds on the published time-current curve being corrected.

I_p = The current in amperes at the point (P) on the published time-current curve being corrected.

Td = The total time in seconds from the opening to the closing of the reclosing protective device for all reclosers (the cooling period of the fuse link); that is, if the portion of the operating cycle involved consisted of three opening operations with two reclosures of x seconds duration, Td = 2 x seconds.

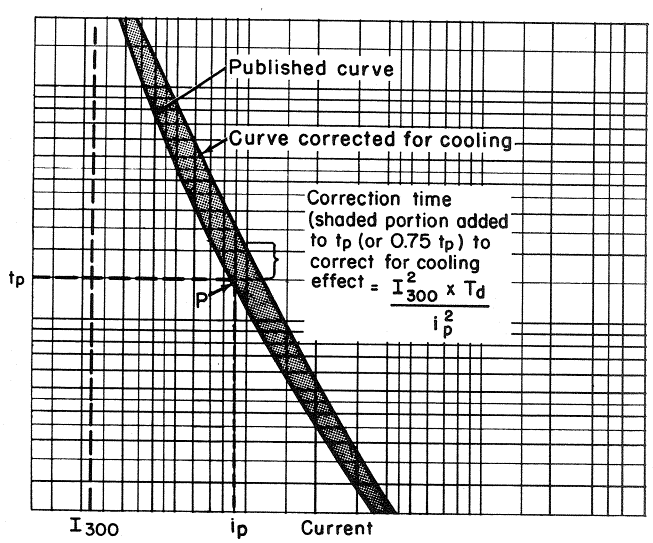


Fig. 31. Showing calculation of time-current curves which are compensated for cooling effect while circuit is open during reclosures

A. Where the Reclosing Device Operates before the Fuse Link is Damaged (reclosing device protects the fuse link)

It is necessary to correct the melting time-current curve of the fuse link and then compare it with the curves for the reclosing device, as follows:

Step 1A – Determine from the published melting time-current curve the current in amperes at which the fuse link melts in 300 seconds. (This is indicative of the rate at which energy can be dissipated by convection, radiation, and conduction from the fusible element).*

Step 2A – Using the formula, calculate the correction time to factor the cooling effect of several points P on each of the published melting time-current curves for each fuse link rating using the value for I_p at the specific point P on the melting time-current curve and the value for T_d as determined from the operating cycle of the recloser (or the portion thereof which is involved).

Step 3A – For each of the points (P), add the correction time as calculated in Step 2A to 75 percent of the melting time and then plot the new correct melting time-current curve. The corrected time-current curve then includes a 25 percent factor for operating variables which is the preferable procedure. The correction time can be added to the melting time but do not attempt to include a factor for operating variables by shifting such a cuve as then only a percentage of the correction for cooling will be obtained.

Step 4A – Compare the corrected melting time-current curves drawn in Step 3A with the total of all opening times of the reclosing device (total clearing time-current curves plotted for maximum variations). If all of the opening periods of

---

*Where there is only a small heat input to the fuse link during the period while the reclosing device is closed, the heat lost by the link while the reclosing device is open as determined in this manner may be large enough to give incorrect results.

The maximum cooling possible for any one of the cooling periods while the reclosing device is open is the heat that could be generated in the link by the current (i_p) in the time (t_p) at point P on the curve Fig. 31. Therefore, the calculated correction time

$$\frac{I^2_{300} \times T_d}{I_p^2}$$

should never exceed t_p times the number of cooling periods.

the reclosing device are uniform the curve for one opening can be multiplied by the number of opening cycles by shifting the curves. If the opening periods are not uniform add the times for each opening period and plot a new curve.

B. Where the Fuse Link Operates to Clear the Circuit before the Reclosing Device Locks Open (fuse protects the reclosing device)

It is necessary to correct the total clearing time-current curves of the fuse link and then compare it with the curves for the reclosing device, as follows:

Step 1B – Determine from the published total clearing time-current curve the current in amperes at which the fuse link clears the circuit in 300 seconds. (This is indicative of the rate at which energy can be dissipated by convection, radiation, and conduction from the fusible element.)*

Step 2B – Using the formula, calculate the correction time to factor the cooling effect at several points P on the published total clearing time-current curves for each fuse link rating using the value for I_p at the specific point P on the total clearing time-current curve and the value for T_d as determined from the operating cycle of the recloser (or the portion thereof which is involved).

Step 3B – For each of the points P add the amount of correction time calculated in Step 2B for that point and then plot a corrected total clearing time-current curve for the fuses.

Step 4B – Compare the corrected total clearing time-current curve draw in Step 3B with a curve including the total of all opening times of the reclosing device (melting or contact opening time only – no arcing time – plotted for minimum variations). If all of the opening periods of the reclosing devices are uniform the curve for one opening can be multiplied by the number of openings by shifting the curve as earlier directed. If the opening periods are not uniform add the times for each opening period and plot a new curve.

* See footnote on page 35.

VI. STEP-BY-STEP PROCEDURE IN MAKING A COORDINATION STUDY

1. Have available complete data on circuit to be studied.

2. After analysis of circuit configuration, establish tentative location of sectionalizing devices.

3. Calculate maximum and minimum values of fault current at each of the tentative sectionalizing points, and at the end of the main, branch, and lateral circuits. Calculate line-to-ground, three-phase, and line-to-line currents.

4. Select the devices at the substation to give complete and adequate protection to the substation transformer from fault currents on the distribution lines.

5. Coordinate the sectionalizing devices from the substation out, or, from the ends of the circuit back to the substation. Revise the tentative locations of sectionalizing points if necessary.

6. Check the selected devices for current-carrying capacity, interrupting capacity, and minimum pick-up rating.

7. Prepare circuit diagram with adequate scale to show circuit configuration, maximum and minimum fault-current values, rating of sectionalizing devices, etc.

DATA NECESSARY TO MAKE COORDINATION STUDY

The following data should be obtained prior to starting a study:

SYSTEM INFORMATION

1. Circuit diagrams of system.

2. Location of consumers or loads to which a lengthy power interruption would be costly or detrimental.

3. Location and size of large power loads.

4. Location of self-protected transformers larger than 25-kva rating.

5. Maximum peak metered load current at the substation and at the tap-off point of each heavy branch circuit.

SUBSTATION INFORMATION

1. Schematic diagram showing transformer connections, protective devices including high-voltage

and low-voltage side, and outgoing circuit configuration.

2. Substation transformer capacity, voltage (high and low side) and percent impedance.

3. Substation transformer time-current damage curve. (If this is not available, use information contained in latest American Standards Association Publication C57.92.)

POWER SUPPLY INFORMATION (Large System)

1. Line-to-line supply-side voltage.

2. Maximum and minimum three-phase and line-to-ground fault current magnitude at supply voltage.

3. Maximum size or rating of high-side fuses specified by transmission relay engineer.

4. Make and type of high-side fuses if specified by transmission relay engineer.

5. Type of protection, if other than high-side fuse specified by transmission relay engineer.

a. Type of relays used – if any.

b. Specified settings of relays.

POWER SUPPLY INFORMATION (Small System)

1. Distance between substation and power plant.

2. Size and configuration of circuit between substation and power plant.

3. Line-to-line supply voltage.

4. For each generator:

a. Kva capacity.

b. Percent direct axis transient reactance.

c. Percent direct axis synchronous reactance.

d. Percent negative sequence reactance.

e. Type of prime mover.

5. Generators normally running during minimum and maximum loads.

6. Maximum size or rating of substation high-side fuse if specified by transmission relay engineer.

7. Make and type of substation high-side fuse if specified by transmission relay engineer.

8. Type of protection if other than high-side fuse specified by transmission relay engineer.

a. Type of relays used – if any

b. Specified setting of relays

EQUIPMENT INFORMATION

1. High-side substation fuse: make, type, time-current characteristic curves, and rating.

2. Make and rating of feeder circuit breakers and relays.

3. Automatic circuit recloser: make, type, table of ratings and time-current characteristic curves.

4. Line-sectionalizing fuse: make, type, and time-current characteristic curves – (melting T-C and total clearing T-C curve).

5. Distribution transformer external and internal fuses: make, type, and time-current characteristic curves.

CONSIDERATIONS IN LOCATION OF SECTIONALIZING DEVICES

The first step is to make a tentative location of sectionalizing devices. These locations may be revised after fault-current calculations are completed and load currents are established at these points. Individual judgment must be used for each case, but the following considerations will be most helpful.

1. Four reclosers or other automatic sectionalizing devices in series on a circuit usually are considered adequate depending upon line length in order to obtain reliable coordination. Non-automatic devices such as disconnect switches, spaced between automatic devices, will be helpful in system operations to minimize circuit outage during permanent faults.

2. Branch lines connected to the main circuit vary in their importance to service reliability depending upon length and at what point they are connected to the main circuit. They present the most exposure to the over-all circuit and are most vulnerable to faults affecting service reliability. Therefore, every branch circuit should be sectionalized regardless of length or connected load. The objective of sectionalizing branch circuits is to protect the main trunk circuit against permanent outage.

3. Lateral circuits connected to branch circuits are usually referred to as second, third, or fourth line sections and have a successively lesser potential for impairing service reliability and they can be correspondingly longer in length or exposure before a sectionalizing device is justified.

4. Any branch or lateral circuit exposed to unusually hazardous conditions should be sectionalized by means of an automatic device such as a recloser or fuse cutout.

5. Where a main trunk line is bifurcated (extending in two different directions), automatic sectionalizing devices, preferably reclosers, should be used to sectionalize each of the circuits at the junction point.

6. All sectionalizing locations should be accessible from roads open the year round.

7. Sectionalizing devices should be located so as to minimize service interruption to important loads; i.e., if a sectionalizing device is to be located near an important load it should be placed beyond that load.

8. When any changes are made to the system, such as additions or revisions of line or increase in size of the substation, a supplementary study must be made to keep the sectionalizing program up-to-date and to see that ratings of devices are still adequate. The system management must also carefully make periodic checks of peak loads on sectionalizing devices, to make sure that overloads do not occur with load growth.

VII. APPENDIX

FUNDAMENTALS OF FAULT-CURRENT CALCULATIONS

Before any protective device can be applied on a distribution system, it is necessary to know the magnitudes of fault current that are possible within the area of operation of the device.

The values of calculated short-circuit currents used in a coordination study need not be of utmost accuracy. Inasmuch as a number of factors are assumed, and some neglected, without appreciably affecting the final results, the task of making short-circuit calculations on a typical distribution system involves a theory no more complicated than Ohms Law.

Two magnitudes of fault current should be computed: the maximum fault current and the minimum fault current.

1. MAXIMUM FAULT CURRENT assumes all generating machines are connected, or the power supply is from a heavy integrated system, the fault is bolted or copper to copper, and fault resistance is zero. Maximum fault current magnitude should be computed for each sectionalizing point including the substation bus.

2. MINIMUM FAULT CURRENT assumes the minimum number of generators are on the line at the time of line-to-ground fault with 30 or 40-ohms fault resistance. These resistance values usually will apply to 12.47, 13.2, or 13.8-kv circuit but not 4.16-kv circuits. On the lower voltage systems, a value of 60 to 70 percent of calculated line-to-ground fault current will be considered the minimum value available. Minimum fault current magnitude should be computed for each sectionalizing point, including the substation, and for the ends of the longest lateral circuits.

It is generally possible, after some practice, to estimate fault currents for intermediate points on the circuit within sufficient accuracy after a number of representative current values have been established.

Fuses and reclosers are coordinated using maximum fault currents to establish the proper interrupting capacity device to use. Minimum currents are used to make certain that reclosing circuit breakers, fuses, and reclosers will operate satisfactorily within their zone of protection established by these values of minimum current.

There are four possible types of faults: three-phase, double line-to-ground, line-to-line, and single line-to-ground. The first can occur only on three-phase circuits, and the second and third on three-phase or V circuits. Even on these circuits usually only single line-to-ground faults will occur, due to the multi-grounded construction.

This discussion will cover methods of calculation for line-to-ground, three-phase and line-to-line faults. For double line-to-ground faults, reference is made to "Symmetrical Components", by Wagner and Evans.

3. SYMBOLS

The following set of symbols is used.

$I_{s*L-L)}$ = Line-to-line fault current in amperes on supply side at the substation.

$E_{s(1-L)}$ = Line-to-line voltage in volts on supply side of substation.

I_{3s} = Three-phase fault current in amperes on supply side of substation.

I_L = Fault current on load side.

E_L = Line-to-ground voltage on load side of substation.

R_s = Equivalent resistance per phase of source at load voltage.

X_s = Equivalent reactance per phase of source at load voltage.

Z_s = Equivalent impedance per phase of source at load voltage.

R_t = Resistance per phase of substation transformers at load voltage.

X_t = Reactance per phase of substation transformers.

Z_t = Impedance per phase of substation transformers.

R_L = Resistance per phase of distribution line (multigrounded).

X_L = Reactance per phase of distribution line (multigrounded).

Z = Total impedance per phase of distribution line, source and substation.

X_1, X_2, X_3 = Reactances of individual machines at load voltage (either direct axis transient or negative sequence).

X_m = Resultant reactance of all machines running in parallel.

n = Number of machines.

KVA_1 = KVA capacity of individual machine (total).

KVA_t = Total KVA capacity of all machines.

The fault current which flows will be equal to the voltage E_L divided by the impedance to the point of fault. There are three main components of the impedance to the fault:

(1) the impedance of the source,

(2) the impedance of the substation, and

(3) the impedance of the distribution lines.

4. LINE-TO-GROUND FAULT CURRENTS

a. Source Impedance

(1) Large system

If the line-to-line fault current is given,

$$Z_s = \frac{(E_L)^2}{I_{s(L-L)} E_{s(L-L)}} \text{ Ohms} \quad (1)$$

Note: For source impedance assume R_s = 0, or take an appropriate ratio between R_s and X_s based on judgment.

If the three-phase fault current is given,

$$Z_s = \left(\frac{2}{\sqrt{3}}\right)\left(\frac{(E_L)^2}{I_{3s} E_{s(L-L)}}\right) \quad (1a)$$

If the supply side positive sequence impedance, Z_1, is given in ohms,

$$Z_s = 2Z_1 \left(\frac{E_L}{E_{s(L-L)}}\right)^2 \quad (1b)$$

(2) Small system

$$X_1 \text{ (ohms)} = \frac{X_1 \text{ (Percent) } (E_L)^2 \text{ (3)}}{KVA_1 \quad (100{,}000)} \quad (2)$$

(Use X_1 = direct-axis transient reactance for maximum fault current)

X_2 and X_3 can be found in a similar manner.

$$\text{Then, } \frac{1}{X_m} = \frac{1}{X_1} + \frac{1}{X_2} + \frac{1}{X_3} + \text{----} \quad (3)$$

$$\text{If all machines are alike, } X_m = \frac{X_1}{n} \quad (3a)$$

(n should be maximum for maximum fault current)

Next determine the negative sequence reactances by using formulas (2) and (3) above, only with the percent negative sequence values.

$$\text{Then } X_s = \frac{X_m \text{ (transient)} + X_m \text{ (neg. seq.)}}{3} \tag{4}$$

X_m values must be in ohms.

If machine reactances are not obtainable, the following values may be used for approximation. (To be used only with discretion.)

Slow speed Diesel or reciprocating steam engine driven generators:

(a) Direct-axis transient reactance = 35 percent

(b) Negative sequence reactance = 22 percent

(c) Synchronous reactance = 110 percent

Non-salient pole turbine-driven generators:

(a) Direct-axis transient reactance = 2 pole 15 percent, 4 pole 23 percent

(b) Negative sequence reactance = 2 pole 11 percent, 4 pole 16 percent

(c) Synchronous reactance = 110 percent

Machine resistance can be neglected.

If the plant is some distance from the substation, the resistance and reactance of the tie line must be obtained. This can be done by using handbook values (see Standard Handbook for Electrical Engineers, for example) for the resistance and reactance of the line, using the conductor sizes and spacings of the line. Simply multiply twice the line distance in miles by the resistance and by the reactance (positive sequence) of the line per phase per mile. Convert each of these values separately to distribution voltage by multiplying each by:

$$\frac{E_L^{\,2}}{(E_{s(L-L)})^2}$$

The above assumes a constant voltage along the tie line. If there is another voltage transformation in this tie line, the resistance and reactance of each section should be computed as above, using the voltage for each section. For any transformer in the tie line, add 2/3 of the transformer impedance per phase calculated as shown by formula 5, below.

The same methods can be used for any transmission line.

The total X_s equals X_s from (4) plus the reactance determined above for the tie line and R_s equals the resistance as determined above.

b. Substation Transformer Impedance

$$Z_t \text{ (ohms)} = \frac{\% Z \; 10 \; (E_{L-L})^2}{KVA_{3\phi}} \tag{5}$$

$X_t = 0.98Z_t$

approximately

$R_t = 0.20Z_t$

c. Distribution Line Impedance

To find impedance to any point on the system, use the appropriate values given in Table 3 (Useful Tables).

