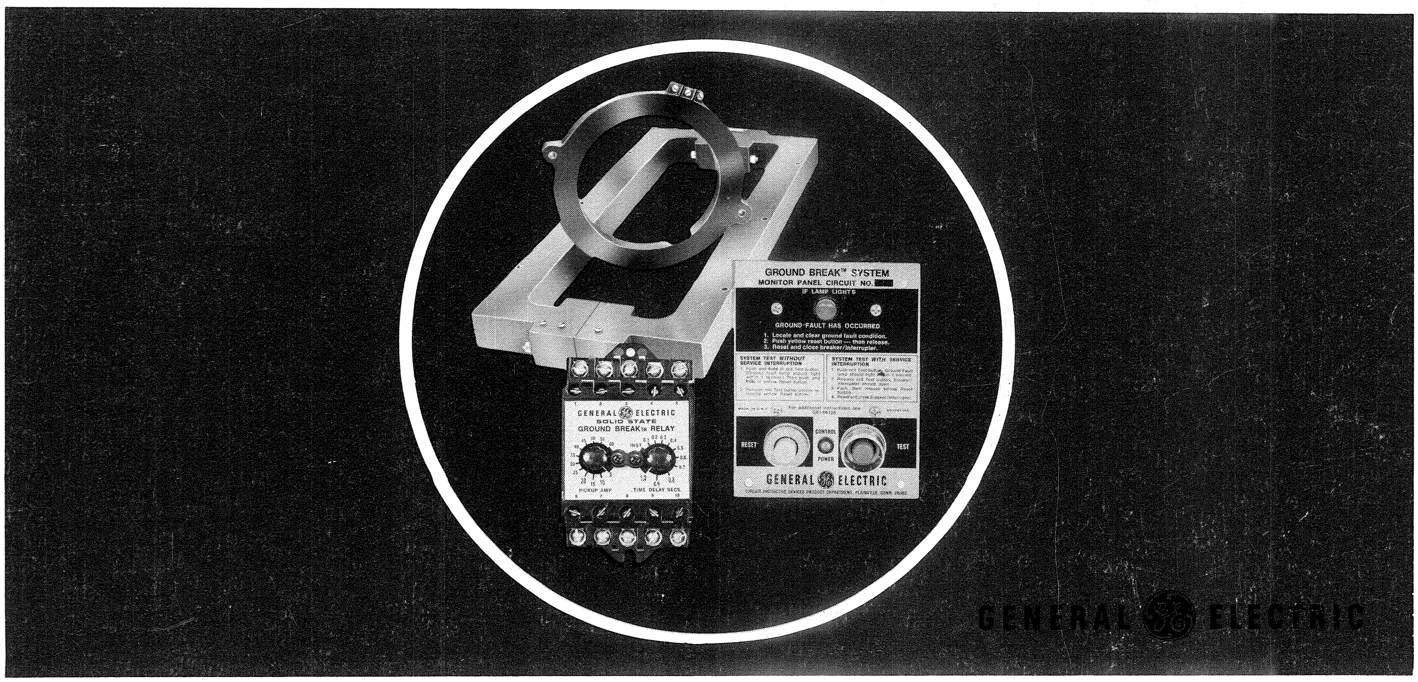
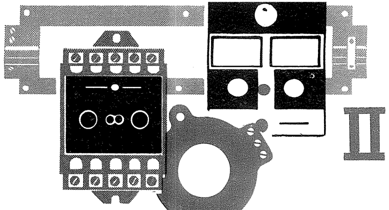
GET-2964D

Ground Break®
Equipment Ground Fault Detection Systems





II Grounding Practices

Background

The concern about arcing faults has arisen from reports of equipment burndowns due to such faults occurring in a variety of distribution equipment — load-center unit substations, switchboards, busway, panelboards, service-entrance equipment, motor-control centers, cable in conduit, to name only a few. The reported incidents have involved both industrial plant and commercial building distribution equipment, without regard to manufacturer, geographical location, operating environment, or the presence or absence of electrical system grounding. In a great many instances, complete and devastating destruction of equipment has occurred. A particularly good documentation of such a case appeared in a reference article, and involved a modern apartment-building complex whose single 10,000 ampere service entrance was from a utility 480Y/277-volt network. The entire main switchboard was completely gutted by the arcing fault, which burned for over an hour and seriously inconvenienced some 10,000 residents of the development.

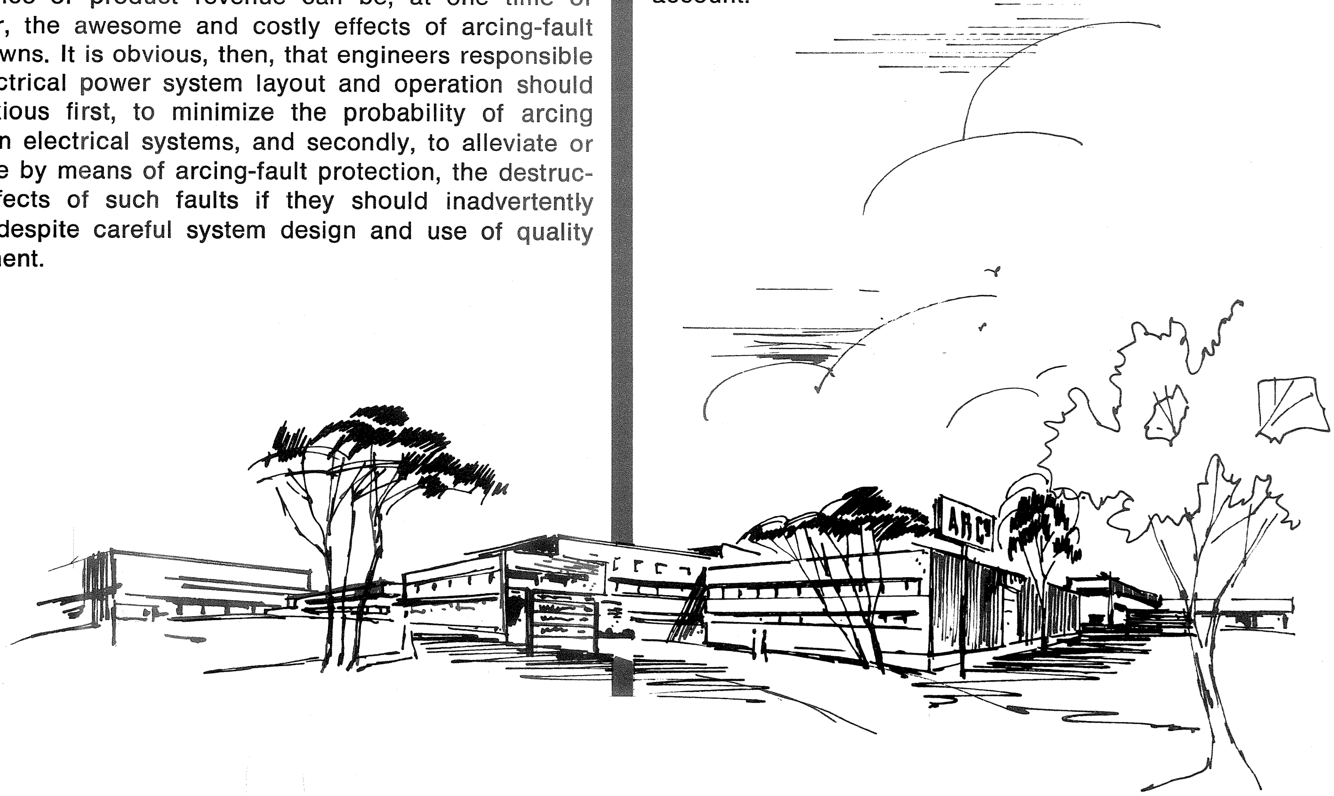
Although this documented example is startling because of the duration and extent of the fault, many other case histories have been reported in which the service outage was just as extensive or serious when measured against the total installation or the critical nature of the loads involved. Personnel fatalities or serious injury, contingent fire damage, complete destruction of electrical equipment, loss of vital services, shutdowns of critical loads, and loss of service or product revenue can be, at one time or another, the awesome and costly effects of arcing-fault burndowns. It is obvious, then, that engineers responsible for electrical power system layout and operation should be anxious first, to minimize the probability of arcing faults in electrical systems, and secondly, to alleviate or mitigate by means of arcing-fault protection, the destructive effects of such faults if they should inadvertently occur despite careful system design and use of quality equipment.

In order to minimize the probability of an arcing fault occurrence we must consider the likely causes;

- the presence of vermin, rodents and insects in equipment
- the intrusion of conducting objects such as fish tapes and tools into bare bus systems
- Loose connection arising from poor installation, heat cycling and high current surges
- Insulation deterioration as a result of mechanical damage, voltage surges, heat aging, or moisture, dust and other contaminants.

Remember that one or more of the above causes of arcing faults is occurring in every piece of electrical equipment.

No matter what preventive measures may be taken against arcing faults, their complete elimination is not possible in practical distribution systems. Arcing faults in equipment can be expected to occur, and the engineering of distribution systems protection should take this into account.



Characteristics of Arcing Faults

Once an arcing fault is established, it may be quickly self-extinguishing, or, on the other hand, it may continue to be self-sustaining as described earlier. If initiated single-phase among metal-enclosed bar buses, the arc will rapidly escalate into a three-phase fault. In grounded systems, ground will usually be involved in the fault. When the bus system is insulated and the fault is initiated single-phase it may be expected to remain that way, provided the current is interrupted promptly.

If the arc is self-sustaining, it is capable of releasing tremendous energy at the point of fault. This energy release, even at low current levels, is sufficient to burn down equipment. It is this characteristic, energy liberation in the arc at the point of fault, which makes the arcing fault so destructive. The bolted fault, in contrast, dissipates energy throughout the distribution system resistance elements, and does not produce the concentrated devastating energy release of the arcing fault.

Another characteristic of the arcing fault is its possible low current level in comparison to the bolted fault. Under favorable conditions the probable minimum value of rms line-to-ground arcing-fault current is only 38 percent of the **bolted line to ground current*** value. Under adverse conditions, such as single-phase operation in the arcing-fault circuit, or possibly the presence of a highly inductive ground-return circuit, a further reduction of arcing-fault current may occur. The lower limit of arcing-fault current is therefore unpredictable, but analytical considerations and field experience both show that it can have values which will not operate the instantaneous trips on low-voltage circuit protective devices.