Multiply each of the values obtained from the table by 5.2 times the number of miles of each conductivity size from the substation to the point being considered.

If two or more different sized conductors are used from the substation to the point, add the total resistance to the first size to the resistance of the next size to the point, and add the total reactance of the first size to the reactance of the next size, etc.

In single phase (L - N) calculators if neutral conductors is not more than two sizes less than the phase wire, use impedance values of the phase wire since the circuit impedance of multigrounded neutral lines is only slightly influenced by the impedance of the neutral conductor.

5. THREE-PHASE FAULT CURRENTS

a. Source Impedance

(1) Large System

If the three-phase fault current on the supply side is given,

$$Z_s = \frac{(E_L)^2 (\sqrt{3})}{(I_{3s})(E_{s(L-L)})} \qquad (8)$$

If the line-to-line fault current on the supply side is the only value given,

$$Z_s = \frac{3E_L^2}{2I_{s(L-L)}E_{s(L-L)}} \qquad (8a)$$

If the supply side positive sequence impedance, Z_1, is given in ohms,

$$Z_s = 3Z_1 \left(\frac{E_L}{E_{s(L-L)}}\right)^2 \qquad (8b)$$

(2) Small system uses direct axis transient reactance only, and apply formulas (2), (3), and (3a). Formula (4) is not required since a three-phase fault is equivalent to a balanced load and consequently no negative or zero sequence components are present.

For any tie line, use three times the positive sequence values only, and convert to load voltage by multiplying by

$$\frac{E_L^2}{E_{s(L-L)}^2}$$

For any transformer in the tie line, use formula (5) directly.

b. Substation Impedance

Use formula (5) as before

c. Distribution Line Impedance

Use resistance and reactance values for three-phase lines in Table I. It is only necessary to carry these values to the nearest 0.1 ohm.

With these values, proceed as before using formulas (6) and (7) or the graphical method described later.

6. LINE-TO-LINE FAULT CURRENTS

a. Source Impedance

(1) Large System

If the line-to-line fault current on the supply side is given,

$$Z_s = \frac{E_L^2 \sqrt{3}}{I_{s(L-L)}E_{s(L-L)}} \qquad (9)$$

If the three-phase fault current on the supply side is the only one given,

$$Z_s = \frac{2E_L^2}{I_{3s}E_{s(L-L)}} \qquad (9a)$$

If the supply side positive sequence impedance, Z_1, is given,

$$Z_s = 2\sqrt{3}\, Z_1 \left(\frac{E_L}{E_{s(L-L)}}\right)^2 \qquad (9b)$$

(2) Small System

For X_1 and X_2 use formulas (2) and (3) or (3a).

$$X_s = \frac{X_m \text{ (transient)} + X_m \text{ (neg. seq.)}}{\sqrt{3}} \qquad (10)$$

NOTE: For any tie line, use $2\sqrt{3}$ times the positive sequence line values, and convert to distribution voltage by multiplying by

$$\frac{E_L^2}{E_{s(L-L)}^2}$$

For any transformer in the tie line, multiply impedance calculated by formula (5) $\frac{2}{\sqrt{3}}$.

b. Substation

$$Z_t \text{ (ohms)} = \frac{Z_t \text{ (percent)} (E_L)^2 (2)}{\text{(KVA per phase) } (100{,}000) \sqrt{3}} \qquad (11)$$

c. Lines

Multiply impedance to positive or negative sequence currents, for three-phase lines, Table I by $\frac{2}{\sqrt{3}}$.

Then $Z = \sqrt{R^2 + X^2}$

and $I_L = \frac{E_L}{Z}$ as in formulas (6) and (7).

Except for systems supplied by small plants, the line-to-line fault current values will usually be $\frac{\sqrt{3}}{2}$ times the three-phase fault current values.

7. FAULT CURRENT ON SUPPLY SIDE

A current on the load side of the substation of course causes a current to flow on the supply side. The following formulas apply for delta-wye banks only.

a. For line-to-ground fault

$$I_s = \frac{E_L}{E_{s(L-L)}} I^*_L \quad (12)$$

b. For three-phase fault

$$I_s = \frac{E_L \sqrt{3}}{E_{s(L-L)}} I_L \quad (13)$$

c. For a line-to-line fault

$$I_s = \frac{2E_L}{E_{s(L-L)}} I_L \quad (14)$$

***NOTE:** I_s is not necessarily the same in all three phases. The formulas give the maximum supply currents in any one phase.

8. FAULT CURRENT ON LOAD SIDE

After total impedance values have been determined, maximum and minimum values of short-circuit current can be determined for any point in the circuit, for example:

a. Maximum $I_{3\phi} = \frac{e}{\sqrt{3}(Z_L + Z_T + Z_S)}$

$$= \frac{e}{\sqrt{3}\, Z_{Total}}$$

b. Line to ground

$$I_{L-N} = \frac{e}{\sqrt{3}(2Z_1 + Z_T + Z_S)}$$

c. Minimum I_{L-N} for 12.5 kv Systems =

$$\frac{e}{\sqrt{3}(2Z_1 + Z_T + Z_S + Z_F)}$$

d. Minimum I_{L-N} for 4.16 kv Systems =

$$\frac{.6e}{\sqrt{3}(2Z_1 + Z_T + Z_S)}$$

where:

Z_S = source impedance

Z_T = transformer impedance

Z_L = line impedance

Z_F = fault impedance = 40 + j0

e = line-to-line voltage in kv on load base

9. MAP PLOTTING

After calculation of the short-circuit currents, put the maximum and minimum values directly on the circuit diagram opposite each sectionalizing or other point.

VIII. USEFUL TABLES

TABLE 1A – FULL LOAD CURRENTS OF DISTRIBUTION TRANSFORMERS – SINGLE PHASE

1B – FULL LOAD CURRENTS OF DISTRIBUTION TRANSFORMERS – THREE PHASE

2A – APPROXIMATE LINE-TO-LINE (240-volt) SECONDARY SHORT-CIRCUIT CURRENTS

2B – APPROXIMATE LINE-TO-NEUTRAL (120-volt) SECONDARY SHORT–CIRCUIT CURRENTS

3 – PHYSICAL AND ELECTRICAL CHARACTERISTICS OF OPEN-WIRE DISTRIBUTION LINE CONDUCTORS

TABLE 1A

FULL-LOAD CURRENTS OF DISTRIBUTION TRANSFORMERS—SINGLE-PHASE CIRCUITS

Kva	CIRCUIT VOLTAGE												
	120	240	480	2400	4160	4330	4800	6600	6900	7200	7620	11,500	13,200
1.5	12.5	6.3	3.1	.63	.36	.35	.31	.23	.22	.21	.20	.13	.11
2.5	20.8	10.4	5.2	1.04	.60	.58	.52	.38	.36	.35	.33	.22	.19
3	25.0	12.5	6.3	1.25	.72	.69	.63	.45	.43	.42	.39	.26	.23
5	41.7	20.8	10.4	2.08	1.20	1.16	1.04	.76	.72	.69	.66	.43	.38
7.5	62.5	31.3	15.6	3.13	1.80	1.73	1.56	1.14	1.09	1.04	.98	.65	.57
10	83.3	41.7	20.8	4.17	2.40	2.31	2.08	1.52	1.45	1.39	1.31	.87	.76
15	125	62.5	31.3	6.25	3.61	3.46	3.13	2.27	2.17	2.08	1.97	1.30	1.14
25	208	104	52.1	10.4	6.01	5.77	5.21	3.79	3.62	3.47	3.28	2.17	1.89
37.5	313	156	78.1	15.6	9.01	8.66	7.81	5.68	5.43	5.21	4.92	3.26	2.84
50	417	208	104	20.8	12.0	11.55	10.4	7.58	7.25	6.94	6.56	4.35	3.79
75	625	313	156	31.3	18.0	17.32	15.6	11.4	10.9	10.4	9.84	6.52	5.68
100	833	417	208	41.7	24.0	23.10	20.8	15.2	14.5	13.9	13.1	8.70	7.58
150	1250	625	313	62.5	36.1	34.64	31.3	22.7	21.7	20.8	19.7	13.0	11.4
200	1667	833	417	83.3	48.1	46.19	41.7	30.3	29.0	27.8	26.2	17.4	15.2
250	2083	1042	521	104	60.1	57.74	52.1	37.9	36.3	34.7	32.8	21.7	18.9
333	2775	1388	694	139	80.0	76.91	69.4	50.5	48.3	46.2	43.7	29.0	25.2
500	4167	2083	1042	208	120	115.47	104	75.8	72.5	69.4	65.6	43.5	37.9

TABLE 1B

FULL-LOAD CURRENTS OF DISTRIBUTION TRANSFORMERS—THREE-PHASE CIRCUITS

Kva	CIRCUIT VOLTAGE													
	208	240	480	2400	4160	4330	4800	6900	7200	8320	11,500	12,470	13,200	33,000
4.5	12.5	10.8	5.41	1.08	.62	.60	.54	.38	.36	.31	.23	.21	.20	.08
7.5	20.8	18.0	9.02	1.80	1.04	1.00	.90	.63	.61	.52	.38	.35	.33	.13
9	25.0	21.7	10.8	2.17	1.25	1.20	1.08	.75	.73	.62	.45	.42	.39	.16
10	27.8	24.1	12.0	2.41	1.39	1.33	1.20	.84	.80	.69	.50	.46	.44	.17
15	41.6	36.1	18.0	3.61	2.08	2.00	1.80	1.26	1.20	1.04	.75	.69	.66	.26
22.5	62.5	54.1	27.1	5.41	3.12	3.00	2.71	1.88	1.80	1.56	1.13	1.04	.98	.39
25	69.4	60.1	30.1	6.01	3.47	3.33	3.01	2.09	2.00	1.73	1.26	1.16	1.09	.44
30	83.3	72.2	36.1	7.22	4.16	4.00	3.61	2.51	2.41	2.08	1.51	1.39	1.31	.52
37.5	104	90.2	45.1	9.02	5.20	5.00	4.51	3.14	3.01	2.60	1.88	1.74	1.64	.66
45	125	108	54.1	10.8	6.25	6.00	5.41	3.77	3.60	3.12	2.26	2.08	1.97	.79
50	139	120	60.1	12.0	6.94	6.67	6.01	4.18	4.01	3.47	2.51	2.32	2.19	.87
75	208	180	90.2	18.0	10.4	10.00	9.02	6.28	6.01	5.21	3.77	3.47	3.28	1.31
100	278	241	120	24.1	13.9	13.33	12.0	8.37	8.02	6.94	5.02	4.64	4.37	1.75
112.5	312	271	135	27.1	15.6	15.00	13.5	9.41	9.02	7.81	5.65	5.21	4.92	1.97
150	416	361	180	36.1	20.8	20.00	18.0	12.6	12.0	10.4	7.53	6.94	6.56	2.62
200	555	481	241	48.1	27.8	26.67	24.1	16.7	16.0	13.9	10.0	9.27	8.75	3.50
225	625	541	271	54.1	31.2	30.00	27.1	18.8	18.0	15.6	11.3	10.4	9.84	3.94
300	833	722	361	72.2	41.6	40.00	36.1	25.1	24.1	20.8	15.1	13.9	13.1	5.25
450	1249	1083	541	108	62.5	60.00	54.1	37.7	36.0	31.2	22.6	20.8	19.7	7.87
500	1388	1203	601	120	69.3	66.67	60.1	41.8	40.1	34.7	25.1	23.2	21.9	8.74
600	1665	1443	722	144	83.3	80.00	72.2	50.2	48.1	41.6	30.1	27.8	26.2	10.5
750	2082	1804	902	180	104	100.01	90.2	62.8	60.1	52.0	37.7	34.7	32.8	13.1
1000	2776	2406	1203	241	139	133.34	120	83.7	80.0	69.4	50.2	46.2	43.7	17.5
1500	4164	3609	1804	361	208	200.01	180	126	120	104	75.3	69.4	65.6	26.2

TABLE 2A

APPROXIMATE LINE-TO-LINE (240 VOLTS) SECONDARY SHORT-CIRCUIT CURRENTS

8-inch Conductor Spacing—Transformers with primaries rated from 2400 to 13,200 volts
Sustained Primary Voltage

Transformer Kva	Conductor Size	Trans. Terminals	Distance from Transformer in Feet: 100	200	400	600	1000	1500
			SHORT CIRCUIT—RMS AMPERES					
50	4/0	8860	5350	3700	2200	1590	1000	675
	2/0		5000	3320	1940	1370	860	575
	2		3875	2450	1370	950	585	390
37½	2/0	6650	4200	2920	1800	1300	840	570
	2		3500	2250	1300	910	575	380
	4		2750	1680	925	640	390	260
25	2	4430	2770	1970	1210	880	560	380
	4		2330	1550	890	625	390	260
	6		1900	1160	650	450	275	180
15	2	2660	2000	1530	1050	780	520	360
	4		1750	1260	790	570	360	250
	6		1520	1020	600	430	265	180
10	2	1770	1450	1200	880	700	480	340
	4		1330	1030	700	530	350	240
	6		1200	870	560	400	255	175
7½	2	1330	1170	1010	780	630	460	340
	4		1100	900	650	500	345	240
	6		1000	760	510	380	250	170
5	4	886	775	670	520	420	300	220
	6		730	600	440	340	240	170
	8		650	500	335	245	160	110
3	4	532	490	450	380	325	250	195
	6		475	420	335	275	205	150
	8		445	345	270	210	145	105
1½	4	266	255	245	225	210	175	150
	6		250	235	210	185	150	110
	8		240	220	180	155	120	90

Actual values will always be less because:

1. Primary voltage usually is not maintained.
2. Transformer may have higher impedance because of older design or of higher voltage rating.
3. Impedance of fault reduces current.

TABLE 2B

APPROXIMATE LINE-TO-NEUTRAL (120 VOLTS) SECONDARY SHORT-CIRCUIT CURRENTS

8-inch Conductor Spacing—Transformers with primaries rated from 2400 to 13,200 volts
Sustained Primary Voltage

Transformer Kva	Conductor Size	Trans. Terminals	Distance from Transformer in Feet: 100	200	400	600	1000	1500
			SHORT CIRCUIT—RMS AMPERES					
50	4/0	11200	3870	2360	1320	913	560	379
	2/0		3400	2020	1105	760	469	316
	2		2530	1400	740	514	308	208
37½	2/0	8310	3080	1900	1070	740	480	324
	2		2330	1340	725	510	308	207
	4		1750	970	515	349	211	144
25	2	5660	2050	1250	695	490	300	204
	4		1600	920	500	343	208	142
	6		1170	640	343	233	140	95
15	2	3360	1650	1808	640	460	285	198
	4		1320	830	475	330	202	139
	6		1030	598	325	225	137	94
10	2	2290	1320	940	590	434	282	195
	4		1125	740	443	312	199	137
	6		900	550	318	220	135	93
7½	2	1695	1100	815	535	403	266	186
	4		950	665	415	295	191	133
	6		780	508	298	210	131	91
5	4	1030	705	530	320	270	179	128
	6		610	426	270	197	127	88
	8		494	323	190	133	84	57
3	4	643	485	400	297	235	164	119
	6		460	345	235	178	118	85
	8		395	275	173	126	81	56
1½	4	297	255	227	187	160	123	97
	6		240	208	160	131	96	72
	8		220	178	130	101	70	51

Actual values will always be less because:

1. Primary voltage usually is not maintained.
2. Transformer may have higher impedance because of older design or of higher voltage rating.
3. Impedance of fault reduces current.

TABLE 3

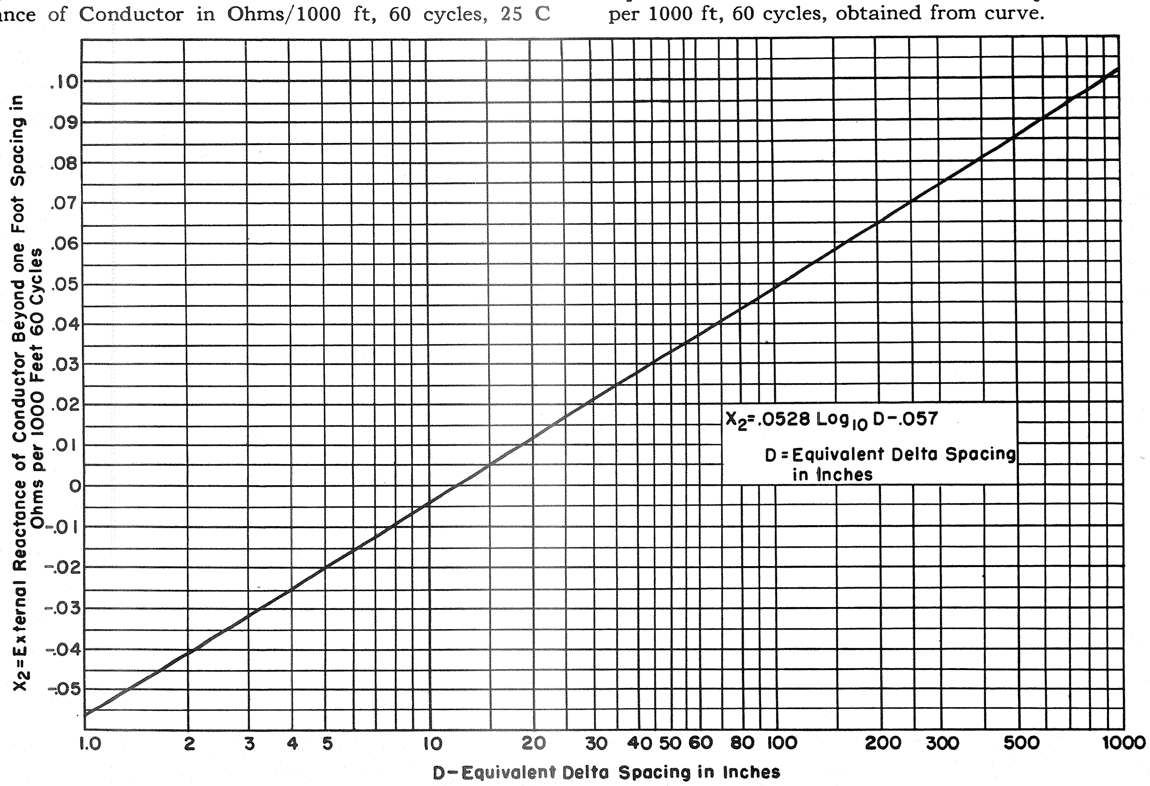
PHYSICAL AND ELECTRICAL CHARACTERISTICS OF OPEN WIRE DISTRIBUTION LINE CONDUCTORS

Size			Diameter in In.	Lbs/1000 Ft	Approx. Amp. Capacity*		Resistance**	Reactance (X_1)*** At 1 Ft Spacing
AWG	(Strands)	MCM						
			COPPER—HARD DRAWN					
8	(1)	16.51	.1285	50	50	80	.656	.126
6	(1)	26.25	.162	80	70	110	.413	.121
4	(3)	41.74	.254	128	110	161	.263	.114
2	(7)	66.37	.292	205	145	210	.167	.109
1	(7)	83.69	.328	258	170	245	.132	.106
1/0	(7)	105.5	.368	326	200	285	.105	.1035
2/0	(7)	133.1	.414	411	240	335	.083	.101
3/0	(7)	167.8	.464	518	280	390	.066	.098
4/0	(7)	211.6	.522	653	330	450	.053	.095
	(19)	250	.574	772	375	510	.045	.092
	(19)	300	.629	926	425	575	.037	.090
	(19)	350	.679	1081	475	635	.032	.088
	Al./Steel		**ACSR**					
6	6/1	26.25	.198	36.2	55	85	.675	.128
4	6/1	41.74	.250	57.6	75	120	.425	.125
2	6/1	66.37	.316	91.6	110	165	.267	.126
1/0	6/1	105.54	.398	145.6	150	225	.168	.124
2/0	6/1	133.1	.447	183.7	175	260	.134	.122
3/0	6/1	167.8	.502	231.6	210	305	.106	.118
4/0	6/1	211.6	.563	292.1	245	355	.084	.110
	26/7	266.8	.642	366.8	290	410	.066	.088
	26/7	366.4	.721	462.4	340	480	.053	.086
	26/7	397.5	.783	546.4	380	535	.045	.084
	26/7	477.0	.858	655.7	430	605	.037	.082
	26/7	556.5	.927	765.0	480	670	.032	.080
	26/7	795.0	1.108	1093.0	620	850	.022	.076
	(Strands)		**ALL ALUMINUM—HARD DRAWN**					
4	(7)		.232	39.0	75	115	.424	.114
2	(7)		.292	62.0	105	160	.267	.109
1/0	(7)		.368	98.5	145	215	.168	.103
2/0	(7)		.414	124.3	170	250	.134	.101
3/0	(7)		.464	156.7	200	290	.106	.098
4/0	(7)		.522	197.6	240	340	.084	.095
	(7)	266.8	.586	249.1	280	400	.066	.092
	(19)	336.4	.666	315.7	330	465	.053	.088
	(19)	397.5	.724	373.0	370	520	.045	.086
	(19)	477.0	.793	447.6	425	590	.037	.084
	(19)	556.5	.856	522.0	465	645	.032	.082
	(37)	795.0	1.026	746.0	605	820	.022	.079
Size			**COPPERWELD—COPPER**					
8A			.199	74.3	60	90	.664	.127
6A			.230	101.6	84	120	.418	.123
4A			.290	161.5	115	165	.263	.118
2A			.366	256.8	185	220	.166	.112

* Conductor at 80 C, 40 C AMBIENT, emissivity = .5 for copper, .2 for aluminum.
Lower current values correspond to still air.
Higher current values correspond to air moving at 2 feet per second.

**Resistance of Conductor in Ohms/1000 ft, 60 cycles, 25 C temperature.

***X_1 Reactance of Conductor Out to 1 Foot in Ohms per 1000 ft, 60 cycles.
Total Reactance Per phase = $X_1 - X_2$.
X_2—External Reactance of Conductor Beyond 1 ft in Ohms per 1000 ft, 60 cycles, obtained from curve.

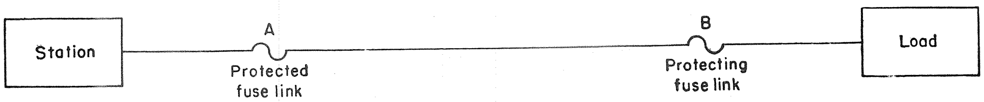


IX. COORDINATION CHARTS FOR GE FUSE LINKS AND GE RECLOSERS

	Protecting Device	Protected Device
Chart 1 –	Type "N" fuse link	Type "N" fuse link
2 –	Type "K" fuse link	Type "K" fuse link
3 –	Type "T" fuse link	Type "T" fuse link
4 –	Type "N" fuse link	Type "T" fuse link
5 –	Internal fuse in Type HSBA transformer	Type "N" fuse link
6 –	Internal fuse in Type HSBA transformer	Type "K" fuse link
7 –	Internal fuse in Type HSBA transformer	Type "T" fuse link
8 –	Type HR recloser (2 inst. and 2 standard TD) 50-100-200 amperes	Type "N" fuse link
9 –	Type HR recloser (2 inst. and 2 standard TD) 50-100-200 amperes	Type "K" fuse link
10 –	Type HR recloser (2 inst. and 2 standard TD) 50-100-200 amperes	Type "T" fuse link
11 –	Type HR recloser (2 inst. and 2 extended TD) 50-100-200 amperes	Type "N" fuse link
12 –	Type HR recloser (2 inst. and 2 extended TD) 50-100-200 amperes	Type "K" fuse link
13 –	Type HR recloser (2 inst. and 2 extended TD) 50-100-200 amperes	Type "T" fuse link
14 –	Type HR recloser (2 inst. and hold-closed function) 50-100-200 amperes	Type "N" fuse link
15 –	Type HR recloser (2 inst. and hold-closed function) 50-100-200 amperes	Type "K" fuse link
16 –	Type HR recloser (2 inst. and hold-closed function) 50-100-200 amperes	Type "T" fuse link
17 –	Type HR-1 and HR-3 recloser (2 inst. and 2 standard or extended TD)	Type HBA transformer internal fuse
18 –	Type HR-1 recloser (2 inst. and hold-closed function)	Type HBA transformer internal fuse
19 –	Type HR recloser (3 instantaneous and 1 standard TD) 50-100 amperes	Type "K" fuse link
20 –	Type HR recloser (3 instantaneous and 1 extended TD) 50-100 amperes	Type "K" fuse link
21 –	Type HR recloser (3 instantaneous and 1 standard TD) 200 amperes	Type "K" fuse link
22 –	Type HR recloser (3 instantaneous and 1 extended TD) 200 amperes	Type "K" fuse link
23 –	Type HR recloser (3 instantaneous and 1 standard TD) 50-100 amperes	Type "T" fuse link
24 –	Type HR recloser (3 instantaneous and 1 extended TD) 50-100 amperes	Type "T" fuse link
25 –	Type HR recloser (3 instantaneous and 1 standard TD) 200 amperes	Type "T" fuse link
26 –	Type HR recloser (3 instantaneous and 1 extended TD) 200 amperes	Type "T" fuse link

COORDINATION CHART 1

Protective Characteristics of G-E Universal Cable-type Fuse Links "N"-rated. Fuse Links in Series with "N"-rated Fuse Link



When the protecting fuse link is used in a G-E single-element fuse cutout.

RATINGS IN AMPERES OF PROTECTING FUSE LINKS (B in Diagram) When Used in a Single-element Fuse Cutout	RATING IN AMPERES OF PROTECTED FUSE LINK (A IN DIAGRAM) "N" RATED LINKS																						
"N" (100% Basis) Rating	3N	5N	8N	10N	15N	20N	25N	30N	40N	45N	50N	51*	75N	85N	95N	52*	100N	125N	101*	150N	102*	103*	200N
	MAXIMUM SHORT-CIRCUIT RMS AMPERES TO WHICH FUSE LINK WILL BE PROTECTED																						
1N	102	145	160	200	262	320	420	520	660	880	1130	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
2N	45	110	160	200	262	320	420	520	660	880	1130	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
3N	—	43	76	125	220	300	420	520	660	880	1130	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
5N	—	—	23	50	145	220	420	520	660	880	1130	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
5-amp Series‡	—	—	—	50	145	220	420	520	660	800	1130	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
8N	—	—	—	21	80	155	290	420	660	880	1130	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
10N	—	—	—	—	50	110	230	370	600	880	1130	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
10-amp Series‡	—	—	—	—	—	—	230	370	600	880	1130	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
15N	—	—	—	—	—	50	170	300	500	880	1130	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
20N	—	—	—	—	—	—	80	225	450	725	1130	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
25N	—	—	—	—	—	—	—	52	300	620	1130	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
30N	—	—	—	—	—	—	—	—	160	450	830	1550	1580	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
40N	—	—	—	—	—	—	—	—	—	170	600	1150	1150	2120	2700	3200	3250	3700	6200	5400	8000	8000	8000
45N	—	—	—	—	—	—	—	—	—	—	150	880	880	1700	2700	3200	3250	3700	6200	5400	8000	8000	8000
50N	—	—	—	—	—	—	—	—	—	—	—	450	260	1350	2100	3200	3250	3700	6200	5400	8000	8000	8000
51*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1700	2200	2400	3000	6200	5400	8000	8000	8000
75N	—	—	—	—	—	—	—	—	—	—	—	—	—	400	1400	2100	1400	3000	6200	5400	8000	8000	8000
85N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1400	2400	6200	5400	8000	8000	8000
95N	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	350 —	1700 —	4600 —	4000 —	8000 8000	8000 8000	8000 6000
52*	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	1200 —	3800 —	3300 —	8000 6000	8000 8000	6500 5000
100N	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	1200 —	3750 —	3300 —	8000 6000	8000 8000	8000 5000
125N	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	1800 —	— —	8000 —	4800 —
101*	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	840 —	— —	8000 —	3500 —
102*	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	1000 —

* The 51- and 52-amp fuse links are co-ordinating fuse links having time-current characteristics similar to 75- and 100-ampere "N" rated fuse links. The 101- and 102-amp fuse links have characteristics similar to fuse links that would be rated 150- and 200-amp fuse links. They will carry their rating continuously but will not blow at 230 per cent of their rating within five minutes and are, therefore, not "N" rated according to NEMA standards. The 51- and 52-amp links are for use in 50-amp fuse cutouts and the 101- and 102-amp fuse links are for use in 100-amp fuse cutouts. They should be used only up to the continuous-current rating of these cutouts.

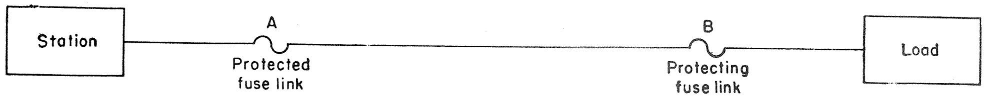
Example: Assume that the largest transformer beyond a sectionalizing point on a feeder requires a 5-amp fuse link (protecting fuse link) and that the maximum available short-circuit current at this point is 500 rms amperes. Then, 30 amperes is the lowest rating for the sectionalizing fuse link which can be protected. However, it may have to be larger than 30 amperes to carry the normal load current.

Assume 800 rms amperes to be the maximum available short-circuit current at the 30-amp sectionalizing fuse link (now the protecting fuse link) or at any intervening load points which do not require more than a 30-amp fuse link. If the 30-amp protecting fuse link is used in a single-element fuse cutout, a 50-amp fuse link is the smallest size that can be protected at a sectionalizing point closer to the substation.

‡ Hi-Surge fuse links.

COORDINATION CHART 2

Protective Characteristics of G-E Type "K" (Fast) Fuse Links When Used in G-E 50-, 100-, or 200-ampere Expulsion Fuse Cutouts and Connected in Series

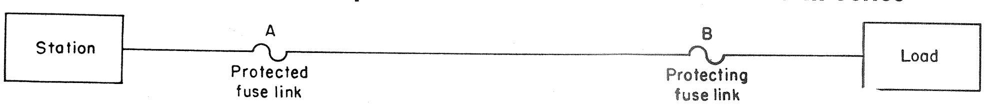


When the protecting fuse link is used in a G-E single-element fuse cutout.

TYPE "K" RATINGS (IN AMPERES) OF THE PROTECTING FUSE LINKS (B IN DIAGRAM)	TYPE "K" RATINGS (IN AMPERES) OF THE PROTECTED FUSE LINKS (A IN DIAGRAM)																		
	6K	8K	10K	12K	15K	20K	25K	30K	40K	50K	65K	80K	52‡	100K	101‡	140K	200K	102‡	103‡
	MAXIMUM SHORT-CIRCUIT RMS AMPERES TO WHICH FUSE LINKS WILL BE PROTECTED																		
1K	135	215	300	395	530	660	820	1100	1370	1720	2200	2750	3250	3600	5800	6000	9700	9500	16000
2K	110	195	300	395	530	660	820	1100	1370	1720	2200	2750	3250	3600	5800	6000	9700	9500	16000
3K	80	165	290	395	530	660	820	1100	1370	1720	2200	2750	3250	3600	5800	6000	9700	9500	16000
5-amp Series Hi-surge	14	133	270	395	530	660	820	1100	1370	1720	2200	2750	3250	3600	5800	6000	9700	9500	16000
6K	...	37	145	270	460	620	820	1100	1370	1720	2200	2750	3250	3600	5800	6000	9700	9500	16000
8K	...	...	133	170	390	560	820	1100	1370	1720	2200	2750	3250	3600	5800	6000	9700	9500	16000
10-amp Series Hi-surge	...	16	24	260	530	660	820	1100	1370	1720	2200	2750	3250	3600	5800	6000	9700	9500	16000
10K	...	...	...	38	285	470	720	1100	1370	1720	2200	2750	3250	3600	5800	6000	9700	9500	16000
12K	...	...	...	...	140	360	660	1100	1370	1720	2200	2750	3250	3600	5800	6000	9700	9500	16000
15K	...	...	...	...	...	95	410	960	1370	1720	2200	2750	3250	3600	5800	6000	9700	9500	16000
20K	...	...	...	...	...	...	70	700	1200	1720	2200	2750	3250	3600	5800	6000	9700	9500	16000
25K	...	...	...	...	...	...	...	140	580	1300	2200	2750	3250	3600	5800	6000	9700	9500	16000
30K	...	...	...	...	...	...	...	...	215	700	1800	2750	3250	3600	5800	6000	9700	9500	16000
40K	...	...	...	...	...	...	...	...	...	170	1200	2750	3250	3600	5800	6000	9700	9500	16000
50K	...	...	...	...	...	...	...	...	...	...	195	1600	3250	3600	5800	6000	9700	9500	16000
65K	...	...	...	...	...	...	...	...	...	...	...	330	....	2300	5800	6000	9700	9500	16000
52‡	...	...	...	...	...	...	...	...	...	...	...	...	....	290	5500	6000	9700	9500	16000
80K	...	...	...	...	...	...	...	...	...	...	...	...	....	580	5800	6000	9700	9500	16000
100K	...	...	...	...	...	...	...	...	...	...	...	...	....	....	300	4300	9700	9500	16000
101‡	...	...	...	...	...	...	...	...	...	...	...	...	....	....	....	385	7500	....	16000
140K	...	...	...	...	...	...	...	...	...	...	...	...	....	....	....	....	2800	....	16000
102‡	...	...	...	...	...	...	...	...	...	...	...	...	....	....	....	....	1250	....	....