Arcing-fault Protection

It is seen from the preceding paragraphs that the peculiarities of arcing faults — high rates of energy release, and possible low fault current levels — make it very desirable that arcing-fault protection be characterized by two important features: a high degree of sensitivity to detect low level arcing-fault current, and fast speed of operation to limit the destructive effects of the arc. The requirements of selective operation of circuit protective devices, however, to secure maximum power service reliability for important loads, may force a reduction in both the maximum speed of operation and maximum sensitivity available in arcing-fault protection. Nevertheless, the adequate arcing-fault protection system must be relatively sensitive and fast, and the available solutions to the protection problem should be measured against these criteria.

*Bolted line to ground current is calculated using all ground return impedences including such objects as fish tapes, insects or carbonized insulation.

Solutions to Protection Problem

Since phase-overcurrent devices of either the circuit breaker or fuse type are almost universally used in low-voltage distribution systems, it is natural to suggest that these alone may provide adequate protection against arcing faults. Unfortunately, fuses and circuit breakers are useless for currents less than their continuous current ratings, yet such currents may occur in arcing faults.

Single-phase devices, when used alone in polyphase systems, without supplemental aids to provide polyphase circuit disconnection, furnish only single-pole interruption of fault current. Case histories and analyses have shown that such single-pole interruption may not extinguish the fault, but often permit it to be backfed with reduced current from the other energized phases. If the fault is an arcing one, the protectors in the other phases may not operate on the reduced current, or may operate only after a prolonged period. In either case severe equipment burndowns may occur. For the reasons cited, fuses alone are not considered self-sufficient agents for arcing-fault protection. It may be noted, however, that certain fast-operating shunt-tripped fusible switches, which provide three-pole circuit disconnection promptly on the occurrence of a single blown fuse, may be coupled with supplementary relaying to furnish protection against arcing ground faults. Appropriate supplementary relaying would be any of the "GSR" type.

The direct-acting trips on molded-case and low-voltage power circuit breakers will provide time-delay or instantaneous tripping of the circuit breaker on overcurrents which exceed their settings. In practice, circuit breaker instantaneous trips must be set above the offset value of transformer or motor-inrush currents to avoid unnecessary tripping. As a result, it has become a widespread but ill-advised practice to set breaker instantaneous trips as high as their range permits, perhaps checking only that such settings do not exceed the maximum fault currents available (three-phase bolted short circuits). In view of the possible low levels of arcing-fault currents, these high instantaneous-trip settings cannot provide assured detection and interruption of destructive arcing faults. It is nevertheless true that improvement in system protection can be secured by instantaneous-trip settings no higher than required to avoid nuisance tripping under normal conditions. Setting of instantaneous trips on this basis should become a general practice in distribution systems. In addition, the use of short-time trips to supplement instantaneous tripping wherever possible is a recommended practice. Despite these precautions, however, arcing-fault currents may have values less than the minimum permissible settings of the instantaneous or short-time trips; in fact, such currents may be less than the normal load current in the circuit. Even where the fault current value may be sufficient to operate the long-time delay element of the circuit breaker trip, the operating time of these elements is generally so long that circuit interruption will not be accomplished before extensive arc damage has occurred.

Because of the inadequacies of fuses and conventional circuit breaker trips in handling arcing ground-fault currents, recourse to supplementary relaying is necessary to secure adequate protection.

Ground-overcurrent Relaying

The defects of phase-overcurrent devices in detecting low-level arcing faults have already been cited. This suggests that the ideal solution to the problem would be sensitive to arcing-fault current alone. Since arcing faults in grounded systems almost invariably involve ground this fact permits a near-perfect approach to the ideal solution.

In a normal, healthy power distribution system there is no significant flow of current in the ground path or no "zero-sequence" current. The presence of appreciable current in the ground circuit is directly indicative of an electric circuit fault. Arcing faults involving ground will produce a distinct ground-fault current. Therefore, monitoring the ground or zero-sequence circuit provides an effectual means of detecting the existence of arcing faults.

An excellent method of monitoring the presence of ground-fault currents (zero-sequence currents) is provided by the *low-voltage ground sensor relay* (GSR) combination. This is a window or ring-type CT in combination with an over-current relay (Fig. 2-1). All of the phase conductors of the circuit to be monitored (plus the neutral conductor, if used) are passed through the window of the CT. With this arrangement only circuit faults involving ground will produce a current in the CT secondary to pick up the relay. Under other circuit conditions — balanced, unbalanced, or single-phase load currents, or single- or three-phase short circuits not involving ground — the net flux produced in the CT core will be nearly zero. (Because of conductor spacing and geometry some net flux will exist which represents an error in the zero sequence summing of currents. The error can be minimized by centrally locating and/or bundling conductors. The error can also be minimized by using CT's with heavy cores.)

Although the GSR as discussed here is for application as arcing-fault protection it is, properly speaking, a *ground-fault* relay, and will operate on all circuit faults involving ground, whether arcing or bolted.

By careful application of the basic GSR scheme shown in Fig. 2-1 a sensitive, fast ground-fault relaying design becomes available for protection of all or part of a low-voltage power distribution system.

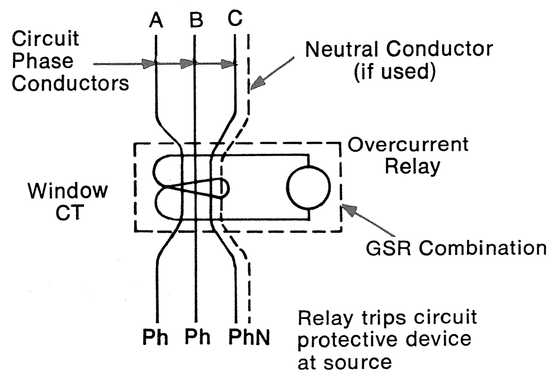


Figure 2-1: Window current transformer and overcurrent relay (GSR) combination monitoring ground-fault currents.

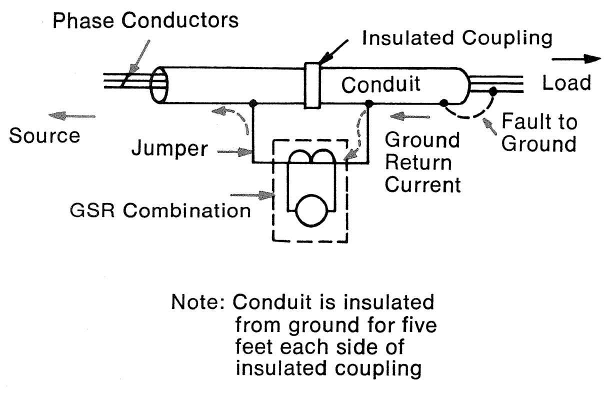


Figure 2-2: Detection of ground-fault current in return circuit of conductor enclosure.

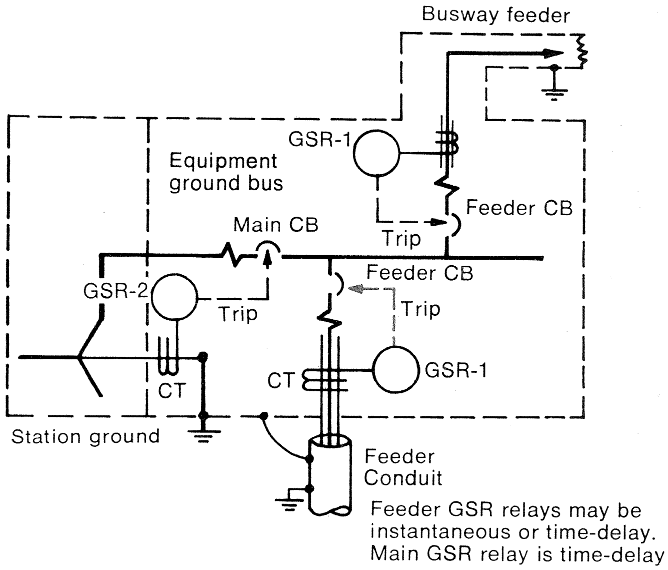


Figure 2-3: Ground-sensor relaying of unit substation and outgoing feeders.

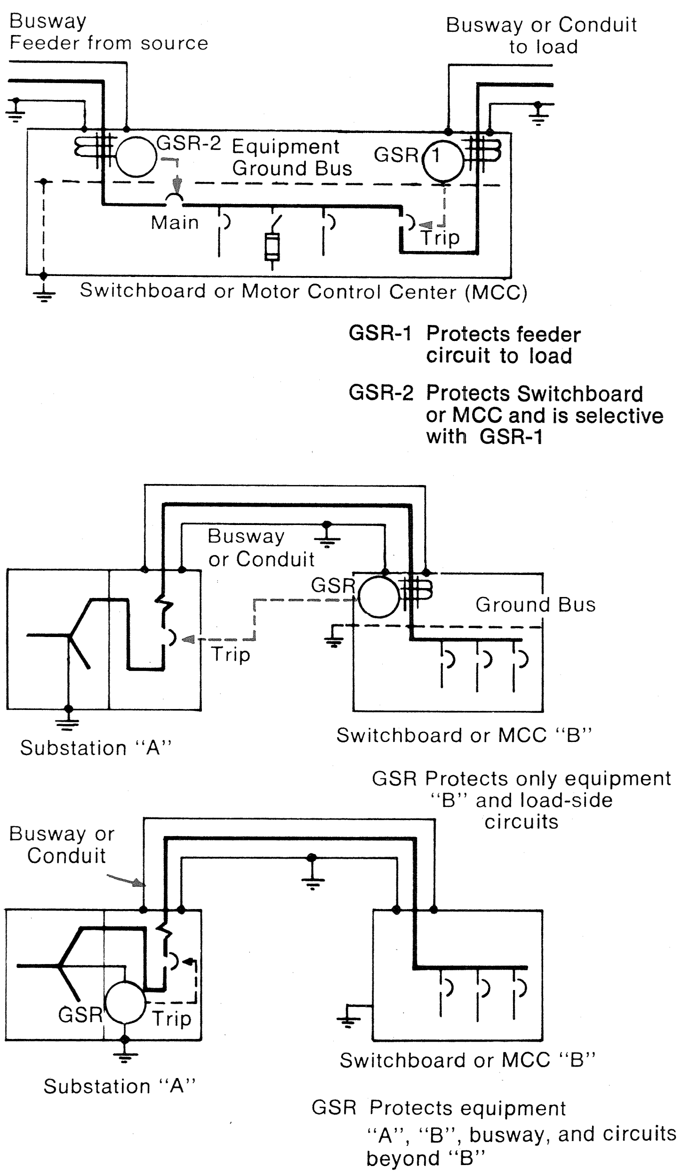


Figure 2-4: Application of ground-sensor relaying with various arrangements of equipment.