COORDINATION CHART 3

Protective Characteristics of G-E Type "T" (Slow) Fuse Links When Used in G-E 50-, 100-, or 200-ampere Expulsion Fuse Cutouts and Connected in Series



When the protecting fuse link is used in a G-E single-element fuse cutout.

TYPE "T" RATINGS (IN AMPERES) OF THE PROTECTING FUSE LINKS (B IN DIAGRAM)	TYPE "T" RATINGS (IN AMPERES) OF THE PROTECTED FUSE LINKS (A IN DIAGRAM)															
	6T	8T	10T	12T	15T	20T	25T	30T	40T	50T	65T	80T	100T	140T	200T	103‡
	MAXIMUM SHORT-CIRCUIT RMS AMPERES TO WHICH FUSE LINKS WILL BE PROTECTED															
1N*	250	395	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000	16000
2N*	250	395	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000	16000
3N*	250	395	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000	16000
6T	....	33	365	650	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000	16000
8T	....	....	125	480	850	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000	16000
10-amp Series Hi-surge	....	19	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000	16000
10T	....	....	....	74	620	1130	1500	1930	2500	3100	3950	4950	6300	9600	15000	16000
12T	....	....	....	....	135	770	1400	1930	2500	3100	3950	4950	6300	9600	15000	16000
15T	....	....	....	....	....	100	880	1750	2500	3100	3950	4950	6300	9600	15000	16000
20T	....	....	....	....	....	....	105	1150	2300	3100	3950	4950	6300	9600	15000	16000
25T	....	....	....	....	....	....	....	190	1500	3100	3950	4950	6300	9600	15000	16000
30T	....	....	....	....	....	....	....	....	115	1900	3950	4950	6300	9600	15000	16000
40T	....	....	....	....	....	....	....	....	....	310	2350	4950	6300	9600	15000	16000
50T	....	....	....	....	....	....	....	....	....	....	150	3400	6300	9600	15000	16000
65T	....	....	....	....	....	....	....	....	....	....	....	270	4300	9600	15000	16000
80T	....	....	....	....	....	....	....	....	....	....	....	....	660	9200	15000	16000
100T	....	....	....	....	....	....	....	....	....	....	....	....	....	6000	15000	16000
140T	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6600	.. ..

* The 1N, 2N, and 3N ampere ratings of the G-E 5-ampere series Hi-surge fuse links have time-current characteristics closely approaching those established by the American Standards for 1T, 2T, and 3T ampere ratings respectively. Hence, they are recommended for applications requiring 1T, 2T, or 3T fuse links.

‡ G-E co-ordinating fuse links.

COORDINATION CHART 4

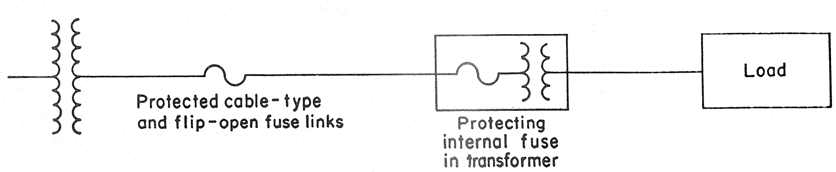
G-E Universal Cable-type "T" (Slow) Series Fuse Links Protected by G-E Universal Cable-type "N"-rated Fuse Links

G-E N Rated Fuse Links (Protecting) ϕ	ϕϕ Ratings in Amperes of Protected G-E Type T Fuse Links														
	6T	8T	10T	12T	15T	20T	25T	30T	40T	50T	65T	80-T	100T	140T	200T
	MAXIMUM SHORT CIRCUIT RMS AMPERES TO WHICH FUSE LINKS WILL BE PROTECTED△														
1N	290	395	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15,000
2N	290	395	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15,000
3N	290	395	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15,000
5N	290	395	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15,000
8N	155	395	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15,000
10N	...	300	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15,000
15N	...	...	500	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15,000
20N	...	...	...	...	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15,000
25N	...	...	...	...	...	1220	1500	1930	2500	3100	3950	4950	6300	9600	15,000
30N	...	...	...	...	...	...	1500	1930	2500	3100	3950	4950	6300	9600	15,000
40N	...	...	...	...	...	...	...	1930	2500	3100	3950	4950	6300	9600	15,000
45N	...	...	...	...	...	...	...	...	2500	3100	3950	4950	6300	9600	15,000
50N	...	...	...	...	...	...	...	...	...	3100	3950	4950	6300	9600	15,000
75N	...	...	...	...	...	...	...	...	...	...	3950	4950	6300	9600	15,000
85N	...	...	...	...	...	...	...	...	...	...	...	4950	6300	9600	15,000
95N	...	...	...	...	...	...	...	...	...	...	...	...	6300	9600	15,000
100N	...	...	...	...	...	...	...	...	...	...	...	...	...	9600	15,000
125N	...	...	...	...	...	...	...	...	...	...	...	...	...	...	15,000
150N	...	...	...	...	...	...	...	...	...	...	...	...	...	...	15,000

ϕ Protecting link is one on load side of protected link.
ϕϕProtected link is one on power source side of protecting link.
△Short-circuit currents must be within the interrupting rating of the cutout used.

COORDINATION CHART 5

Protective Characteristics of Internal Fuses Used in G-E Distribution Transformers Connected in Series, to Protect G-E Universal Cable-type "N"-rated Fuse Link When Used in G-E 50-, 100-, or 200-ampere Expulsion Fuse Cutouts



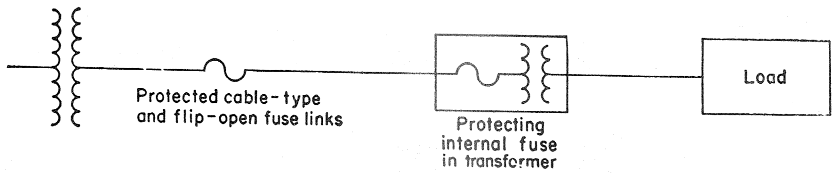
Internal fuses clear before external fuse links are partially melted.

Designation Number of Protecting Internal Fuses‡	RATING IN AMPERES OF PROTECTED UNIVERSAL CABLE-TYPE FUSE LINK "N" (100 PER CENT BASIS) RATING																			
	5N	8N	10N	15N	20N	25N	30N	40N	45N	50N	51#	75N	85N	95N	52N	100N	125N	101N	150N	102# 200N
	MAXIMUM RMS AMPERES SHORT-CIRCUIT CURRENT TO WHICH UNIVERSAL CABLE-TYPE FUSE LINK WILL BE PROTECTED (APPLIES ONLY UP TO INTERRUPTING RATING OF CUTOUT USED)																			
1	...	160	200	262	320	405	520	650	850	1120	1550	1550	2120	2750	3200	3350	3700	5000	5000	5000
2	...	...	200	262	320	405	520	650	850	1120	1550	1550	2120	2750	3200	3350	3700	5000	5000	5000
3	...	...	...	260	320	405	520	650	850	1120	1550	1550	2120	2750	3200	3350	3700	5000	5000	5000
4	...	...	...	...	250	405	520	650	850	1120	1550	1550	2120	2750	3200	3350	3700	5000	5000	5000
5	...	...	...	...	...	240	470	650	850	1120	1550	1550	2120	2750	3200	3350	3700	5000	5000	5000
6	...	...	...	...	...	...	250	650	850	1120	1550	1550	2120	2750	3200	3350	3700	5000	5000	5000
7	...	...	...	...	...	...	...	210	700	1120	1550	1550	2120	2750	3200	3350	3700	5000	5000	5000
8	...	...	...	...	...	...	...	...	250	920	1550	1550	2120	2750	3200	3350	3700	5000	5000	5000
9	...	...	...	...	...	...	...	...	...	150	1150	1200	2120	2750	3200	3350	3700	5000	5000	5000
10	...	...	...	...	...	...	...	...	...	...	250	190	1800	2750	3200	3350	3700	5000	5000	5000
11	...	...	...	...	...	...	...	...	...	...	...	...	1000	2050	3100	3350	3700	5000	5000	5000
12	...	...	...	...	...	...	...	...	...	...	...	...	...	350	1730	2000	3300	5000	5000	5000
13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	350	400	2350	5000	5000	5000
14	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1500	4750	4200	5000
30	...	...	...	...	...	...	...	...	70	100	550	350	1800	2650	3200	3150	3700	5000	5000	5000
31	...	...	...	...	...	...	...	...	...	...	...	110	185	1300	2300	2300	3400	5000	5000	5000
32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	300	1700	5000	4900	5000
33	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	590	2700	2500	5000
34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	730	2500†
35	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	950†

‡ See Table VIII under Transformer Protection on page 30.
\# G-E coordinating fuse links
† These ratings apply only to 200N fuse links

COORDINATION CHART 6

G-E Distribution Transformer Internal Fuses with G-E, Type "K" Fuse Links When Used in 50-, 100-, or 200-ampere Expulsion Fuse Cutouts

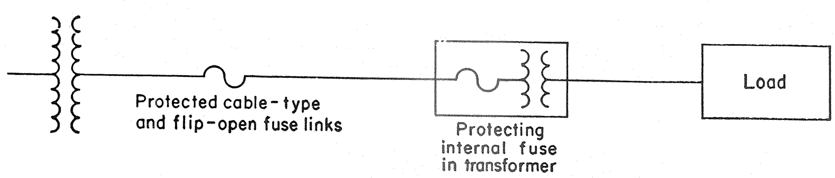


Designation Number of Protecting Internal Fuses‡	RATING IN AMPERES OF PROTECTED G-E TYPE K (FAST) FUSE LINKS														
	6K	9K	10K	12K	15K	20K	25K	30K	40K	50K	65K	80K	100K	140K	200K
	MAXIMUM RMS AMPERES SHORT-CIRCUIT CURRENT TO WHICH UNIVERSAL CABLE-TYPE FUSE LINK WILL BE PROTECTED (APPLIES ONLY UP TO INTERRUPTING RATING OF CUTOUT USED)														
1	175	240	300	395	530	660	820	1100	1370	1720	2200	2750	3600	6000	9700
2	...	240	300	395	530	660	820	1100	1370	1720	2200	2750	3600	6000	9700
3	...	...	300	395	530	660	820	1100	1370	1720	2200	2750	3600	6000	9700
4	...	...	...	395	530	660	820	1100	1370	1720	2200	2750	3600	6000	9700
5	...	...	...	...	500	660	820	1100	1370	1720	2200	2750	3600	6000	9700
6	...	...	...	...	...	590	820	1100	1370	1720	2200	2750	3600	6000	9700
7	...	...	...	...	...	...	660	1100	1370	1720	2200	2750	3600	6000	9700
8	...	...	...	...	...	...	...	860	1370	1720	2200	2750	3600	6000	9700
9	...	...	...	...	...	...	...	....	780	1570	2200	2750	3600	6000	9700
10	...	...	...	...	...	...	...	....	....	830	1950	2750	3600	6000	9700
11	...	...	...	...	...	...	...	....	....	....	1050	2300	3600	6000	9700
12	...	...	...	...	...	...	...	....	....	....	....	410	2800	6000	9700
13	...	...	...	...	...	...	...	....	....	....	....	....	950	6000	9700
14	...	...	...	...	...	...	...	....	....	....	....	....	....	5100	9700
30	...	...	...	...	...	...	...	....	170	1050	2150	2750	3600	6000	9700
31	...	...	...	...	...	...	...	....	....	....	210	1350	3200	6000	9700
32	...	...	...	...	...	...	...	....	....	....	....	240	700	6000	9700
33	...	...	...	...	...	...	...	....	....	....	....	....	....	2900	9700
34	...	...	...	...	...	...	...	....	....	....	....	....	....	....	5800
35	...	...	...	...	...	...	...	....	....	....	....	....	....	....	....

‡ See Table VIII under Transformer Protection on page 30.

COORDINATION CHART 7

G-E Distribution Transformer Internal Fuses with G-E, Type "T" Fuse Links When Used in 50-, 100-, or 200-ampere Expulsion Fuse Cutouts

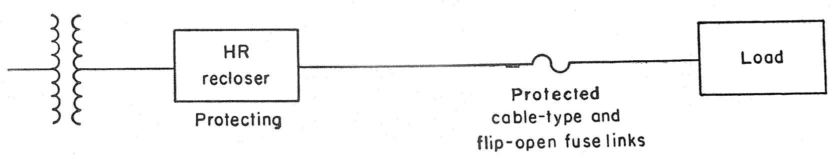


Designation Number of Protecting Internal Fuses*	RATING IN AMPERES OF PROTECTED G-E TYPE T (SLOW) FUSE LINKS														
	6T	8T	10T	12T	15T	20T	25T	30T	40T	50T	65T	80T	100T	140T	200T 103#
	MAXIMUM RMS AMPERES SHORT-CIRCUIT CURRENT TO WHICH UNIVERSAL CABLE-TYPE FUSE LINK WILL BE PROTECTED (APPLIES ONLY UP TO INTERRUPTING RATING OF CUTOUT USED)														
1	295	395	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000
2	295	395	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000
3	...	...	540	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000
4	...	...	...	710	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000
5	...	...	...	...	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000
6	...	...	...	...	950	1220	1500	1930	2500	3100	3950	4950	6300	9600	15000
7	...	...	...	...	...	....	1500	1930	2500	3100	3950	4950	6300	9600	15000
8	...	...	...	...	...	....	....	1930	2500	3100	3950	4950	6300	9600	15000
9	...	...	...	...	...	....	....	....	2500	3100	3950	4950	6300	9600	15000
10	...	...	...	...	...	....	....	....	....	3100	3950	4950	6300	9600	15000
11	...	...	...	...	...	....	....	....	....	....	3950	4950	6300	9600	15000
12	...	...	...	...	...	....	....	....	....	....	....	4950	6300	9600	15000
13	...	...	...	...	...	....	....	....	....	....	....	....	6300	9600	15000
14	...	...	...	...	...	....	....	....	....	....	....	....	5700	9600	15000
30	...	...	...	...	...	....	....	1450	2500	3100	3950	4950	6300	9600	15000
31	...	...	...	...	...	....	....	....	....	2000	3600	4950	6300	9600	15000
32	...	...	...	...	...	....	....	....	....	....	....	3600	6300	9600	15000
33	...	...	...	...	...	....	....	....	....	....	....	....	....	9600	15000
34	...	...	...	...	...	....	....	....	....	....	....	....	....	....	15000
35	...	...	...	...	...	....	....	....	....	....	....	....	....	....	.....

* See Table VIII under Transformer Protection on page 30. # G-E co-ordinating fuse links.

COORDINATION CHART 8

HR Recloser Sequence—2 Instantaneous, Plus 2 Standard Time-delay with G-E "N"-type Fuse Links Located on Load Side of the Recloser

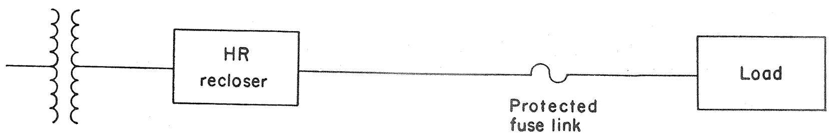


Recloser Rating Amp (Cont.)	Frame Size Amp		1N	2N	3N	5N	8N	10N	15N	20N	25N	30N	40N	45N	50N	51#	75N	85N	95N	52#	100N	125N	101#	150N	200N	102#
			RATINGS IN AMPERES OF G-E TYPE K FUSE LINKS — RANGE OF CO-ORDINATION—RMS AMPERES																							
5	50	Min			10	20	48	70	115																	
		Max			23	57	72	94	125																	
10	50	Min					20	20	57	99	162															
		Max					45	68	106	141	200															
15	50	Min							30	59	118	175	285													
		Max							77	116	177	237	322													
25	50, 100	Min									50	95	190	305	445											
	50, 100	Max									125	155	272	390	570											
35	50, 100	Min										70	82	215	335	650	610	1000								
	50, 100	Max										100	225	342	505	780	775	1120								
50	50, 100	Min												100	205	500	430	760	1050	1300	1420					
	50, 100	Max												266	435	645	690	1025	1250 1405	1710	1720					
70	100	Min													140	345	250	580	810	1030	1150					
		Max													300	595	585	935	1320	1600	1610					
100	100	Min														200	200	265	530	770	830	1750				
		Max														425	360	800	1175	1410	1450	1900				
140	100	Min																	280	490	500	1400				
		Max																	880	1140	1200	1700				
25	200	Min									50	80	125	320												
		Max									132	185	257	365												
35	200	Min										70	70	155	320											
		Max										147	227	330	477											
50	200	Min											100	100	170	470	310	830	1120	1400						
		Max											170	282	420	660	645	970	1310	1590						
70	200	Min													140	285	210	395	850	1100	1240					
		Max													355	580	580	890	1210	1425	1500					
100	200	Min														200	200	230	400	570	600	1900	2650			
		Max														485	465	790	1100	1330	1390	1800	2950			
140	200	Min																280	280	455	425	1320	2050	2300		
		Max																640	950	1190	1220	1700	2725	2700		
200	200	Min																	400	400	400	730	950	1400	3000	3350
		Max																	575	980	1015	1500	2475	2450	3800	4000
280	200	Min																				620	620	1050	2200	1400
		Max																				1200	2100	2100	3800	3900

G-E coordinating fuse links.

COORDINATION CHART 9

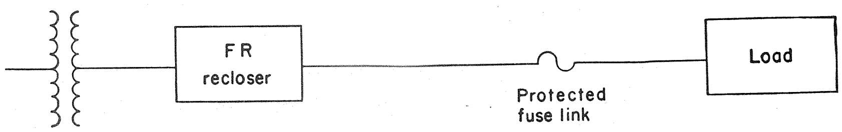
HR Recloser Sequence—2 Instantaneous, Plus 2 Standard Time-delay with "K"-type Fuse Links Located on Load Side of the Recloser



Recloser Rating Amp (Continuous)	Frame Size Amp		2K	3K	6K	8K	10K	12K	15K	20K	25K	30K	40K	50K	65K	80K	100K	140K	200K
			RATINGS IN AMPERES OF G-E TYPE K FUSE LINKS — RANGE OF CO-ORDINATION—RMS AMPERES																
5	50	Min	..	10	58	105	...	...	...	...	...	...	...	...	....	....	....	....	....
		Max	..	27	82	120	...	...	...	...	...	...	...	...	....	....	....	....	....
10	50	Min	..	..	20	48	90	140	...	...	...	...	...	...	....	....	....	....	....
		Max	..	..	55	96	136	187	...	...	...	...	...	...	....	....	....	....	....
15	50	Min	..	..	..	30	32	92	170	250	...	...	...	...	....	....	....	....	....
		Max	..	..	..	66	112	159	252	327	...	...	...	...	....	....	....	....	....
25	50 / 100	Min	..	..	..	...	...	50	82	155	230	380	580	...	....	....	....	....	....
	50 / 100	Max	..	..	..	...	...	87	207	280	380	535	705	...	....	....	....	....	....
35	50 / 100	Min	..	..	..	...	...	...	70	74	130	275	440	690	....	....	....	....	....
	50 / 100	Max	..	..	..	...	...	...	127	232	337	485	660	877	....	....	....	....	....
50	50 / 100	Min	..	..	..	...	...	...	...	...	100	110	320	510	860	1280	....	....	....
	50 / 100	Max	..	..	..	...	...	...	...	...	250	422	585	810	1105	1435	....	....	....
70	100	Min	..	..	..	...	...	...	...	...	...	140	140	160	350	640	980	1450	....
		Max	..	..	..	...	...	...	...	...	...	260	472	710	1005	1325	1825	2000	....
100	100	Min	..	..	..	...	...	...	...	...	...	...	...	200	380	720	1130	....	....
		Max	..	..	..	...	...	...	...	...	...	...	...	535	875	1200	1700	....	....
140	100	Min	..	..	..	...	...	...	...	...	...	...	...	...	280	340	820	....	....
		Max	..	..	..	...	...	...	...	...	...	...	...	...	550	950	1405	....	....
25	200	Min	..	..	..	...	...	50	75	108	190	430	620	...	....	....	....	....	....
		Max	..	..	..	...	...	119	202	267	357	495	655	...	....	....	....	....	....
35	200	Min	..	..	..	...	...	...	70	70	110	185	480	725	....	....	....	....	....
		Max	..	..	..	...	...	...	165	235	325	462	610	820	....	....	....	....	....
50	200	Min	..	..	..	...	...	...	...	100	100	100	230	500	910	....	....	....	....
		Max	..	..	..	...	...	...	...	165	275	417	555	770	1070	....	....	....	....
70	200	Min	..	..	..	...	...	...	...	...	...	140	150	280	580	1080	1600	....	....
		Max	..	..	..	...	...	...	...	...	...	340	477	680	965	1250	1710	....	....
100	200	Min	..	..	..	...	...	...	...	...	...	...	200	200	310	480	1150	....	....
		Max	..	..	..	...	...	...	...	...	...	...	345	575	855	1140	1590	....	....
140	200	Min	..	..	..	...	...	...	...	...	...	...	...	...	280	410	660	2450	....
		Max	..	..	..	...	...	...	...	...	...	...	...	...	710	990	1430	2725	....
200	200	Min	..	..	..	...	...	...	...	...	...	...	...	...	....	400	420	1050	....
		Max	..	..	..	...	...	...	...	...	...	...	...	...	....	720	1235	2500	....
280	200	Min	..	..	..	...	...	...	...	...	...	...	...	...	....	....	....	660	2900
		Max	..	..	..	...	...	...	...	...	...	...	...	...	....	....	....	2100	4000

COORDINATION CHART 10

HR Recloser Sequence—2 Instantaneous, Plus 2 Standard Time-delay with G-E "T"-type Fuse Link. Located on Load Side of Recloser



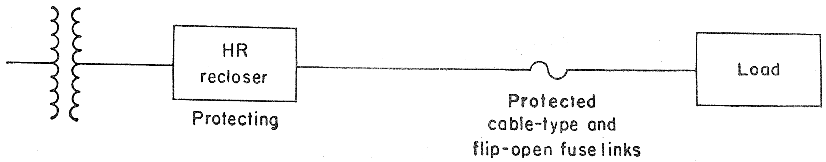
Recloser Rating Amp (Continuous)	Frame Size Amp		RATINGS IN AMPERES OF G-E TYPE T FUSE LINKS																
			2N*	3N*	6T	8T	10T	12T	15T	20T	25T	30T	40T	50T	65T	80T	100T	140T	200T 103#
			RANGE OF CO-ORDINATION—RMS AMPERES																
5	50	Min	17.5	28	112	...	...	...	...	...	...	....	....	....	....	....	....	....	....
		Max	49	49	125	...	...	...	...	...	...	....	....	....	....	....	....	....	....
10	50	Min	..	..	55	105	185	...	...	...	...	....	....	....	....	....	....	....	....
		Max	..	..	122	187	250	...	...	...	...	....	....	....	....	....	....	....	....
15	50	Min	..	..	30	50	130	220	340	...	...	....	....	....	....	....	....	....	....
		Max	..	..	98	160	247	360	375	...	...	....	....	....	....	....	....	....	....
25	50 / 100	Min	..	..	...	50	50	110	225	360	530	820	....	....	....	....	....	....	....
	50 / 100	Max	..	..	...	87	200	310	470	605	625	1000	....	....	....	....	....	....	....
35	50 / 100	Min	..	..	...	...	70	70	70	260	440	670	1050	....	....	....	....	....	....
	50 / 100	Max	..	..	...	...	110	255	367	555	735	875	1360	....	....	....	....	....	....
50	50 / 100	Min	..	..	...	...	...	...	100	100	285	490	760	1120	1500	....	....	....	....
	50 / 100	Max	..	..	...	...	...	...	317	477	660	915	1235	1250 / 1635	.... / 2000	....	....	....	....
70	100	Min	..	..	...	...	...	...	...	140	140	290	580	890	1300	1870	....	....	....
		Max	..	..	...	...	...	...	...	370	560	815	1125	1515	2000	2000	....	....	....
100	100	Min	..	..	...	...	...	...	...	...	...	200	200	610	990	1470	....	....	....
		Max	..	..	...	...	...	...	...	...	...	660	985	1365	1845	2000	....	....	....
140	100	Min	..	..	...	...	...	...	...	...	...	....	280	280	580	1105	1700	....	....
		Max	..	..	...	...	...	...	...	...	...	....	700	1100	1560	2000	2000	....	....
25	200	Min	..	..	...	50	50	78	200	430	680	880	....	....	....	....	....	....	....
		Max	..	..	...	117	197	292	415	565	735	985	....	....	....	....	....	....	....
35	200	Min	..	..	...	...	70	70	70	165	440	720	1080	1470	....	....	....	....	....
		Max	..	..	...	...	162	255	372	515	680	920	1200	1600	....	....	....	....	....
50	200	Min	..	..	...	...	...	100	100	100	190	480	830	1200	1730	2380	....	....	....
		Max	..	..	...	...	...	202	330	467	620	860	1145	1510	2000	2525	....	....	....
70	200	Min	..	..	...	...	...	...	140	140	140	180	365	910	1400	2000	2750	....	....
		Max	..	..	...	...	...	...	235	395	550	775	1055	1400	1850	2400	3200	....	....
100	200	Min	..	..	...	...	...	...	...	...	200	200	200	415	940	1550	2280	....	....
		Max	..	..	...	...	...	...	...	...	445	675	950	1300	1700	2225	3050	....	....
140	200	Min	..	..	...	...	...	...	...	...	...	280	280	280	720	710	1750	....	....
		Max	..	..	...	...	...	...	...	...	...	485	810	1150	1565	2075	2875	....	....
200	200	Min	..	..	...	...	...	...	...	...	...	....	....	400	400	400	880	3200	....
		Max	..	..	...	...	...	...	...	...	...	....	....	960	1380	1850	2600	4000	....
280	200	Min	..	..	...	...	...	...	...	...	...	....	....	....	....	620	620	1350	....
		Max	..	..	...	...	...	...	...	...	...	....	....	....	....	1500	2200	4000	....

* The 1N, 2N, and 3N ampere ratings of the G-E 5-ampere series Hi-surge fuse links have time-current characteristics closely approaching those established by the American standards for 1T, 2T, and 3T ampere ratings, respectively. Hence, they are recommended for applications requiring 1T 2T, or 3T fuse links.

G-E co-ordinating fuse links.

COORDINATION CHART 11

HR Recloser Sequence—2 Instantaneous, Plus 2 Extended Time-delay with G-E "N"-type Link. Located on Load Side of the Recloser

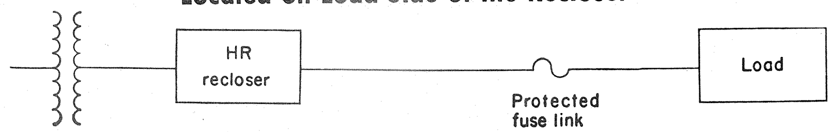


Recloser Rating Amp (Cont.)	Frame Size Amp		1N	2N	3N	5N	8N	10N	15N	20N	25N	30N	40N	45N	50N	51#	75N	85N	95N	52#	100N	125N	101#	150N	200N	102#
			RANGE OF CO-ORDINATION—RMS AMPERES																							
5	50	Min	...	...	10	10	17	37	68	110	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Max	...	...	23	57	72	94	125	125	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	50	Min	...	...	...	...	20	20	24	56	100	150	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Max	...	...	...	...	45	68	106	141	200	250	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	50	Min	...	...	...	...	...	...	30	30	60	105	180	285	...	...	...	...	...	...	...	...	...	...	...	...
		Max	...	...	...	...	...	...	77	116	177	237	322	325	...	...	...	...	...	...	...	...	...	...	...	...
25	50 100	Min	...	...	...	...	...	...	...	...	50	50	82	175	270	530	480	820	...	...	...	...	...	...	...	...
	50 100	Max	...	...	...	...	...	...	...	...	125	185	272	390	570	625 840	625 830	... 1000	...	...	...	...	...	...	...	...
35	50 100	Min	...	...	...	...	...	...	...	...	...	70	70	97	180	410	355	650	880	1080	1200	...	...	...	...	...
	50 100	Max	...	...	...	...	...	...	...	...	...	100	225	342	505	780	775	875 1120	... 1400	... 1400	... 1400	...	...	...	...	...
50	50 100	Min	...	...	...	...	...	...	...	...	...	...	...	100	108	300	205	455	750	840	940	...	...	...	...	...
	50 100	Max	...	...	...	...	...	...	...	...	...	...	...	266 266	435 435	695 695	690 690	1025 1025	1250 1405	1250 1710	1250 1720	...	...	...	...	...
70	100	Min	...	...	...	...	...	...	...	...	...	...	...	...	140	205	140	265	450	650	690	1500	...	...	...	...
		Max	...	...	...	...	...	...	...	...	...	...	...	...	300	595	585	935	1320	1600	1610	2000	...	...	...	...
100	100	Min	...	...	...	...	...	...	...	...	...	...	...	...	...	200	200	200	245	450	420	1120	1500	1850	...	...
		Max	...	...	...	...	...	...	...	...	...	...	...	...	...	425	360	800	1175	1410	1450	1900	2000	2000	...	...
140	100	Min	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	280	350	280	800	1110	1500	...	...
		Max	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	880	1140	1200	1700	2000	2000	...	...
25	200	Min	...	...	...	...	...	...	...	...	50	50	73	118	180	415	365	630	850	1000	1140	...	...	...	...	...
		Max	...	...	...	...	...	...	...	...	132	185	257	365	510	760	770	1100	1500	1500	1500	...	...	...	...	...
35	200	Min	...	...	...	...	...	...	...	...	...	70	70	93	135	300	215	475	660	840	920	1700	...	...	...	...
		Max	...	...	...	...	...	...	...	...	...	147	227	330	477	700	700	1000	1400	1650	1700	2100	...	...	...	...
50	200	Min	...	...	...	...	...	...	...	...	...	...	100	100	105	225	170	280	450	650	710	1470	1900	2150	...	...
		Max	...	...	...	...	...	...	...	...	...	...	170	282	420	660	645	970	1310	1590	1600	2000	3000	3000	...	...
70	200	Min	...	...	...	...	...	...	...	...	...	...	...	...	140	200	140	210	300	460	430	1150	1550	1810	2900	3000
		Max	...	...	...	...	...	...	...	...	...	...	...	...	355	580	580	890	1210	1425	1500	1900	3000	3000	4000	4000
100	200	Min	...	...	...	...	...	...	...	...	...	...	...	...	...	200	200	200	235	390	340	760	1150	1470	2500	2400
		Max	...	...	...	...	...	...	...	...	...	...	...	...	...	485	465	790	1100	1330	1390	1800	2950	2800	4000	4000
140	200	Min	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	280	280	330	280	580	700	1100	2150	1800
		Max	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	640	950	1190	1220	1700	2775	2700	4000	4000
200	200	Min	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	400	400	400	485	530	840	1600	960
		Max	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	575	980	1015	1500	2475	2450	3800	4000
280	200	Min	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	620	620	720	1200	680
		Max	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1200	2100	2100	3800	3900

G-E co-ordinating fuse links.