Application of GSR Relaying

Feeder Protection

Where feeder ground fault protection is desired, the arrangements in Fig. 2-3 are applicable. The GSR relays on the feeder circuits operate to trip their individual breakers on external ground faults. If selectivity with downstream protective devices on ground faults is not necessary, such as in a branch circuit, the feeder breaker GSR relay may be the instantaneous type, and have a sensitivity in the order of 15-amperes ground fault current. If a degree of selectivity is necessary with other GSR relays or with smaller phase-overcurrent devices downstream, it may be obtained with a time-delay GSR relay, through the proper combination of relay pickup and time-delay settings, or through zone selective interlocking.

To protect against equipment internal arcing faults to ground (i.e., those involving the main bus), a main breaker and time-delay GSR device in the transformer-neutral connection are required, as shown in Fig. 2-3. The main breaker GSR is set one-step slower than the slowest feeder breaker GSR. Thus, for external faults the main GSR relay waits for the feeder breaker GSR to clear the fault before tripping its breaker, and will provide back-up protection if for any reason the feeder breaker fails to clear the circuit.

On internal faults to ground, all of the ground fault current flows from the equipment enclosure through the main breaker GSR to the transformer neutral. After a timing-out interval the main breaker is tripped to extinguish the fault. In the absence of a secondary main breaker, the GSR can transfer-trip the primary metal-clad breaker.

Application Flexibility

To illustrate the flexibility in application which is available with low-voltage ground fault relaying, Fig. 2-4 has been included. This shows the use of one or two steps of GSR relaying to secure protection for individual or multiple sections of power distribution equipment. In each case, of course, a means of electrically tripping the associated circuit-protective device — as with a shunt-trip or undervoltage device — will be necessary. Also, from earlier comments regarding the desirability of prompt extinction of arcing faults, it should be apparent in all cases that effective application of the GSR relay requires the protective device to be fast-operating — such as a circuit breaker or shunt-tripped fusible switch — so as to provide fault-current interruption within a few cycles after receiving a trip signal from the relay.

Selectivity

Through the use of "standard" GSR relay combinations with minimum pickup values and operating times in the order of 300-400 amperes and .1 to .2 Secs. respectively, inherent selectivity with the smaller branch circuit fuses and circuit breakers (such as those used in lighting panelboards) may be obtained. Fig. 2-5 illustrates this.

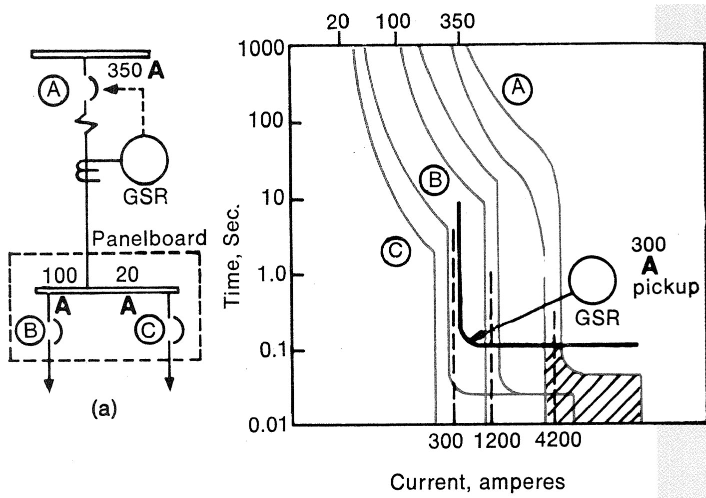
A 350-ampere low-voltage circuit breaker supplying a panelboard with 20-amp and 100-amp molded-case circuit breakers is shown in Fig. 2-5a. The time-current characteristics of the three circuit breakers are presented as curves A, B and C in Fig. 2-5b. Several observations of interest may be made.

First, at high short-circuit currents — above approximately 3800 amp — the instantaneous-trip characteristic of breaker 'A' overlaps that of breakers 'B' and 'C'. For short circuits beyond breakers 'B' and 'C', supply breaker 'A' may be tripped unnecessarily. It is recognized that the use of a low set short-time delay rather than an instantaneous-tripping element on breaker 'A' would avoid this nuisance-tripping problem, and in many cases would also significantly improve, even without supplemental ground fault relaying, the protection provided by breaker 'A' on the occurrence of ground faults. Nevertheless, the characteristic curves in Fig. 2-5b are representative of those frequently encountered in circuits of this type, and serve to illustrate the combined effect of GSR relaying and circuit breaker instantaneous-trip elements.

Secondly, in the absence of any ground fault protection at location A, arcing faults 3800 amperes or less in the panelboard or closer to breaker 'A' will be removed only after a considerable time delay by breaker 'A'. Extensive arcing fault damage to equipment, of course, can occur in the interval before breaker 'A' operates.

Finally, the addition of a low-set GSR relay combination at location A to furnish ground fault protection very markedly reduces the risk of arcing fault burndown in this circuit. The operating band of the GSR relay, including the breaker's tripping and clearing time, is labeled in Fig. 2-5b. The combined characteristic of the GSR relay and the breaker instantaneous trip is shown by the shaded area.

With a relay-pickup setting of 300 amp (less than the continuous rating of breaker 'A'), selectivity with the 20-amp circuit breakers is secured for arcing line-to-ground faults from 300 amp to 3800 amp, above which level the breaker 'A' instantaneous trip takes over. But *most important*, for arcing ground faults in this range the fault-clearing time of breaker 'A' is reduced from minutes to cycles, tremendously diminishing the arcing damage that would be incurred for such faults.



(b)

Figure 2-5: Protective characteristics with low-set GSR relay, showing selective co-ordination with 20-ampere panelboard breakers.

Sensitivity

The application of GSR ground fault protection will require a decision as to how sensitive the relay-pickup setting shall be, since maximum sensitivity may make it nonselective with downstream phase-overcurrent devices on low-level ground faults, resulting in nuisance tripping. In Fig. 2-5, for example, the low-set GSR relay will not be selective with 100-amp circuit breaker 'B' for ground fault currents between 300 and 1400 amperes. Ground fault current of this magnitude beyond breaker 'B' will cause breaker 'A' to trip via a signal from the GSR relay. Adding ground-sensor relaying at breaker 'B', of course, will avoid this nuisance tripping but may not be economically acceptable. Then the possible courses of action are to accept the non-selective operation (presently done for phase-overcurrent devices in many systems today) or to raise the GSR relay-pickup values. This latter procedure has been put into effect in Fig. 2-6.

In this figure, the decreased sensitivity of the GSR relay makes it completely selective with the phase-over-current trip devices on breakers 'B' and 'C' for ground faults beyond their terminals. Now, however, in contrast to the situation in Fig. 2-5b, the ground fault currents between 300 and 1400 amperes occurring beyond breaker 'B' will not be quickly removed, but must wait for the operation of the long-time-delay (thermal) element of breaker 'B' allowing severe damage to occur.

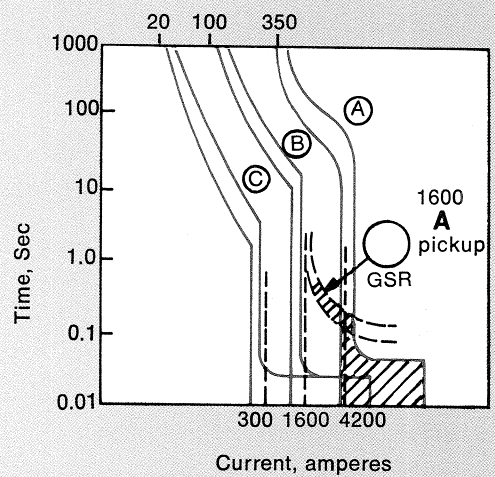
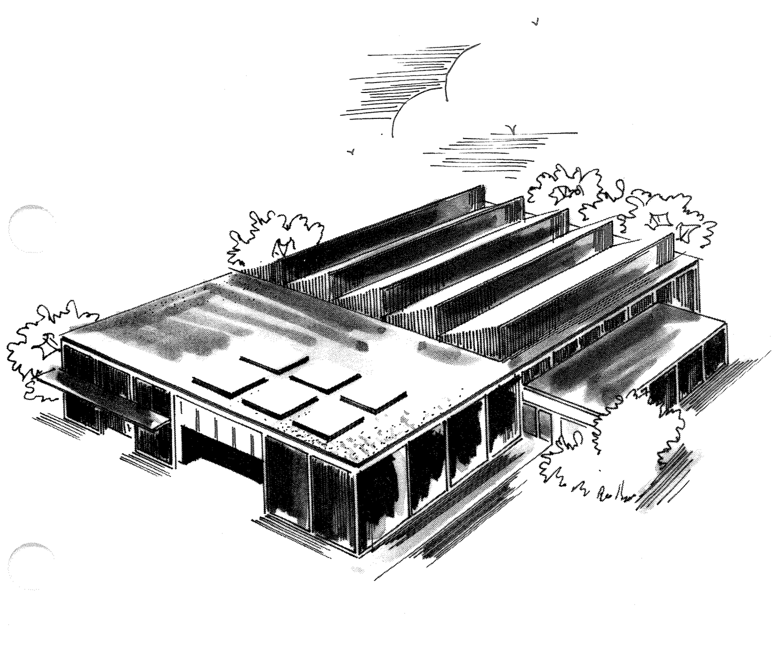


Figure 2-6: Obtaining selectivity of GSR relay with breaker B of Figure 2-5 by raising relay-pickup value.