COORDINATION CHART 12

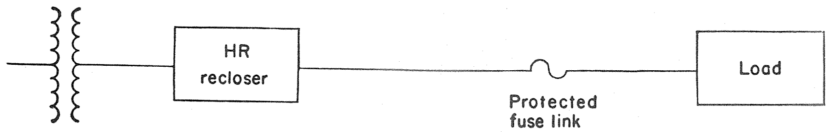
HR Recloser Sequence—2 Instantaneous, Plus 2 Extended Time-delay with G-E "K"-type Fuse Link. Located on Load Side of the Recloser



Recloser Rating Amp (Continuous)	Frame Size Amp		2K	3K	6K	8K	10K	12K	15K	20K	25K	30K	40K	50K	65K	80K	100K	140K	200K
			RATINGS IN AMPERES OF G-E TYPE K FUSE LINKS — RANGE OF CO-ORDINATION—RMS AMPERES																
5	50	Min	..	10	31	63	100	...	...	...	...	...	...	...	....	....	....	....	....
		Max	..	27	82	120	125	...	...	...	...	...	...	...	....	....	....	....	....
10	50	Min	..	..	20	20	35	79	142	...	...	...	...	...	....	....	....	....	....
		Max	..	..	55	96	136	187	250	...	...	...	...	...	....	....	....	....	....
15	50	Min	..	..	..	30	30	37	90	155	210	...	...	...	....	....	....	....	....
		Max	..	..	..	66	112	159	252	327	375	...	...	...	....	....	....	....	....
25	50 100	Min	..	..	..	...	...	50	50	75	115	210	365	530 {	 900	....	....	....	....
	50 100	Max	..	..	..	...	...	87	207	280	380	535 {	625 705	625 970	 1000	....	....	....	....
35	50 100	Min	..	..	..	...	...	...	70	70	70	115	270	435	720 {	 1060	....	....	....
	50 100	Max	..	..	..	...	...	...	127	232	337	485	660 {	850 877	850 1200	 1400	....	....	....
50	50 100	Min	..	..	..	...	...	...	...	...	100	100	160	300	510	800	1200	....	....
	50 100	Max	..	..	..	...	...	...	...	...	250	422	585	810	1105 {	1250 1435	1250 2000	....	....
70	100	Min	..	..	..	...	...	...	...	...	...	140	140	185	315	560	950	....	....
		Max	...	..	..	...	...	...	...	...	...	260	472	710	1005	1325	1825	....	....
100	100	Min	..	..	..	...	...	...	...	...	...	...	...	200	200	330	720	....	....
		Max	..	..	..	...	...	...	...	...	...	...	...	535	875	1200	1700	....	....
140	100	Min	..	..	..	...	...	...	...	...	...	...	...	...	280	280	470	....	....
		Max	..	..	..	...	...	...	...	...	...	...	...	...	550	950	1405	....	....
25	200	Min	..	..	..	...	...	50	50	69	90	130	275	430	690	1000	1380	....	....
		Max	..	..	..	...	...	119	202	267	357	495	655	860	1150	1500	1500	....	....
35	200	Min	..	..	..	...	...	...	70	70	70	105	175	310	540	810	1200	....	....
		Max	..	..	..	...	...	...	165	235	325	462	610	820	1100	1400	1900	....	....
50	200	Min	..	..	..	...	...	...	...	100	100	100	150	210	315	580	950	2200	....
		Max	..	..	..	...	...	...	...	165	275	417	555	770	1070	1310	1800	3000	....
70	200	Min	..	..	..	...	...	...	...	...	...	140	140	185	235	360	740	1750	3600
		Max	..	..	..	...	...	...	...	...	...	340	477	680	965	1250	1710	3100	4000
100	200	Min	..	..	..	...	...	...	...	...	...	...	200	200	200	295	510	1280	3100
		Max	..	..	..	...	...	...	...	...	...	...	345	575	855	1140	1590	2900	4000
140	200	Min	..	..	..	...	...	...	...	...	...	...	...	...	280	280	425	770	2450
		Max	..	..	..	...	...	...	...	...	...	...	...	...	710	990	1430	2725	4000
200	200	Min	..	..	..	...	...	...	...	...	...	...	...	...	....	400	400	570	1850
		Max	..	..	..	...	...	...	...	...	...	...	...	...	....	720	1235	2500	4000
280	200	Min	..	..	..	...	...	...	...	...	...	...	...	...	....	....	....	620	1350
		Max	..	..	..	...	...	...	...	...	...	...	...	...	....	....	....	2100	4000

COORDINATION CHART 13

HR Recloser Sequence—2 Instantaneous, Plus 2 Extended Time-delay with G-E "T"-type Fuse Link. Located on Load Side of the Recloser



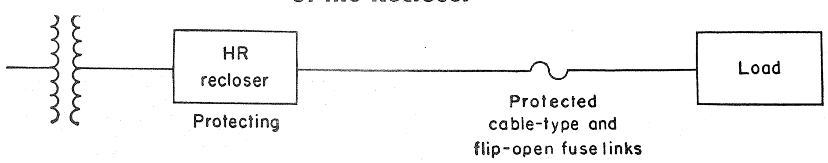
Recloser Rating Amp (Continuous)	Frame Size Amp		2N*	3N*	6T	8T	10T	12T	15T	20T	25T	30T	40T	50T	65T	80T	100T	140T	200T 103#
			RANGE OF CO-ORDINATION—RMS AMPERES																
5	50	Min	10	10	68	112	...	...	...	...	...	....	....	....	....	....	....	....	....
		Max	49	49	125	125	...	...	...	...	...	....	....	....	....	....	....	....	....
10	50	Min	..	..	20	45	110	185	...	...	...	....	....	....	....	....	....	....	....
		Max	..	..	122	187	250	250	...	...	...	....	....	....	....	....	....	....	....
15	50	Min	..	..	30	30	30	120	210	335	...	....	....	....	....	....	....	....	....
		Max	..	..	98	160	247	360	375	375	...	....	....	....	....	....	....	....	....
25	50 / 100	Min	..	..	...	50	50	50	50	195	340	520	810	....	....	....	....	....	....
	50 / 100	Max	..	..	...	87	200	310	470	605	625 / 750	625 / 1000	.... / 1000	.... /	....	....	....	....	....
35	50 / 100	Min	..	..	...	...	...	70	70	70	220	395	650	.... / 950	....	....	....	....	....
	50 / 100	Max	..	..	...	...	...	255	367	555	735	875 / 990	875 / 1360	.... / 1400	....	....	....	....	....
50	50 / 100	Min	..	..	...	...	...	...	100	100	100	175	430	700	1060	.... / 1550	....	....	....
	50	Max	..	..	...	...	...	...	317	477	660	915	1235	1250 / 1635	.... / 2000	.... / 2000	....	....	....
70	100	Min	..	..	...	...	...	...	...	140	140	140	140	480	810	1220	....	....	....
		Max	..	..	...	...	...	...	...	370	560	815	1125	1515	2000	2000	....	....	....
100	100	Min	..	..	...	...	...	...	...	...	...	200	200	200	425	850	1380	....	....
		Max	..	..	...	...	...	...	...	...	...	660	985	1365	1845	2000	2000	....	....
140	100	Min	..	..	...	...	...	...	...	...	...	....	280	280	280	280	1010	....	....
		Max	..	..	...	...	...	...	...	...	...	....	700	1100	1560	2000	2000	....	....
25	200	Min	..	..	...	50	50	50	50	94	225	400	620	900	1250	....	....	....	....
		Max	..	..	...	117	197	292	415	565	735	985	1300	1500	1500	....	....	....	....
35	200	Min	..	..	...	...	70	70	70	70	105	210	460	720	1060	1480	....	....	....
		Max	..	..	...	...	162	255	372	515	680	920	1200	1600	2100	2100	....	....	....
50	200	Min	..	..	...	...	...	100	100	100	100	130	225	490	820	1200	1720	....	....
		Max	..	..	...	...	...	202	330	467	620	860	1145	1510	2000	2525	3000	....	....
70	200	Min	..	..	...	...	...	...	140	140	140	140	140	295	430	890	1400	2900	....
		Max	..	..	...	...	...	...	235	395	550	775	1055	1400	1850	2400	3200	4000	....
100	200	Min	..	..	...	...	...	...	...	...	200	200	200	200	260	450	1000	2300	....
		Max	..	..	...	...	...	...	...	...	445	675	950	1300	1700	2225	3050	4000	....
140	200	Min	..	..	...	...	...	...	...	...	...	280	280	280	280	280	620	1720	....
		Max	..	..	...	...	...	...	...	...	...	485	810	1150	1565	2075	2875	4000	....
200	200	Min	..	..	...	...	...	...	...	...	...	....	....	400	400	400	400	830	3000
		Max	..	..	...	...	...	...	...	...	...	....	....	960	1380	1850	2600	4000	4000
280	200	Min	..	..	...	...	...	...	...	...	...	....	....	....	....	620	620	620	1700
		Max	..	..	...	...	...	...	...	...	...	....	....	....	....	1500	2200	4000	4000

* The 1N, 2N, and 3N ampere ratings of the G-E 5-ampere series Hi-surge fuse links have time-current characteristics closely approaching those established by the American standards for 1T, 2T, and 3T ampere ratings, respectively. Hence, they are recommended for applications requiring 1T, 2T, or 3T fuse links.

G-E co-ordinating fuse links.

COORDINATION CHART 14

HR Recloser Sequence—2 Instantaneous, Plus Hold-closed with G-E "N"-type Fuse Links. Located on Load Side of the Recloser

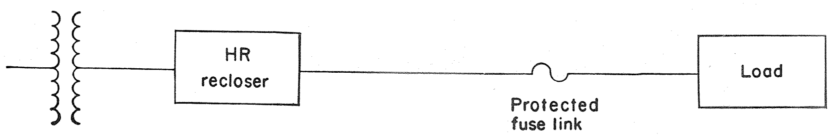


Recloser Rating Amp (Cont.)	Frame Size Amp		1N	2N	3N	5N	8N	10N	15N	20N	25N	30N	40N	45N	50N	51#	75N	85N	95N	52#	100N	125N	101#	150N	200N	102#
		RANGE OF CO-ORDINATION—RMS AMPERES																								
5	50	Min			11	11	12	15	20																	
		Max			23	57	72	94	125																	
10	50	Min					22	22	22	27	35	47														
		Max					45	68	106	141	200	250														
15	50	Min							33	33	35	47	60													
		Max							77	116	177	237	322													
25	50 / 100	Min									55	55	60	72	92	160										
	50 / 100	Max									125	185	272	390	570	625										
35	50 / 100	Min										77	77	77	90	125	120	149	175							
	50 / 100	Max										100	225	342	505	780	775	875 / 1120	1400							
50	50 / 100	Min												110	110	120	120	142	165	160						
	50 / 100	Max												266	435	695	690	1025	1250 / 1405	1710						
70	100	Min													154	154	154	154	165	158	205	380				
		Max													300	595	585	935	1320	1600	1610	2000				
100	100	Min														220	220	220	220	220	220	350	300			
		Max														425	360	800	1175	1410	1450	1900	2000			
140	100	Min																	308	308	308	325	298			
		Max																	880	1140	1200	1700	2000			
25	200	Min									55	55	60	72	92	143	121	151	190							
		Max									132	185	257	365	510	760	770	1100	1500							
35	200	Min										77	77	77	90	130	120	145	182	192	245	450				
		Max										147	227	330	477	700	700	1000	1400	1650	1700	2100				
50	200	Min											110	110	110	125	119	142	162	160	228	410	375			
		Max											170	282	420	660	645	970	1310	1590	1600	2000	3000			
70	200	Min													154	154	154	154	168	160	200	382	350	590	810	
		Max													355	580	580	890	1210	1425	1500	1900	3000	3000	4000	
100	200	Min														220	220	220	220	220	220	380	300	520	780	
		Max														485	465	790	1100	1330	1390	1800	2950	2800	4000	
140	200	Min																308	308	308	308	325	308	400	685	
		Max																640	950	1190	1220	1700	2725	2700	4000	
200	200	Min																	440	440	440	440	440	440	495	440
		Max																	575	980	1015	1500	2475	2450	3800	4000
280	200	Min																				616	616	616	616	616
		Max																				1200	2100	2100	3800	3900

G-E co-ordinating fuse links.

COORDINATION CHART 15

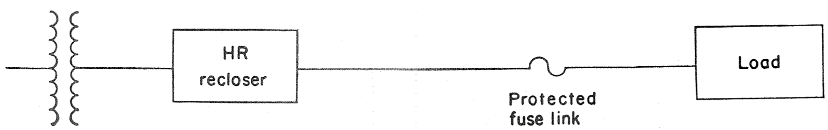
HR Recloser Sequence—2 Instantaneous, Plus Hold-closed with G-E "K"-type Fuse Link. Located on Load Side of the Recloser



Recloser Rating Amp (Continuous)	Frame Size Amp		2K	3K	6K	8K	10K	12K	15K	20K	25K	30K	40K	50K	65K	80K	100K	140K	200K
			RATINGS IN AMPERES OF G-E TYPE K FUSE LINKS — RANGE OF CO-ORDINATION—RMS AMPERES																
5	50	Min	..	11	14	18	24	...	...	...	...	...	...	...	....	....	....	....	....
		Max	..	27	82	120	125	...	...	...	...	...	...	...	....	....	....	....	....
10	50	Min	..	..	22	22	23	29	38	...	...	...	...	...	....	....	....	....	....
		Max	..	..	55	96	136	187	250	...	...	...	...	...	....	....	....	....	....
15	50	Min	..	..	..	33	33	33	37	45	60	...	...	...	....	....	....	....	....
		Max	..	..	..	66	112	159	252	327	375	...	...	...	....	....	....	....	....
25	50 100	Min	..	..	..	...	...	55	55	55	56	71	100	134	 188	....	....	....	....
	50 100	Max	..	..	..	...	...	87	207	280	380	535	625 705	625 970	 1000	....	....	....	....
35	50 100	Min	..	..	..	...	...	...	77	77	77	77	92	120	 170	 225	....	....	....
	50	Max	..	..	..	...	...	...	127	232	337	485	660	850 877	 1200	 1400	....	....	....
50	50 100	Min	..	..	..	...	...	...	...	...	110	110	110	119	150	205 200	 275	....	....
	50 100	Max	..	..	..	...	...	...	...	...	250	422	585	810	1105	1250 1435	 2000	....	....
70	100	Min	..	..	..	...	...	...	...	...	...	154	154	154	154	190	290	450	....
		Max	..	..	..	...	...	...	...	...	...	260	472	710	1005	1325	1825	2000	....
100	100	Min	..	..	..	...	...	...	...	...	...	...	...	220	220	220	228	....	....
		Max	..	..	..	...	...	...	...	...	...	...	...	535	875	1200	1700	....	....
140	100	Min	..	..	..	...	...	...	...	...	...	...	...	...	308	308	308	....	....
		Max	..	..	..	...	...	...	...	...	...	...	...	...	550	950	1405	....	....
25	200	Min	..	..	..	...	...	55	55	55	57	71	98	130	187	240	....	....	....
		Max	..	..	..	...	...	119	202	267	357	495	655	860	1150	1500	....	....	....
35	200	Min	..	..	..	...	...	...	77	77	77	77	93	122	170	220	300	....	....
		Max	..	..	..	...	...	...	165	235	325	462	610	820	1100	1400	1900	....	....
50	200	Min	..	..	..	...	...	...	...	110	110	110	110	119	150	200	265	450	....
		Max	..	..	..	...	...	...	...	165	275	417	555	770	1070	1310	1800	3000	....
70	200	Min	..	..	..	...	...	...	...	...	...	154	154	154	154	190	225	435	925
		Max	..	..	..	...	...	...	...	...	...	340	477	680	965	1250	1710	3100	4000
100	200	Min	..	..	..	...	...	...	...	...	...	...	220	220	220	220	225	410	890
		Max	..	..	..	...	...	...	...	...	...	...	345	575	855	1140	1590	2900	4000
140	200	Min	..	..	..	...	...	...	...	...	...	...	...	...	308	308	308	385	715
		Max	..	..	..	...	...	...	...	...	...	...	...	...	710	990	1430	2725	4000
200	200	Min	..	..	..	...	...	...	...	...	...	...	...	...	....	440	440	440	600
		Max	..	..	..	...	...	...	...	...	...	...	...	...	....	720	1235	2500	4000
280	200	Min	..	..	..	...	...	...	...	...	...	...	...	...	....	....	....	616	616
		Max	..	..	..	...	...	...	...	...	...	...	...	...	....	....	....	2100	4000

COORDINATION CHART 16

HR Recloser Sequence—2 Instantaneous, Plus Hold-closed with G-E "T"-type Fuse Link. Located on Load Side of the Recloser



Recloser Rating Amp (Continuous)	Frame Size Amp		2N*	3N*	6T	8T	10T	12T	15T	20T	25T	30T	40T	50T	65T	80T	100T	140T	200T 103#
			RATINGS IN AMPERES OF G-E TYPE T FUSE LINKS — RANGE OF CO-ORDINATION—RMS AMPERES																
5	50	Min	11	11	14	...	...	...	...	...	...	....	....	....	....	....	....	....	....
		Max	49	49	125	...	...	...	...	...	...	....	....	....	....	....	....	....	....
10	50	Min	..	..	22	22	24	...	...	...	...	....	....	....	....	....	....	....	....
		Max	..	..	122	187	250	...	...	...	...	....	....	....	....	....	....	....	....
15	50	Min	..	..	33	33	33	33	37	...	...	....	....	....	....	....	....	....	....
		Max	..	..	98	160	247	360	375	...	...	....	....	....	....	....	....	....	....
25	50 / 100	Min	..	..	...	55	55	55	55	55	58	.... / 73	....	....	....	....	....	....	....
	50 / 100	Max	..	..	...	87	200	310	470	605	625 / 750	.... / 1000	....	....	....	....	....	....	....
35	50 / 100	Min	..	..	...	...	77	77	77	77	77	77	.... / 90	.... / 111	....	....	....	....	....
	50 / 100	Max	..	..	...	...	110	255	367	555	735	875 / 990	.... / 1360	.... / 1400	....	....	....	....	....
50	50 / 100	Min	..	..	...	...	...	...	110	110	110	110	110	111	... / 142	....	....	....	....
	50 / 100	Max	..	..	...	...	...	...	317	477	660	915	1235	1250 / 1635	.... / 2000	....	....	....	....
70	100	Min	..	..	...	...	...	...	...	154	154	154	154	154	154	....	....	....	....
		Max	..	..	...	...	...	...	...	370	560	815	1125	1515	2000	....	....	....	....
100	100	Min	..	..	...	...	...	...	...	...	...	220	220	220	220	220	....	....	....
		Max	..	..	...	...	...	...	...	...	...	660	985	1365	1845	2000	....	....	....
140	100	Min	..	..	...	...	...	...	...	...	...	....	308	308	308	308	308	....	....
		Max	..	..	...	...	...	...	...	...	...	....	700	1100	1560	2000	2000	....	....
25	200	Min	..	..	...	55	55	55	55	55	58	73	95	128	170	....	....	....	....
		Max	..	..	...	117	197	292	415	565	735	985	1300	1500	1500	....	....	....	....
35	200	Min	..	..	...	...	77	77	77	77	77	77	90	112	168	210	....	....	....
		Max	..	..	...	...	162	255	372	515	680	920	1200	1600	2100	2100	....	....	....
50	200	Min	..	..	...	...	...	110	110	110	110	110	110	112	141	192	270	....	....
		Max	..	..	...	...	...	202	330	467	620	860	1145	1510	2000	2525	3000	....	....
70	200	Min	..	..	...	...	...	...	154	154	154	154	154	154	154	181	240	420	....
		Max	..	..	...	...	...	...	235	395	550	775	1055	1400	1850	2400	3200	4000	....
100	200	Min	..	..	...	...	...	...	...	...	220	220	220	220	220	220	222	390	....
		Max	..	..	...	...	...	...	...	...	445	675	950	1300	1700	2225	3050	4000	....
140	200	Min	..	..	...	...	...	...	...	...	...	308	308	308	308	308	308	365	....
		Max	..	..	...	...	...	...	...	...	...	485	810	1150	1565	2075	2875	4000	....
200	200	Min	..	..	...	...	...	...	...	...	...	....	....	440	440	440	440	440	....
		Max	..	..	...	...	...	...	...	...	...	....	....	960	1380	1850	2600	4000	....
280	200	Min	..	..	...	...	...	...	...	...	...	....	....	....	....	616	616	616	....
		Max	..	..	...	...	...	...	...	...	...	....	....	....	....	1500	2200	4000	....