A Choice of Alternatives

Figures 2-5 and 2-6 illustrate that raising the relay-pickup settings to avoid undesired tripping on low-current ground faults sacrifices the maximum protection these relays can provide against low-level arcing ground faults in their area of action. Thus, a choice of alternatives must be made when ground-sensor arcing fault protection is only partially applied throughout the distribution system: choosing GSR relay maximum sensitivity and minimum operating time provides maximum protection but may result in undesired tripping for low-level ground faults; selecting less-sensitive relay settings and increased operating time improves system service continuity but may lead to aggravated burning damage and possibly a more prolonged downtime should an arcing ground fault occur.

Ideally, of course, ground fault relaying should be applied at each circuit interrupter throughout the distribution system. Circuit and equipment protection and service continuity would be optimized since relay-pickup values and operating time would be set no higher than required for selective operation on ground faults. It will be a rare case, however, in which justification of complete system ground-fault protection can be shown. In particular, out at the outer fringes of the distribution system, where circuit ratings and protective devices are usually small, and where continuity of service generally is much less vital than at the main switchboards and substations, the risk of an occasional burndown due to an arcing ground fault may be accepted because the alternative of protecting every branch circuit is unacceptably costly. Of course, new product developments such as insulated case circuit breakers with Versatrip® Solid State tripping (GE Publication GET-6202) will make the desired protection economically more feasible. For the present, it can be expected that only the more vital and important of branch circuits will be equipped with instantaneous ground fault protection. The remaining branch circuits will rely on only their phase-overcurrent devices, such as circuit breaker, direct-acting trips or fuses.

Closer to the source, at the bulk power centers where continuity of service is essential and the risk of burndowns must be minimized, time-delay ground fault relaying on the feeder circuits will be imperative.

A Recommendation

As a practical matter (as explained above), electrical distribution systems will have only partially complete ground fault relaying, and the system designer will generally have to choose between the alternatives noted in a preceding paragraph. Only the system designer thoroughly familiar with the electrical system in question and the loads it supplies can make the "correct" decision between these tempting alternatives, weighing service continuity against protection, and the risks of false tripping against the hazards and costs of equipment burndowns. Naturally, no single suggestion can be made to cover all situations, but the recommendation can be offered that in choosing alternatives it is better to favor sensitive relay settings and the occasional problem of undesired tripping, rather than high-set relay pickups and the risk of total equipment burnout.

Ground Break® Systems

III

General Description

The General Electric Ground Break system provides protection for systems in addition to that provided by the conventional phase over-current protective devices. The Ground Break system can be set to operate at lower magnitudes of ground fault current and shorter time delays than conventional overcurrent protective devices by responding only to ground currents, thus providing a greater degree of protection than would otherwise be possible.

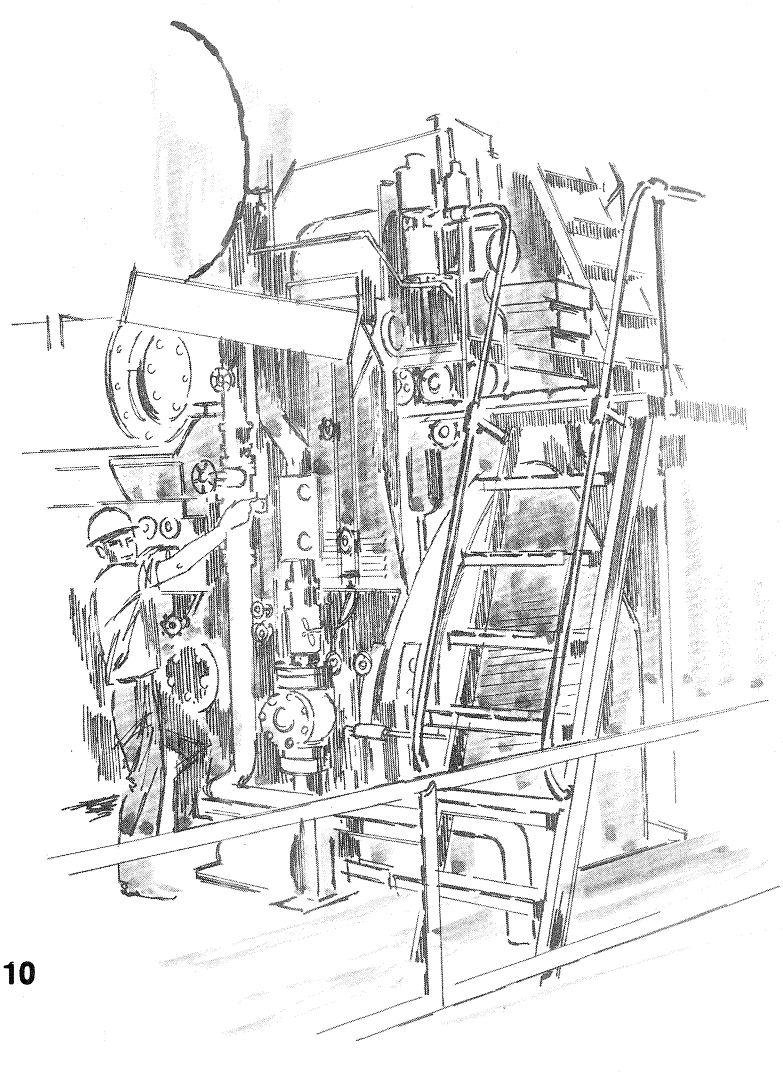
The Ground Break System also includes a Monitor Panel which provides the functions of ground fault indication, system testing and system reset.

Figure 3-1: Ground Break Components

In a typical application, a ground fault produces a signal in a special window-type current transformer called a GROUND BREAK SENSOR. Sensor can be applied so as to measure the main circuit ground fault current directly as it returns to the power source by encircling only the equipment ground conductor. **This application is called ground strap method.** To measure the ground fault current of any circuit indirectly as the vectorial unbalance of current in the phase and neutral conductors, encircle all the phase and neutral conductors, but not the equipment ground conductor. **This application is called zero sequence method.**

The output signal of the sensor is fed to a GROUND BREAK RELAY which is adjustable for current pick-up and time delay. The relay integrates the signal from the sensor. If the signal is greater than the preselected settings (current and time) the relay completes a control power circuit to a shunt trip installed in the circuit protective device, thereby tripping that device.

The relay will remain ON (latched) to continue energizing any ground fault signaling devices. The relay should not be reset until the cause of the ground fault has been investigated and cleared. Only after the relay is reset, by operating the Monitor Panel reset pushbutton, will it be possible to successfully reclose the breaker/interrupter.



The Ground Break Monitor Panel is an integral part of any complete Ground Break system. In addition to the functions of ground fault indication, control power indication and reset after ground fault trip, it is provided with circuitry which can test the complete Ground Break system with or without tripping the protective device. This test feature is easy to use, uncomplicated and foolproof. The Monitor Panel test is not just a test of the electronics but a true test of the response of the system to a ground fault.*

*Ground Break Monitor Panel produces a 1600 ampere ground fault in test mode.

GROUND BREAK RELAY

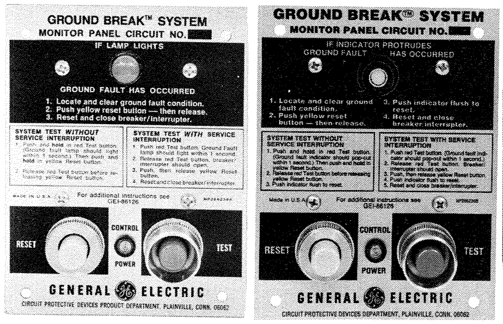


Figure 3-2

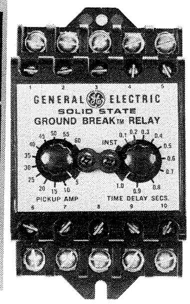


Figure 3-3

The Ground Break series of relays are hybrid devices. They combine the precision, speed, reliability and intelligence of solid state electronic sensing with the isolated switching capabilities of electromechanical devices. Relays are used in conjunction with a circuit protective device having a shunt trip. The relay, with its sensor, will detect ground currents and cause the circuit protecting device to open (or activate a signalling device) when these currents reach preselected values. Optional zone selective interlocking provides instantaneous tripping in each protected zone, and time delay back-up protection between zones for a fully coordinated and selective system. Three pick-up current ranges are available: continuously adjustable ranges of 2-12, 5-60; or 100-1200 amperes. The relays also have a continuously adjustable time delay range of Instantaneous (0.03) to 1.0 seconds. The time delay characteristic is shown on page 26. Once settings have been selected, adjusting knobs can be clamped in position by means of the clamping bar on the face of the relay. (Fig. 3-3).

Because of the highly intermittent and erratic nature of arcing ground faults, a memory circuit has been incorporated in the Ground Break relay which integrates intermittent faults with time.

In the following diagrams it can be seen how the memory function works. Diagram 3-4A shows a typical ground fault with half cycle, whole cycles and multiple cycles missing as normally occurs. Diagram 3-4B shows trip response of a typical ground fault relay which does not include a memory function. The relay never trips because the time delay circuits are reset with every missing cycle. Diagram 3-4C shows response of the Ground Break relay to the same ground fault, the relay's memory carries thru the missing cycles and generates a trip signal after the preset time delay.

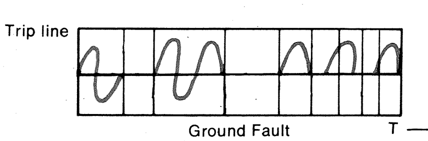


Figure 3-4A

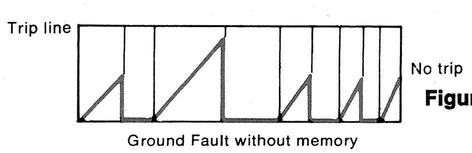


Figure 3-4B

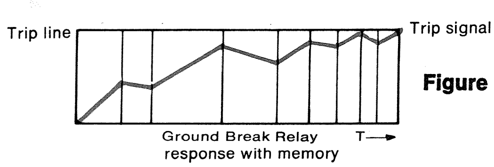


Figure 3-4C

TIME COORDINATION

The standard means of obtaining ground fault selectivity between main and feeder breakers is by incorporating time-coordinated GROUND BREAK relays in the system. This consists of setting the furthest downstream Ground Break Relay with a small time delay, progressively increasing the time delay, as you get closer to the main protective device. The main device must have the longest time delay in the ground fault system. See chart for recommended settings for devices with clearing time of less than .04 sec.

Zone Selective Interlocking Type Z Coordination

Another means of obtaining selectivity that offers advantages over time coordination is Zone Selective Interlocking. (Type Z) The main purpose of ground fault protection is to detect low level arcing faults. However, one disadvantage of the time coordination method is that for minor ground faults "downstream", the main device may trip. To preclude this, a time delay is normally introduced, but at a sacrifice in the degree of protection, except in the Zone Selective System.

In the Zone Selective Interlock system, the relay farthest downstream (farthest from the power source) which senses the fault initiates tripping of its protective device and sends a signal to all "upstream" relays to block them from tripping. The "upstream" (closer to the power source) relays respond to a fault in a "downstream" zone by timed tripping. Timed tripping provides backup protection for the downstream devices.

For ground faults in their own zones, Ground Break Zone Selective relays respond by tripping instantaneously to minimize equipment damage. See Fig. 3-5.

Zone Selective Interlocking can be illustrated by considering a system with two zones. The main breaker is set to trip after a time delay as a backup to feeder breakers. The main breaker will trip instantaneously, however, for a ground fault in its zone regardless of its time dial setting.

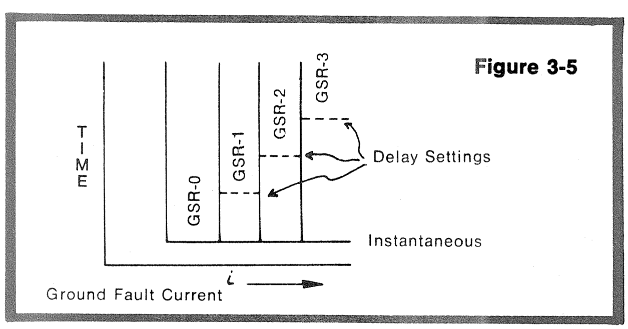


Figure 3-5

SYSTEM OPERATION

Recommended Settings for Standard or Type "Z" Relays

Ground Break relay settings of pick-up current and time-delay for main, feeder and branch circuits should be selected so as to provide optimum ground fault protection and coordination with the conventional overcurrent devices in the distribution system. Since the ratings of the conventional devices will vary with application, no general statement can be made. However, the following recommendations are basic for satisfactory performance of most systems.

Recommended ground fault current pick-up values are shown in Table 3-6 for various equipments or locations within a system. Maximum relay operating times should be in the area of maximum 0.2 sec. (12 cycles) to 0.4 sec. (24 cycles) to minimize damage. The longer times should only be used where necessary for selectivity with downstream devices or ground relays. Note that with Zone Selective Interlocking, time settings on a main device apply only to backup protection, as this relay picks up instantaneously for a fault in its own zone.

The standard GROUND BREAK relay has time and current pickup settings that can be adjusted to provide selectivity between GROUND BREAK relays at different levels in the same system. These relays are designated GSR-1, GSR-2, and GSR-3, with higher suffix numbers indicating increasing time-delay. The instantaneous GSR is designated GSR-0. For larger feeders or mains the suggested minimum pick-up for a GSR-1 is 400 amperes. This provides selectivity on ground faults between the GSR system and 20 ampere lighting and appliance branch circuits.

Table 3-6

RECOMMENDED CURRENT PICK-UP VALUES

Area	Current Magnitude
Individual Motor Circuits	5-60 A
Panelboards, Motor Control Centers, Feeder Circuits to Busway Risers, Multiple Panels or Other Feeders	200-800 A
Main Services	400-1200 A

One of the steps necessary to assure selectivity between GSR-1, 2 and 3, is to increase the pick-up values of the relays a minimum of 100 amperes (5 amperes, for 5 to 60A relay) per step. For example, a GSR-1 set at 400A pick-up should be backed up with a GSR-2 set at 500 amp pick-up, with an appropriate time setting to obtain selectivity.

The coordination curves between GSR-1, GSR-2, GSR-3 and GSR-0 for a particular system plus recommended pick-up and time settings are shown in Fig. 3-9, and Table 3-7. Table 3-8 gives the recommended GSR designations for desired location in any given system.

Table 3-7

TABLE OF PICK-UP SETTINGS AND TIMES FOR FIGURE 3-9

Device	GSR-3 D		GSR-2 E		GSR-1 F		GSR-0 G	
	Pick-Up	*Time	Pick-Up	*Time	Pick-Up	*Time	Pick-Up	*Time
Main A	800A	0.3						
Feeder B			500A	0.2				
Sub-Feeder C					400A	0.1		
Branch H							25A	0.03†

* Relay Operating Time in Seconds
† Inst. Setting

Table 3-8

RECOMMENDED GROUND SENSOR RELAYS

Desired Location of GSR	Recommended GSR		
	M	F	SF
M	GSR-1		
M+F	GSR-2	GSR-1	
M+ F + SF	GSR-3	GSR-2	GSR-1

M=Main F=Feeder SF=Sub-feeder

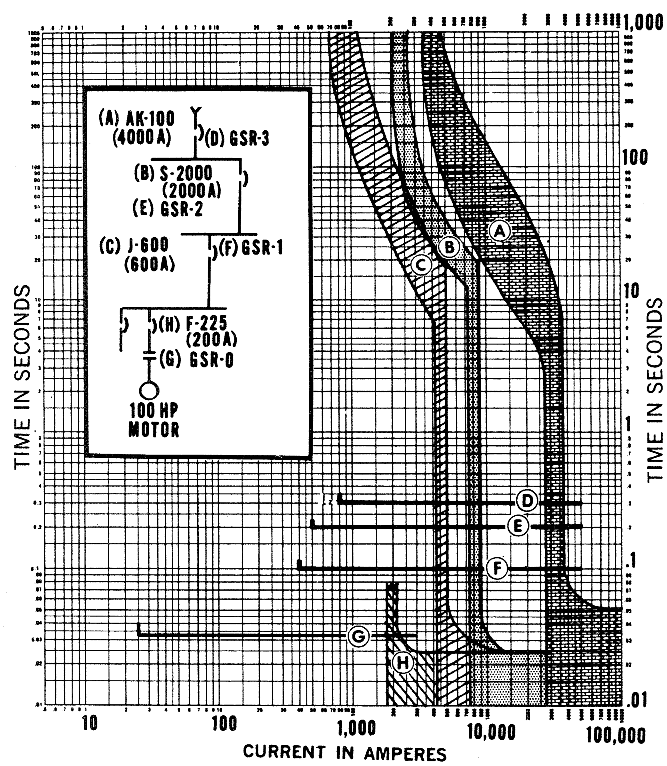


Figure 3-9: Typical system showing device coordinating curves, and GSR selectivity, using GROUND BREAK.

CONTROL VOLTAGE

Ground Break Systems are designed for 24, 36, 48, 125V dc and 120, 120/208-120/240V ac.

All Ground Break Relays are provided with two normally open contacts as standard. One of these contacts is tied to one control power terminal on the relay, the second is totally isolated so that it may be used for electrical interlocking of relays or for other control voltages. Both contacts are rated 5 amperes continuous and 30 amperes inrush at any of the above voltages.

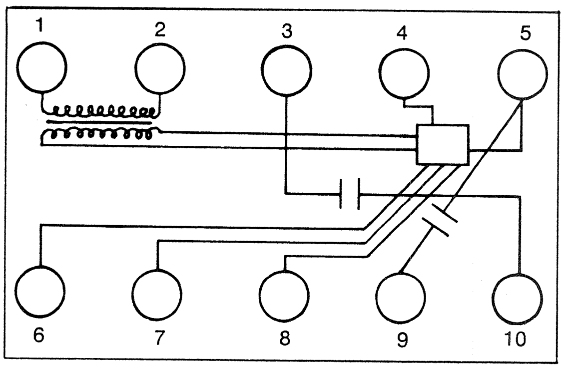


Diagram of relay terminals and line drawing of contacts and electronics.

MONITOR PANELS

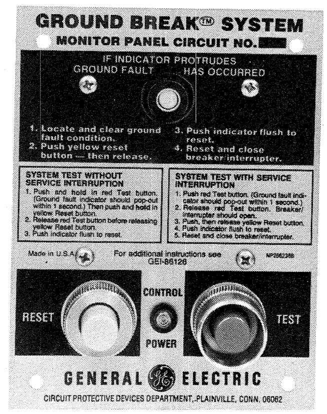
A flush mounted monitor panel is a component part of the Ground Break system. It provides the functions of monitoring and testing the Ground Break system.

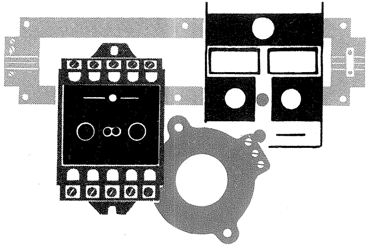
A pilot light is provided to indicate presence of control power. If the pilot light is "out", control power fuses and circuit should be checked.

There are two pushbuttons provided — red, marked "Test and yellow, marked "Reset". The ground fault lamp (red) lights or the mechanical indicator pops out, to show that the Ground Break relay has operated to trip a breaker/interrupter. The reset button must be pushed to reset the relay after the fault has been located before the breaker/interrupter can be successfully reclosed.

The monitor panel has the ability to test the complete ground break system with or without tripping the circuit protective device. Instructions for performing tests are printed on the face plate.

During the few seconds of each test operation, the monitor panel energizes the sensor test windings. This energy requirement dictates the use of a control power source of at least 250 VA. The test signal simulates a ground fault of approximately 1600 amperes. (For other test currents see section on System Testing.)





Ground Break®
Component Specifications

GROUND BREAK SENSORS

Current Transformer Ratio — 800:1 Except Type TGM

Integral Test Winding Ratio — 1:700 Except Type TGM

Thermal Rating —
- TGM Sensors — 600 Amperes
- TGS0002 — 1600 Amperes
- TGS0005 — 2500 Amperes
- TGS0408 and TGS0808 — 4000 Amperes
- All other sensors — 3000 Amperes

(Thermal rating is the maximum *continuous*, current which can exist without overheating the sensor)

SYSTEM WITHSTAND RATINGS		
	TGS-TGSR	TGM-TGMR
Maximum Primary Short Circuit Current rating (thru fault current Sym)	200,000 A	50,000 A
Maximum Ground Fault Current Ratings	200,000 A 0.1 sec. 60,000 A 1.0 sec.	35,000 A 0.1 sec. 12,000 A 1.0 sec. 5,000 A 5.0 sec.