* The 1N, 2N, and 3N ampere ratings of the G-E 5-ampere series Hi-surge fuse links have time-current characteristics closely approaching those established by the American standards for 1T, 2T, and 3T ampere ratings, respectively. Hence, they are recommended for applications requiring 1T, 2T, or 3T fuse links.

G-E co-ordinating fuse links.

COORDINATION CHART 17

Internal Fuses with HR-1 and HR-3 Reclosers—2 Instantaneous Plus 2 Standard or 2 Extended Time Delay Functions. Protective Characteristics of Internal Fuses in Type HBA and Other Transformers. Connected in Series with the HR Oil Circuit Recloser

Designation No. of Internal Fuse △	Two Instantaneous Plus Two **Standard** Time Delay Function															Two Instantaneous Plus Two **Extended** Time Delay Function														
	50-Amp and 100-Amp Frame Sizes								200-Amp Frame Size							50-Amp and 100-Amp Frame Sizes								200-Amp Frame Size						
	RECLOSER RATING IN CONTINUOUS RMS AMPERES																													
	5#	10#	15#	25	35	50	70*	100*	25	35	50	70	100	140	200	5#	10#	15#	25	35	50	70*	100*	25	35	50	70	100	140	200
	MINIMUM CURRENT ABOVE WHICH INTERNAL FUSE WILL PREVENT RECLOSER FROM LOCKING OPEN†																													
1	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
2	30	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	12	12	12	12	12	12	12	12	12	12	12	12	12	12
3	58	20	17	17	17	17	17	17	17	17	17	17	17	17	17	35	17	17	17	17	17	17	17	17	17	17	17	17	17	17
4	100	53	22	22	22	22	22	22	22	22	22	22	22	22	22	65	25	22	22	22	22	22	22	22	22	22	22	22	22	22
5	...	106	56	29	29	29	29	29	29	29	29	29	29	29	29	110	52	30	29	29	29	29	29	29	29	29	29	29	29	29
6	...	150	97	34	34	34	34	34	34	34	34	34	34	34	34	...	82	40	34	34	34	34	34	34	34	34	34	34	34	34
7	...	220	160	64	42	42	42	42	64	42	42	42	42	42	42	...	140	88	42	42	42	42	42	42	42	42	42	42	42	42
8	...	...	260	160	52	52	52	52	120	52	52	52	52	52	52	...	225	165	62	52	52	52	52	60	52	52	52	52	52	52
9	...	...	...	280	210	66	66	66	310	150	66	66	66	66	66	...	...	275	160	70	66	66	66	98	70	66	66	66	66	66
10	...	...	...	450	340	220	80	80	480	350	170	80	80	80	80	...	...	...	275	180	80	80	80	180	120	80	80	80	80	80
11	...	...	...	660*	520	400	100	100	740	580	300	150	100	100	100	...	...	...	440	325	170	100	100	340	190	125	100	100	100	100
12	...	...	...	....	820	670	500	130	1150	920	700	350	130	130	130	...	...	...	700*	560	390	150	130	550	400	225	145	130	130	130
13	...	...	...	....	1300	1020	800	540	....	1400	1120	840	400	170	170	...	...	...	....	890	660	475	170	830	680	450	280	170	170	170
14	...	...	...	....	.....	1370*	1100	800	....	1800	1500	1200	600	380	195	...	...	...	....	1130*	900	680	330	1080	880	670	400	270	195	195
30	...	...	...	360	270	150	63	63	400	220	140	63	63	63	63	...	...	350	225	140	63	63	63	145	105	63	63	63	63	63
31	...	...	...	840*	680	520	360	100	900	730	540	280	100	100	100	...	...	...	560	430	295	100	100	440	300	190	100	100	100	100
32	...	...	...	....	1270*	1050	820	600	....	1360	1110	890	450	150	150	...	...	...	....	875*	680	500	150	830	690	500	310	150	150	150
33	...	...	...	....	.....	.....	1600	1250	....	....	2100	1800	1320	560	230	...	...	...	....	.....	1300*	1050	720	....	1290	1000	790	440	230	230
34	...	...	...	....	.....	.....	....	....	....	....	....	3500	2900	2400	1250	...	...	...	....	.....	.....	....	1820	....	....	2200	1820	1400	840	590
35	...	...	...	....	.....	.....	....	....	....	....	....	....	....	....	3400	...	...	...	....	.....	.....	....	....	....	....	....	3200	2650	2100	1200

\# 50-ampere frame size only.
* 100-ampere frame size only.
△ See Table VIII under Transformer Protection, page 30, with which these fuses are used.
† The fuse will isolate a failed transformer at all currents above these values. It will clear current values less than the minimum pick-up current at the recloser without the recloser opening.

COORDINATION CHART 18

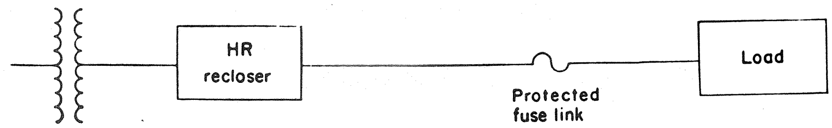
Internal Fuses with HR-1 Reclosers—2 Instantaneous Plus Hold Closed Function. Protective Characteristics of Internal Fuses in Type HBA and Other Transformers. Connected in Series with the HR-1 Oil Circuit Recloser

Designation No. of Internal Fuse △	50-Amp Frame Size						100-Amp Frame Size				
	RECLOSER RATING ON CONTINUOUS RMS AMPERES										
	5‡	10‡	15‡	25	35	50	25	35	50	70	100
	MINIMUM CURRENT ABOVE WHICH FUSE WILL PROTECT RECLOSER COIL AGAINST OVERHEATING‡										
1	8	8	8	8	8	8	8	8	8	8	8
2	12	12	12	12	12	12	12	12	12	12	12
3	17	17	17	17	17	17	17	17	17	17	17
4	23	22	22	22	22	22	22	22	22	22	22
5	30	29	29	29	29	29	29	29	29	29	29
6	40	34	34	34	34	34	34	34	34	34	34
7	48	43	43	43	43	43	43	43	43	43	43
8	...	53	53	52	52	52	52	52	52	52	52
9	...	70	68	66	66	66	66	66	66	66	66
10	...	110	84	81	80	80	81	80	80	80	80
11	...	...	110	105	100	100	102	100	100	100	100
12	...	...	...	135	135	130	132	132	130	130	130
13	...	...	...	180	170	170	175	170	170	170	170
14	...	...	...	280	200	200	220	200	200	195	195
30	...	90	70	63	63	63	63	63	63	63	63
31	...	...	175	115	105	100	115	105	100	100	100
32	...	...	...	205	170	155	180	170	155	150	150
33	...	...	...	...	300	250	350	270	250	240	230
34	...	...	...	...	...	...	...	800	470	400	375
35	...	...	...	...	...	...	...	...	1000	660	600

△ See Table VIII under Transformer Protection, page 30, with which these fuses are used.
‡ The fuse will isolate a failed transformer at all currents above these values. It will clear current values less than the minimum pick-up current of the recloser without the recloser opening.

COORDINATION CHART 19

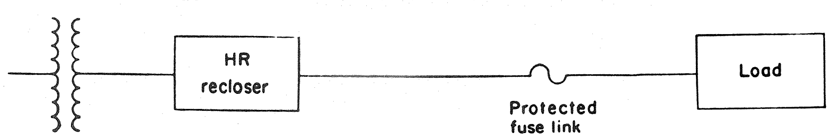
Type HR 100-ampere Reclosers—Recloser Sequence, 3 Instantaneous Plus 1 Standard Time-delay Function. In Series with G-E "K"-type (Fast) Fuse Links. Located on Load Side of the Recloser



Recloser Rating RMS Amp (Continuous)	Fuse Link Ratings RMS Amp	RATINGS IN AMPERES OF G-E TYPE K FUSE LINKS													
		3	6	8	10	12	15	20	25	30	40	50	65	80	100
					RANGE OF CO-ORDINATION—RMS AMPERES										
5	Min	10	43	78	120	165	...	...	...	...	...	...	....	....	..
	Max	27	80	120	155	200	...	...	...	...	...	...	....	....	....
10	Min	..	20	29	67	100	180	260	...	...	...	...	....	....	....
	Max	..	54	93	135	180	270	350	...	...	...	...	....	....	....
15	Min	..	..	30	30	60	135	190	290	480	...	...	....	....	....
	Max	..	..	60	110	160	250	320	420	600	...	...	....	....	....
25	Min	..	..	..	...	50	57	120	180	325	490	700	....	....	....
	Max	..	..	..	...	90	200	270	370	515	695	910	....	....	....
35	Min	..	..	..	...	...	70	70	115	230	380	550	900	....	....
	Max	..	..	..	...	...	125	225	320	470	630	860	1200	....	....
50	Min	..	..	..	...	...	...	...	100	115	275	420	740	1050	1550
	Max	..	..	..	...	...	...	...	245	400	575	790	1100	1400	1900
70	Min	..	..	..	...	...	...	...	...	140	170	290	580	870	1270
	Max	..	..	..	...	...	...	...	...	280	470	700	1000	1350	1750
100	Min	..	..	..	...	...	...	...	...	...	...	200	320	610	1050
	Max	..	..	..	...	...	...	...	...	...	...	500	840	1250	1650

COORDINATION CHART 20

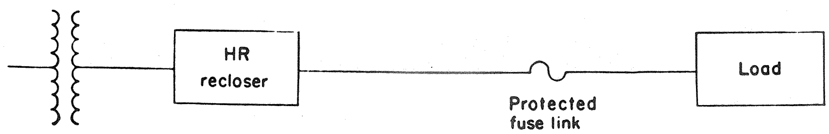
Type HR 100-ampere Reclosers—Recloser Sequence, 3 Instantaneous Plus 1 Extended Time-delay Function. In Series with G-E "K"-type (Fast) Fuse Links. Located on Load Side of the Recloser



Recloser Rating RMS Amp (Continuous)	Fuse Link Ratings RMS Amp	RATINGS IN AMPERES OF G-E TYPE K FUSE LINKS														
		3	6	8	10	12	15	20	25	30	40	50	65	80	100	140
		RANGE OF CO-ORDINATION—RMS AMPERES														
5	Min	10	25	50	85	120	...	...	...	...	...	...	....	....	....	....
	Max	27	80	120	155	200	...	...	...	...	...	...	....	....	....	....
10	Min	..	20	20	35	60	120	180	270	...	...	...	....	....	....	....
	Max	..	54	93	135	180	270	350	400	...	...	...	....	....	....	....
15	Min	..	..	30	30	38	75	130	190	330	480	...	....	....	....	....
	Max	..	..	60	110	160	250	320	420	600	600	...	....	....	....	....
25	Min	..	..	...	...	50	50	73	115	200	340	490	840	....	....	....
	Max	..	..	...	...	90	200	270	370	515	695	910	1000	....	....	....
35	Min	..	..	...	...	...	70	70	77	120	250	380	670	950	....	....
	Max	..	..	...	...	...	125	225	320	470	630	860	1200	1400	....	....
50	Min	..	..	...	...	...	...	...	100	100	175	260	480	740	1200	....
	Max	..	..	...	...	...	...	...	245	400	575	790	1100	1400	1900	....
70	Min	..	..	...	...	...	...	...	...	140	145	200	330	540	940	2400
	Max	..	..	...	...	...	...	...	...	280	470	700	1000	1350	1750	2500
100	Min	..	..	...	...	...	...	...	...	...	...	200	200	340	710	1700
	Max	..	..	...	...	...	...	...	...	...	...	500	840	1250	1650	2500

COORDINATION CHART 21

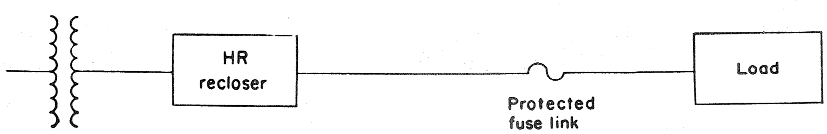
Type HR 200-ampere Reclosers—Recloser Sequence, 3 Instantaneous Plus 1 Standard Time-delay Function. In Series with G-E "K"-type (Fast) Fuse Links. Located on Load Side of the Recloser



Recloser Rating RMS Amp (Continuous)	Fuse Link Ratings RMS Amp	RATINGS IN AMPERES OF G-E TYPE K FUSE LINKS											
		12	15	20	25	30	40	50	65	80	100	140	200
		RANGE OF CO-ORDINATION—RMS AMPERES											
25	Min	50	56	110	155	350	515	720	1100	1450	....	....	....
	Max	120	200	265	360	500	650	860	1150	1500	....	....	....
35	Min	...	70	70	115	185	400	590	950	1250	1750	....	....
	Max	...	160	230	320	460	600	810	1100	1400	1850	....	....
50	Min	...	...	100	100	115	235	390	795	1100	1550	....	....
	Max	...	...	160	265	410	550	750	1050	1300	1750	....	....
70	Min	...	...	...	...	140	185	270	580	900	1400	....	....
	Max	...	...	...	...	350	475	690	960	1250	1700	....	....
100	Min	...	...	...	...	...	200	200	310	495	1050	....	....
	Max	...	...	...	...	...	320	560	840	1160	1540	....	....
140	Min	...	...	...	...	...	...	...	280	380	680	2150	....
	Max	...	...	...	...	...	...	...	695	1000	1420	2700	....
200	Min	...	...	...	...	...	...	...	....	400	530	1070	3600
	Max	...	...	...	...	...	...	...	....	740	1250	2450	4000
280	Min	...	...	...	...	...	...	...	....	....	....	650	2600
	Max	...	...	...	...	...	...	...	....	....	....	2100	4000

COORDINATION CHART 22

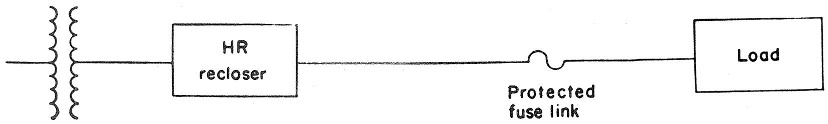
Type HR 200-ampere Reclosers—Recloser Sequence, 3 Instantaneous Plus 1 Extended Time-delay Function. In Series with G-E "K"-type (Fast) Fuse Links



Recloser Rating RMS Amp (Continuous)	Fuse Link Ratings RMS Amp	RATINGS IN AMPERES OF G-E TYPE K FUSE LINKS											
		12	15	20	25	30	40	50	65	80	100	140	200
		RANGE OF CO-ORDINATION—RMS AMPERES											
25	Min	50	50	67	91	135	280	410	680	910	1300	....	....
	Max	120	200	265	360	500	650	860	1150	1500	1500	....	....
35	Min	...	70	70	70	110	190	285	540	780	1150	....	....
	Max	...	160	230	320	460	600	810	1100	1400	1850	....	....
50	Min	...	...	100	100	100	155	215	340	600	980	2100	....
	Max	...	...	160	265	410	550	750	1050	1300	1750	3000	....
70	Min	...	...	...	...	140	145	180	260	400	840	1850	3700
	Max	...	...	...	...	350	475	690	960	1250	1700	3000	4000
100	Min	...	...	...	...	...	200	200	200	310	580	1450	3100
	Max	...	...	...	...	...	320	560	840	1160	1540	2900	4000
140	Min	...	...	...	...	...	...	...	280	280	460	810	2600
	Max	...	...	...	...	...	...	...	695	1000	1420	2700	4000
200	Min	...	...	...	...	...	...	...	....	400	400	590	1900
	Max	...	...	...	...	...	...	...	....	740	1250	2450	4000
280	Min	...	...	...	...	...	...	...	....	....	....	560	1450
	Max	...	...	...	...	...	...	...	....	....	....	2100	4000