Dielectric
- Windings to mtg. bushings — 1.5 kV
- Windings to CT window surface — 2.2 kV
- Mounting bushings to CT window surface — 2.2 kV

Insulation — Cast Epoxy all sizes

Sensor Construction

Model	Inside Dimensions	Type
TGS0002	2.5″ dia.	Solid Core
TGS0005	5″ dia.	Solid Core
TGS0008	8″ dia.	Solid Core
TGS0808	8″ x 8″	Split Core
TGS0810	8⅜″ x 10⅜″	Split Core
TGS0818	8″ x 18″	Split Core
TGS0808A	8″ x 8	Split Core
TGS0808S	8⅜″ x 8⅜″	Solid Core
TGS1113	11″ x 13″	Split Core
TGS0824	8″ x 24″	Split Core
TGS0832	8″ x 32″	Split Core
TGS0838	8″ x 38″	Split Core
TGS0418	4″ x 18″	Split Core
TGS0424	4″ x 24″	Split Core
TGS0432	4″ x 32″	Split Core
TGS0408	4″ x 8″	Split Core

Sensors may be used 1 per phase or any other combination. For this type of use all outputs except "T" should be connected in parallel. When sensors are used more than 1 per circuit the thermal rating (current) must not be less than the maximum phase current.

Sensors For Use With TGMR Relays Only

Model	Inside Dimensions	Type
TGM0002	2.5″ dia.	Solid Core
TGM0005	5″ dia.	Solid Core
TGM0008	8″ dia.	Solid Core

Sensor Turns Ratio 160:1
Test Winding 80 Turns

GROUND BREAK RELAYS

120V a-c & 125V d-c, 5 A Output

Adjustable Trip Range Amperes LO	Adjustable Trip Range Amperes HI	Relay and Shunt Trip Voltage	Cat. No. Without Zone Selectivity	Cat. No. With Type Z Zone Selectivity
2	12	120/240 VAC	TGMR1	. . . . .
2	12	125 VDC	TGMR1	. . . . .
2	12	48 VDC	TGMR1B	. . . . .
2	12	32 VDC	TGMR1C	. . . . .
2	12	24 VDC	TGMR1D	. . . . .
5	60	120/240 VAC	TGSR06	TGSR06Z
5	60	125 VDC	TGSR06	TGSR06Z
5	60	48 VDC	TGSR06B	TGSR06BZ
5	60	32 VDC	TGSR06C	TGSR06CZ
5	60	24 VDC	TGSR06D	TGSR06DZ
100	1200	120/240 VAC	TGSR12	TGSR12Z
100	1200	125 VDC	TGSR12	TGSR12Z
100	1200	48 VDC	TGSR12B	TGSR12BZ
100	1200	32 VDC	TGSR12C	TGSR12CZ
100	1200	24 VDC	TGSR12D	TGSR12DZ

Tolerance: ±10%, but not exceeding 1200A.

Time Delay: Adj. Inst. to 1.0 sec. max.
Calibration: ±10% Refer to GES-6135

Ambient Temperature Range: −35°C to 80°C

Control Power (Nom.)
- 120V ac
- 120/208V ac, 120/240V ac
- 24, 36, 48, 125V dc

Nom. power dissipation — 1 watt

Maximum power dissipation (Relay tripped) (excluding aux. devices) — 2 watts

Output — 2 normally open contacts *each* rated

	Continuous	Inrush
240V ac Max.	5A	30A
125V dc Max.	5A	30A

Open Contact Breakdown Voltage—2000 VAC RMS

Dielectric (all relay terminals shorted) terminals to ground 1500V rms

Relay Reset by disconnecting control power

Zone Selective Interlocking

Type Z —
Instantaneous trip, convertible to time delay trip by signal from a downstream Type Z relay.

Other —
All Ground Break relays incorporate a memory function which permits the relay to properly interpret the cumulative effect of an intermittent ground fault. Memory time constant 7 sec.

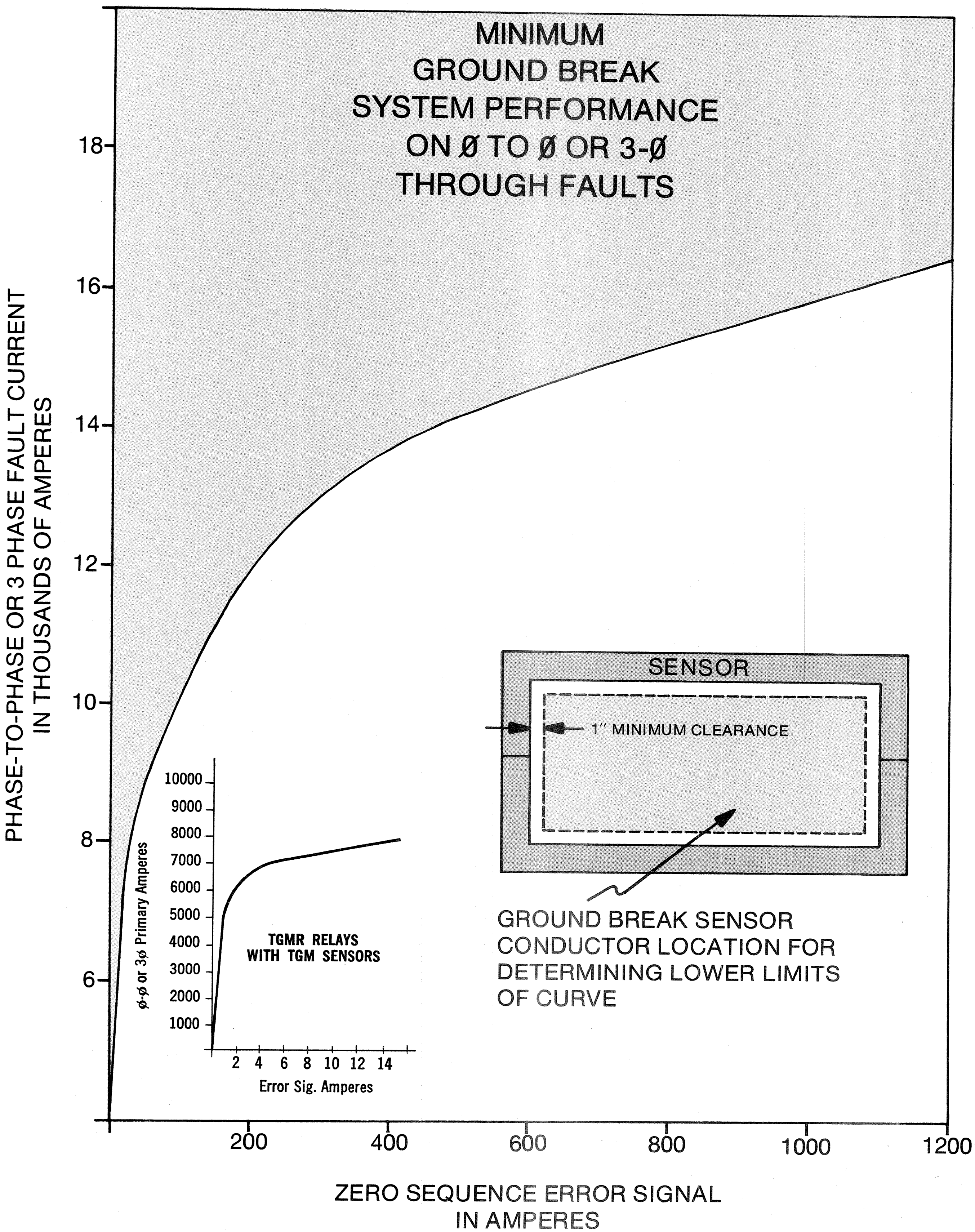
MONITOR PANELS

Function — Control power indicator light
Ground fault trip indicator
Ground Break System Reset Button
Ground Break System Test Button

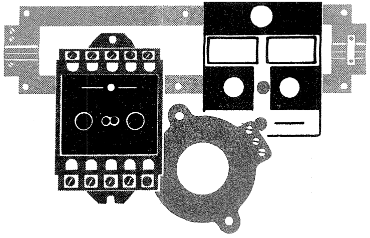
Test Function — Control power 120V ac, 250 Va during short test period is required. Simulates 1600 amperes ground fault during test (TGSR relays) and 190 amperes (TGMR relays).

Ground Break System Control Voltage

Monitor Panel: With GF Indicator Light	Monitor Panel: With GF Mechanical Indicator	Relay Control Voltage
TGSMP	TGSMA	120V ac, 120/208V ac 120/240V ac
TGSMPA	. . . . .	125V dc
TGSMPB	. . . . .	48V dc
TGSMPC	. . . . .	36V dc
TGSMPD	. . . . .	24V dc



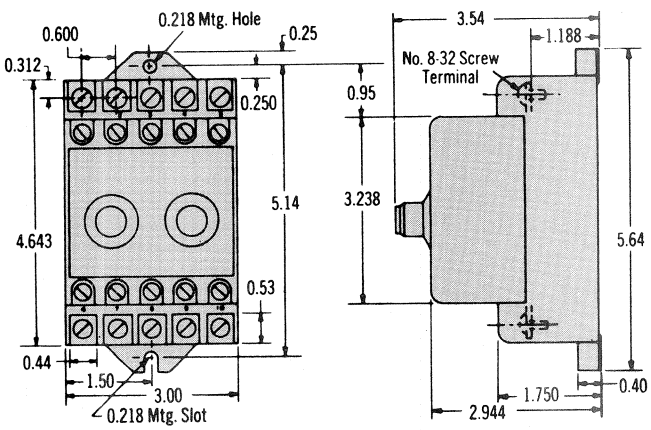
MINIMUM
GROUND BREAK
SYSTEM PERFORMANCE
ON Ø TO Ø OR 3-Ø
THROUGH FAULTS
PHASE-TO-PHASE OR 3 PHASE FAULT CURRENT
IN THOUSANDS OF AMPERES
18
16
14
12
10
8
6
200
400
600
800
1000
1200
ZERO SEQUENCE ERROR SIGNAL
IN AMPERES
SENSOR
1″ MINIMUM CLEARANCE
GROUND BREAK SENSOR
CONDUCTOR LOCATION FOR
DETERMINING LOWER LIMITS
OF CURVE
Ø-Ø or 3Ø Primary Amperes
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
TGMR RELAYS
WITH TGM SENSORS
2 4 6 8 10 12 14
Error Sig. Amperes



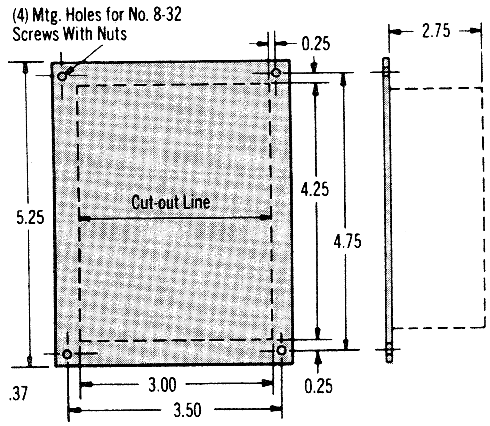
Specifications

OUTLINES (All dimensions are in inches)

Relay and Monitor Panel

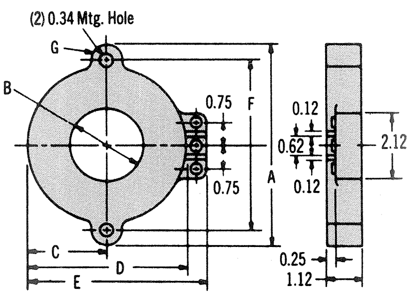


Relay

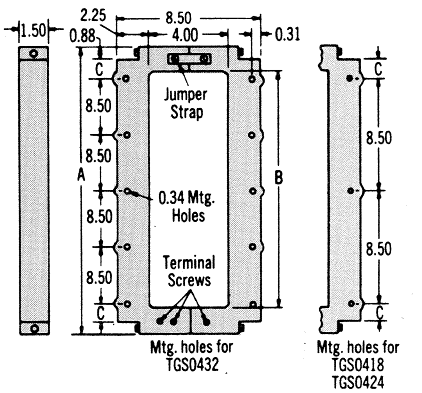


Monitor Panel (Flush-mounted)

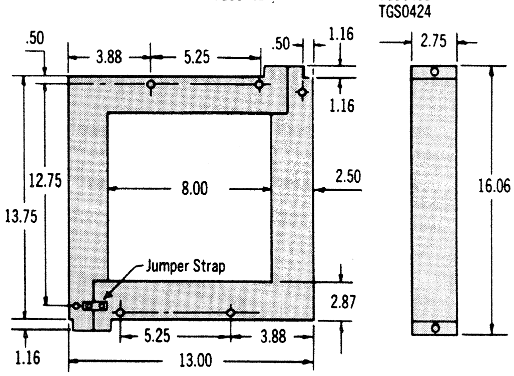
Sensors



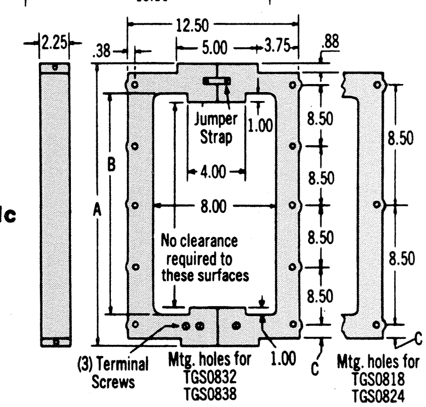
4-1a



4-1b



4-1c



Round Sensor Dimensions (inches)

Cat. No.	A	B	C	D	E	F	G
TGM0002/TGS0002	6.62	2.50	2.56	5.12	5.75	5.62	0.50
TGM0005/TGS0005	9.50	5.00	3.94	7.88	8.50	8.50	0.50
TGM0008/TGS0008	12.75	8.00	5.44	10.88	11.50	11.50	0.62

Rectangular Sensor Dimensions (inches)

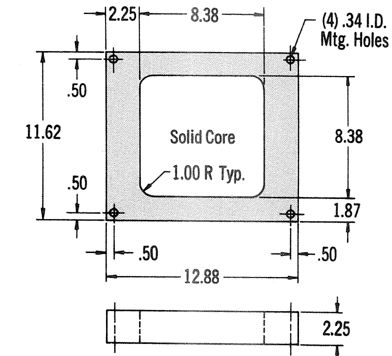
Cat. No.	No. of Mfg. Holes	A	B	C	Fig. No.	Cat. No.	No. of Mfg. Holes	A	B	C	Fig. No.
TGS0418	6	23.25	18.00	2.12	1a	TGS0818	6	23.25	18.00	2.12	1c
TGS0424	6	29.25	24.00	5.12	1a	TGS0824	6	29.25	24.00	5.12	1c
TGS0432	10	37.25	32.00	0.62	1a	TGS0832	10	37.25	32.00	0.62	1c
TGS0808	6	See Outline Dwg.			1b	TGS0838	10	43.25	38.00	3.62	1c

GROUND BREAK® SENSORS

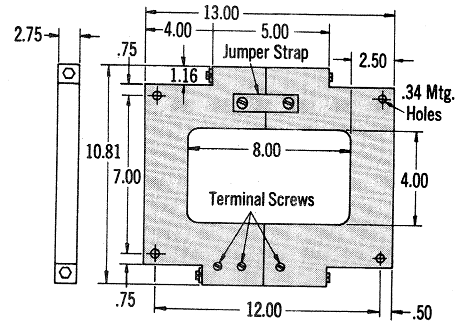
Cat. No.	Window Size	Type Core	Weight
ROUND (Solid Core)			
TGS0002	2½ in. I.D.	Solid	3 lbs
TGS0005	5 in. I.D.	Solid	4 lbs
TGS0008	8 in. I.D.	Solid	7 lbs
TGM0002	2½ in. I.D.	Solid	3 lbs
TGM0005	5 in. I.D.	Solid	4 lbs
TGM0008	8 in. I.D.	Solid	7 lbs
RECTANGULAR (Split Core)			
TGS0408	4 x 8 in.	Split	15 lbs
TGS0418	4 x 18 in.	Split	18 lbs
TGS0424	4 x 24 in.	Split	21 lbs
TGS0432	4 x 32 in.	Split	25 lbs
TGS0808	8 x 8 in.	Split	25 lbs
TGS0808S	8⅜ x 8⅜ in.	Solid	20 lbs
TGS0810	8⅜ x 10⅜ in.	Split	25 lbs
TGS0818	8 x 18 in.	Split	31 lbs
TGS0824	8 x 24 in.	Split	37 lbs
TGS0832	8 x 32 in.	Split	50 lbs
TGS0838	8 x 38 in.	Split	57 lbs
TGS1113	11 x 13 in.	Split	25 lbs
TGS0808A	8 x 8 in.	Split	20 lbs

Rectangular Sensor Dimensions (Inches)

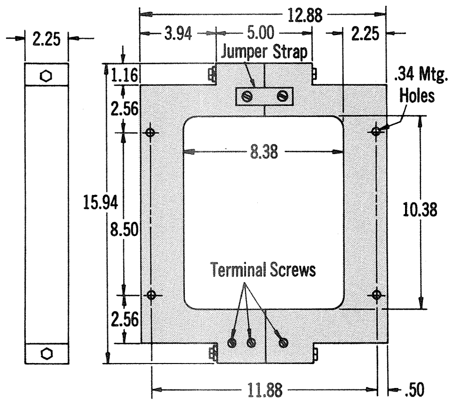
Cat. No.	No. of Mfg. Holes	A B C	Fig. No.
TGS0408	4	See Outline Drawing	1e
TGS0808S	4	See Outline Drawing	1d
TGS0810	4	See Outline Drawing	1f
TGS1113	4	See Outline Drawing	1g