COORDINATION CHART 23

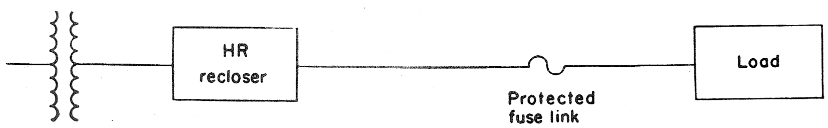
Type HR 100-ampere Reclosers—Recloser Sequence, 3 Instantaneous Plus 1 Standard Time-delay Function. In Series with G-E "T"-type (Slow) Fuse Links. Located on Load Side of the Recloser



Recloser Rating RMS Amp (Continuous)	Fuse Link Ratings RMS Amp	RATINGS IN AMPERES OF G-E TYPE T FUSE LINKS															
		1T	2T	3T	6T	8T	10T	12T	15T	20T	25T	30T	40T	50T	65T	80T	100T
		RANGE OF CO-ORDINATION—RMS AMPERES															
5	Min	12	23	26	110	160	...	...	...	...	...	....	....	....	....	....	....
	Max	48	48	48	145	200	...	...	...	...	...	....	....	....	....	....	....
10	Min	..	..	..	80	100	190	300	...	...	...	....	....	....	....	....	....
	Max	..	..	..	120	175	260	370	...	...	...	....	....	....	....	....	....
15	Min	..	..	..	30	55	135	230	360	510	...	....	....	....	....	....	....
	Max	..	..	..	98	155	245	340	470	600	...	....	....	....	....	....	....
25	Min	..	..	..	...	...	50	125	230	370	575	850	....	....	....	....	....
	Max	..	..	..	...	...	190	300	420	580	770	1000	....	....	....	....	....
35	Min	..	..	..	...	...	...	70	140	270	450	680	1000	....	....	....	....
	Max	..	..	..	...	...	...	250	375	530	710	970	1250	....	....	....	....
50	Min	..	..	..	...	...	...	...	100	100	300	510	800	1120	1650	....	....
	Max	..	..	..	...	...	...	...	310	460	640	890	1200	1550	2000	....	....
70	Min	..	..	..	...	...	...	...	...	140	140	360	610	920	1400	2000	....
	Max	..	..	..	...	...	...	...	...	360	540	800	1100	1500	1900	2500	....
100	Min	..	..	..	...	...	...	...	...	...	...	200	200	680	1100	1550	2250
	Max	..	..	..	...	...	...	...	...	...	...	640	950	1300	1750	2300	2500

COORDINATION CHART 24

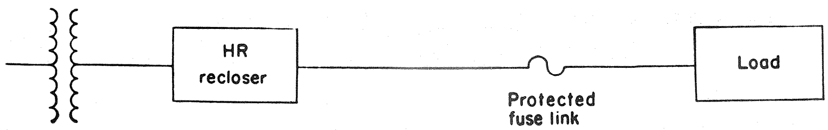
Type HR 100-ampere Reclosers—Recloser Sequence, 3 Instantaneous Plus 1 Standard Time-delay Function. In Series with G-E "T"-type (Slow) Fuse Links. Located on Load Side of the Recloser



Recloser Rating RMS Amp (Continuous)	Fuse Link Rating RMS Amp	RATINGS IN AMPERES OF G-E TYPE T FUSE LINKS															
		1T	2T	3T	6T	8T	10T	12T	15T	20T	25T	30T	40T	50T	65T	80T	100T
		RANGE OF CO-ORDINATION—RMS AMPERES															
5	Min	10	10	17	74	120	...	...	...	...	...	....	....	....	....	....	....
	Max	48	48	48	145	200	...	...	...	...	...	....	....	....	....	....	....
10	Min	..	..	..	20	58	120	210	...	...	...	....	....	....	....	....	....
	Max	..	..	..	120	175	260	370	...	...	...	....	....	....	....	....	....
15	Min	..	..	..	30	30	50	140	240	370	...	....	....	....	....	....	....
	Max	..	..	..	98	155	245	340	470	600	...	....	....	....	....	....	....
25	Min	..	..	..	...	...	50	50	115	250	380	610	....	....	....	....	....
	Max	..	..	..	...	...	190	300	420	580	770	1000	....	....	....	....	....
35	Min	..	..	..	...	...	..	70	70	70	260	460	710	....	....	....	....
	Max	..	..	..	....	...	...	250	375	530	710	970	1250	....	....	....	....
50	Min	..	..	..	...	...	...	...	100	100	100	290	540	810	1250	....	....
	Max	..	..	..	...	...	...	...	310	460	640	890	1200	1550	2000	....	....
70	Min	..	..	..	...	...	...	...	...	140	140	140	300	600	940	1400	2100
	Max	..	..	..	...	...	...	...	...	360	540	800	1100	1500	1900	2500	2500
100	Min	..	..	..	...	...	...	...	...	...	...	200	200	260	640	1100	1650
	Max	..	..	..	...	...	...	...	...	...	...	640	950	1300	1750	2300	2500

COORDINATION CHART 25

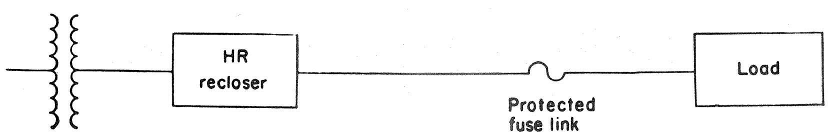
Type HR 100-ampere Reclosers—Recloser Sequence, 3 Instantaneous Plus 1 Standard Time-delay Function. In Series with G-E "T"-type (Slow) Fuse Links. Located on Load Side of the Recloser



Recloser Rating RMS Amp (Continuous)	Fuse Link Rating RMS Amp	RATINGS IN AMPERES OF G-E TYPE T FUSE LINKS												
		8T	10T	12T	15T	20T	25T	30T	40T	50T	65T	80T	100T	140T
	RANGE OF CO-ORDINATION—RMS AMPERES													
25	Min	50	50	100	200	400	600	850	1150	....	....	....	....	....
	Max	115	190	280	410	550	710	880	1250	....	....	....	....	....
35	Min	...	70	70	120	260	470	710	1050	1400	1800	....	....	....
	Max	...	160	250	370	510	690	900	1200	1600	2050	....	....	....
50	Min	...	...	100	100	100	240	540	850	1200	1650	2250	....	....
	Max	...	...	200	325	460	600	850	1100	1500	1900	2500	....	....
70	Min	...	...	...	...	140	140	300	650	1000	1500	2050	2700	....
	Max	...	...	...	...	400	540	780	1050	1400	1800	2400	3200	....
100	Min	...	...	...	...	...	200	200	270	540	1100	1650	2400	....
	Max	...	...	...	...	...	450	675	950	1250	1700	2200	3000	....
140	Min	...	...	...	...	...	...	...	280	280	600	1200	2000	....
	Max	...	...	...	...	...	...	...	800	1150	1550	2000	2800	....
200	Min	...	...	...	...	...	...	...	....	400	400	530	1150	3300
	Max	...	...	...	...	...	...	...	....	940	1350	1750	2550	4000
280	Min	...	...	...	...	...	...	...	....	....	....	560	560	2100
	Max	...	...	...	...	...	...	...	....	....	....	1750	2250	4000

COORDINATION CHART 26

Type HR 200-ampere Reclosers—Recloser Sequence, 3 Instantaneous Plus 1 Extended Time-delay Function. In Series with G-E "T"-type (Slow) Fuse Links. Located on Load Side of the Recloser



Recloser Rating RMS Amp (Continuous)	Fuse Link Rating RMS Amp	RATINGS IN AMPERES OF G-E TYPE T FUSE LINKS													
		8T	10T	12T	15T	20T	25T	30T	40T	50T	65T	80T	100T	140T	200T
	RANGE OF CO-ORDINATION														
25	Min	50	50	50	60	140	310	490	710	1000	....	....	....	....	....
	Max	115	190	280	410	550	710	880	1250	1500	....	....	....	....	....
35	Min	...	70	70	70	70	140	350	600	880	1200	1600	....	....	....
	Max	...	160	250	370	510	690	900	1200	1600	2050	2100	....	....	....
50	Min	...	...	100	100	100	100	165	350	680	1000	1450	2000	....	....
	Max	...	...	200	325	460	600	850	1100	1500	1900	2500	3000	....	....
70	Min	...	...	...	...	140	140	140	175	380	800	1200	1750	3400	....
	Max	...	...	...	...	400	540	780	1050	1400	1800	2400	3200	4000	....
100	Min	...	...	...	...	...	200	200	200	200	300	700	1400	2800	....
	Max	...	...	...	...	...	450	675	950	1250	1700	2200	3000	4000	....
140	Min	...	...	...	...	...	...	...	280	280	280	280	840	2200	....
	Max	...	...	...	...	...	...	...	800	1150	1550	2000	2800	4000	....
200	Min	...	...	...	...	...	...	...	....	400	400	400	510	1200	....
	Max	...	...	...	...	...	...	...	....	940	1350	1750	2550	4000	....
280	Min	...	...	...	...	...	...	...	....	....	....	560	560	600	2600
	Max	...	...	...	...	...	...	...	....	....	....	1550	2250	4000	4000

X. REFERENCE TO USEFUL CURVES

TIME CURRENT CHARACTERISTIC CURVES
G-E FUSE LINKS, RECLOSERS, RELAYS AND TRANSFORMERS

Copies of these curves may be obtained from the nearest General Electric Apparatus Sales Office or from General Electric Company, Schenectady, New York by asking for the publication number GES or GET.

PUBLICATION NUMBER New	Supersedes	DEVICE Fuses	CURVE NUMBER
GES-8403	(GET-2196)	"N" rated Universal cable type fuse link. Total clearing time	4
GES-8402	(GET-2197)	"N" rated Universal cable type fuse link. Melting time	5
GES-8401	(GET-1923)	"K" – American Standard cable type fuse link. Total clearing time	21
GES-8400	(GET-1924)	"K" – American Standard cable type fuse link. Melting time	22
GES-8405	(GET-1925)	"T" – American Standard cable type fuse link. Total clearing time	23
GES-8404	(GET-1926)	"T" – American Standard cable type fuse link. Melting time	24
GES-8501	(GET-1807)	Oil fuse cutout link. Total clearing time	16
GES-8500	(GET-1808A)	Oil fuse cutout link. Melting time	17
----	GET-1805	Hi-surge fuse links. Total clearing time	14
----	GET-1806	Hi-surge fuse links. Melting time	15
----	GET-2198A	Coordinating Universal cable-type fuse link. Total clearing time	6
----	GET-2199A	Coordinating Universal cable-type fuse link. Melting time	7
----	GET-2194	Secondary fuse link. Total clearing time	2
----	GET-2195	Outdoor type secondary fuse link. Total clearing time	3
GES-8100	----	EJ-2 2.4 and 4.8 kv Current-limiting power fuse Sizes D and DD Minimum melting time	--
GES-8101	----	EJ-2 2.4 and 4.8 kv Current-limiting power fuse Sizes D and DD Maximum total clearing time	--

PUBLICATION NUMBER		DEVICE	CURVE NUMBER
New	Supersedes	Fuses (Cont'd)	
GES-8102	----	EJ-1 2.4 and 4.16 and 4.8 kv Current-limiting power fuse Size DD Minimum melting time	--
GES-8103	----	EJ-1 2.4 and 4.16 and 4.8 kv Current-limiting power fuse Size DD Maximum total clearing time	--
GES-8104	----	EJ-1 and EJO-1 14.4 kv Current-limiting power fuse Sizes C, D, DD (EJO-1) and EE (EJ-1) Minimum melting time	--
GES-8105	----	EJ-1 and EJO-1 14.4 kv Current-limiting power fuse Sizes C, D, DD (EJO-1) and EE (EJ-1) Maximum total clearing time	--
GES-8106	----	EJ-1 and EJO-1 2.4 and 4.8 kv Current-limiting power fuse Sizes C, D and DD Maximum melting time	--
		Relays	
GES-7001	(GET-1773A)	Induction overcurrent IAC-51 Inverse	9.1
GES-7005	(GET-1868A)	Induction overcurrent IAC-77 - Extremely Inverse	10.1
GES-7002	(GET-1774A)	Induction overcurrent IAC-53 - Very Inverse	10.2
		Transformers	
GES-8300	(GET-1804)	Internal fuse for distribution transformers No. 1 to 14	13
GES-8301	(GET-2678)	Internal fuse for distribution transformers No. 30 to 35	13A
GES-8302	----	Internal fuse for distribution transformers. Composite curve of bushing current-limiting and internal fuse	--
----	GET-1711	Internal breaker for distribution transformers Dated before 1945-46	13.1
----	GET-1710	Internal breaker for distribution transformers Dated 1945-46 to 1954	13.2
----	GET-2652	Internal breaker for distribution transformers Dated 1955 to 1956	13.3

PUBLICATION NUMBER		DEVICE	CURVE NUMBER
New	Supersedes	Transformers (Cont'd)	
----	GET-2902	Internal breaker for distribution transformers Dated 1956 to present	13.4
----	GET-1712	ASA Safe Loading Curve for distribution transformers	11
		Reclosers	
----	GET-1971	FR-1 5-50 amperes	25
----	GET-1972	FR-1 Hold-Closed	26
----	GET-1973	FR-1H 25-140 amperes	27
----	GET-1974	FR-1E 25-140 amperes	28
GES-6413	(GET-2539)	HR-50 amp - 14.4 kv Instantaneous and standard	30
----	GET-2543	HR-50 amp - 14.4 kv Instantaneous and extended	31
GES-6400	(GET-2549)	HR-100 amp - 14.4 kv Instantaneous and standard	32
----	GET-2639	HR-100 amp - 14.4 kv Instantaneous and extended	33
----	GET-2640	HR-100 amp - 23 kv Instantaneous and standard	34
----	GET-2641	HR-100 amp - 23 kv Instantaneous and extended	35
----	GET-2642	HR-200 amp - 4.8 kv Instantaneous and standard	36
----	GET-2643	HR-200 amp - 4.8 kv Instantaneous and extended	37
GES-6415	(GET-2644)	HR-200 amp - 14.4 kv Instantaneous and standard	38
----	GET-2645	HR-200 amp - 14.4 kv Instantaneous and extended	39
GES-6414	(GET-2646)	HR-50 amp - 14.4 kv Hold Closed	40
----	GET-2647	HR-100 amp - 14.4 kv Hold Closed	41
----	GET-2697	HR-280 amp - 14.4 kv Instantaneous and Modified Extended	42
GES-6401	----	OR-560 ampere - 14.4 kv Phase Trip "B"	--

PUBLICATION NUMBER New	Supersedes	DEVICE Reclosers (Cont'd)	CURVE NUMBER
GES-6402	----	OR-560 ampere - 14.4 kv Phase Trip "C"	--
GES-6403	----	OR-560 ampere - 14.4 kv Phase Trip "D"	--
GES-6404	----	OR-560 ampere - 14.4 kv Ground trip "BG"	--
GES-6405	----	OR-560 ampere - 14.4 kv Ground trip "CG"	--
GES-6406	----	OR-560 ampere - 14.4 kv Ground trip "DG"	--
GES-6407*	----	VIR-560 ampere - 14.4 kv Phase trip "B"	--
GES-6408*	----	VIR-560 ampere - 14.4 kv Phase trip "C"	--
GES-6409*	----	VIR-560 ampere - 14.4 kv Phase trip "D"	--
GES-6410*	----	VIR-560 ampere - 14.4 kv Ground trip "BG"	--
GES-6411*	----	VIR-560 ampere - 14.4 kv Ground trip "CG"	--
GES-6412*	----	VIR-560 ampere - 14.4 kv Ground trip "DG"	--

* GES-5001 includes all VIR Recloser Curves.

CAPACITORS

----	GET-2901	Capacitor protection - 25 kvar	20A
----	GET-2900	Capacitor protection - 50 & 100 kvar	20B

MISCELLANEOUS CURVES

----	GET-1713A	Conductor burndown Weatherproof conductor tests at 4.8 kv	18
----	GET-1828	Secondary line length where fuse will provide short-circuit protection to transformer.	12

GENERAL ELECTRIC