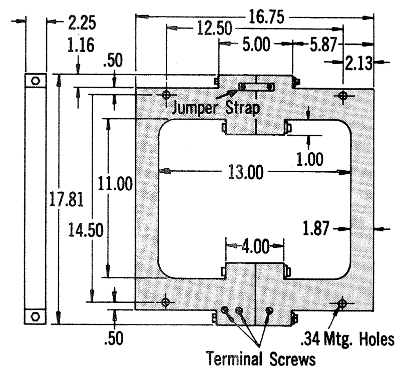
4-1e



4-1d

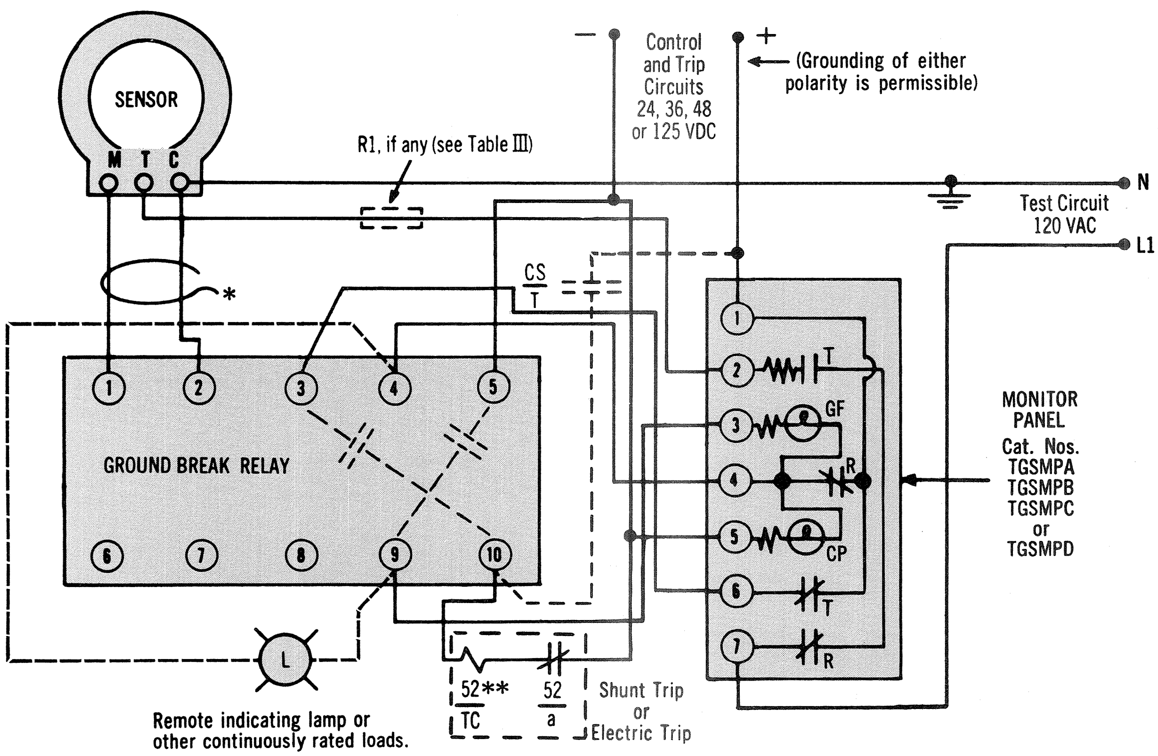


4-1f



4-1g

Connection Diagrams



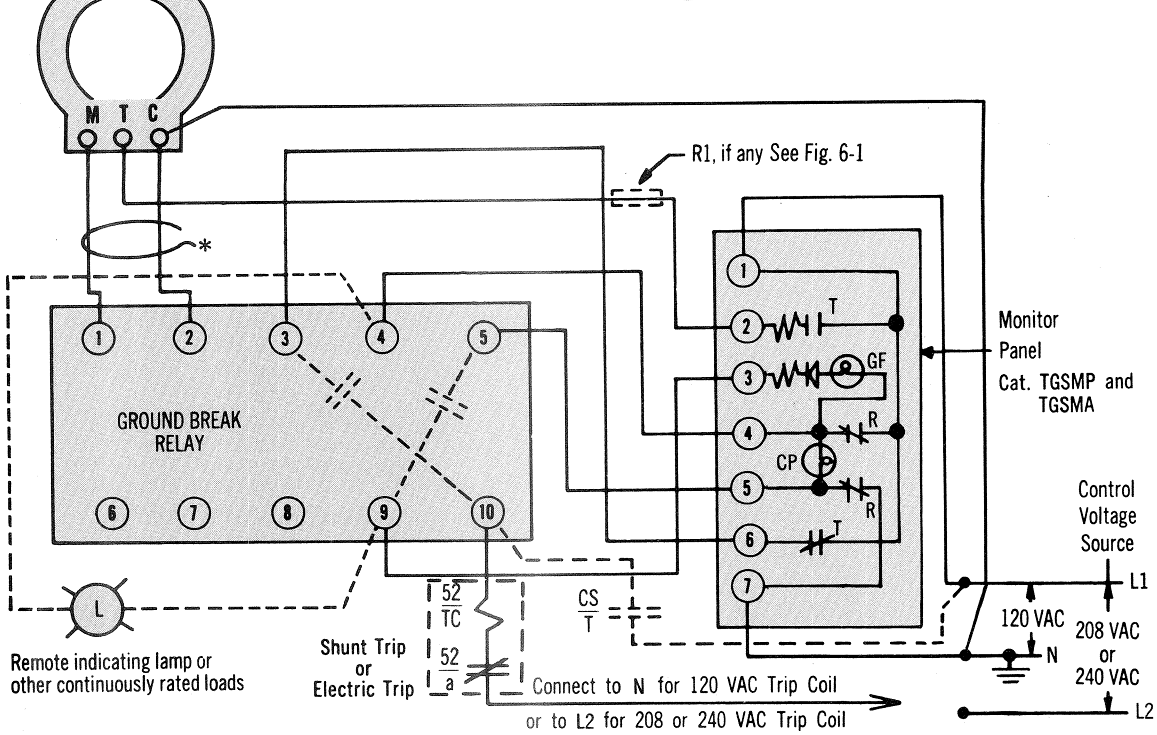
*Wires, #14 AWG min., routed together for 100 ft. max. run. Wires should not be harnessed with power conductors.

**Same voltage rating as DC control circuit

Wiring diagram for Ground Break Relay and Monitor Panel using dc control voltage

Figure 4-2

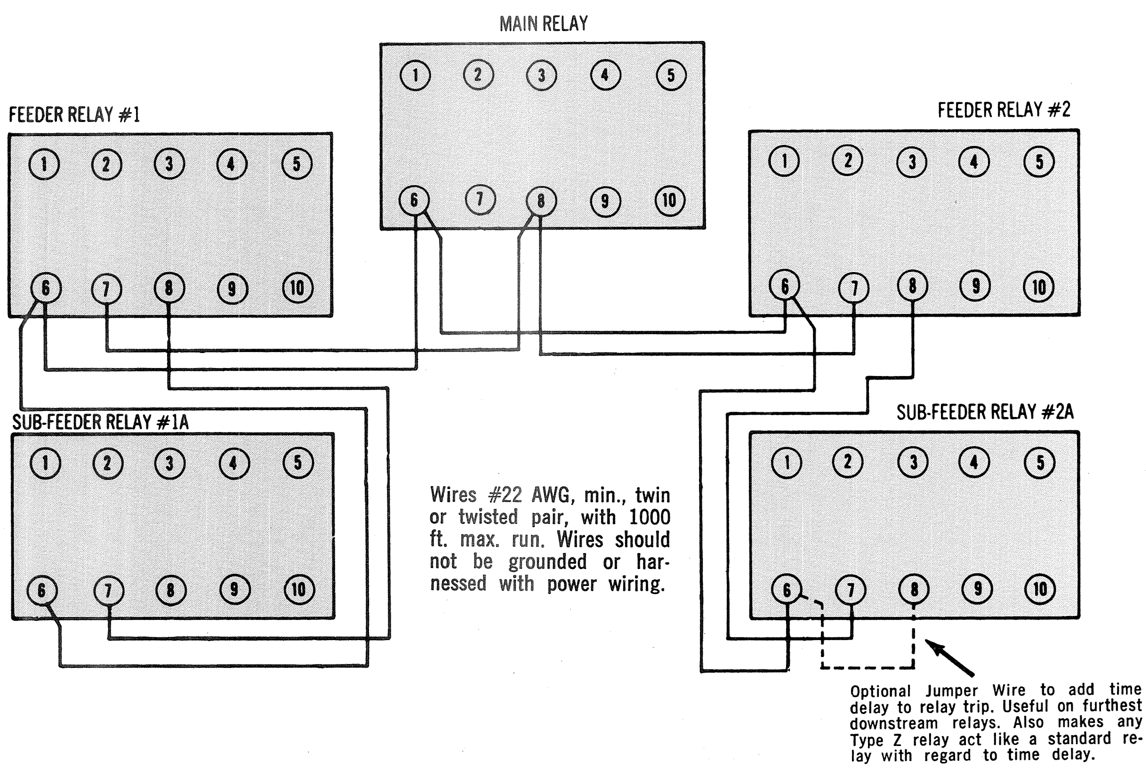
Connection Diagrams (continued)



*Wires, #14 AWG min., routed together for 100 ft. max. run. Wires should not be harnessed with power conductors.

Wiring diagram for Ground Break Relay and Monitor Panel using ac control voltage

Figure 4-3



Typical Zone Selective Interlocking Connections for a system having a main protective device and two feeders, with each feeder having a sub-feeder.

Figure 4-4

*Wires, #14 AWG min., routed together for 100 ft. max. run. Wires should not be harnessed with power conductors.

**The function of S3 is to inactivate the Trip Coil, if desired during the Test function and until after Reset has been accomplished.

***Other values of R1, if used, will simulate ground faults as shown in Fig. 6-1.

Note:
All switches should be momentary spring-return type.

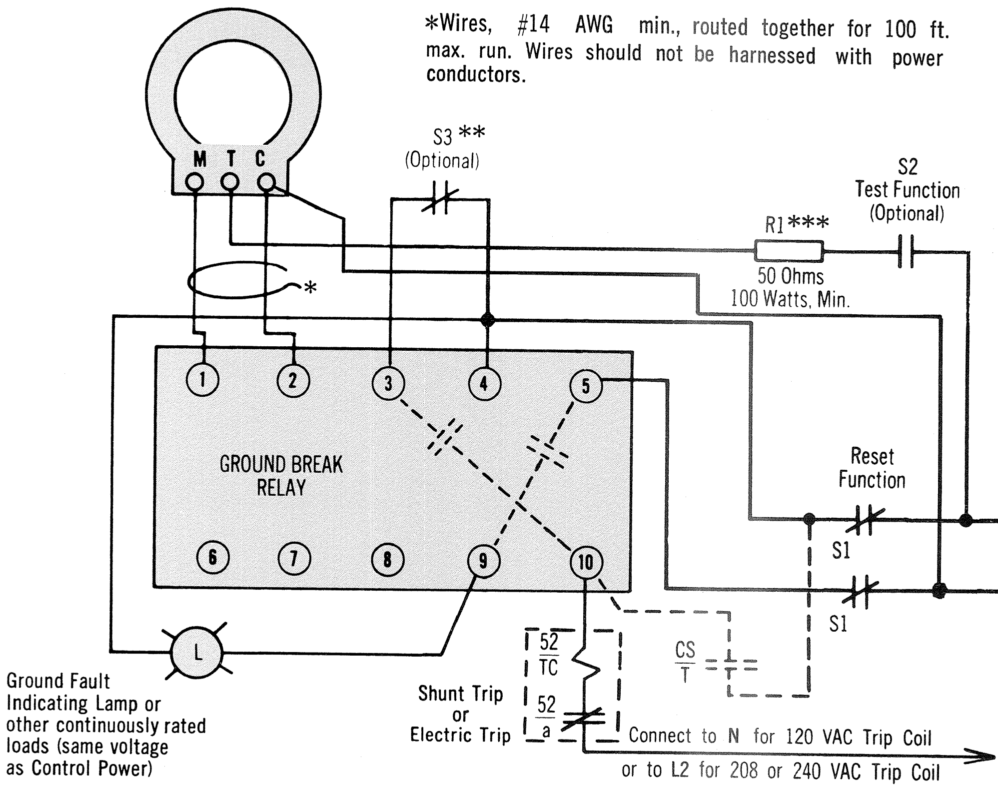
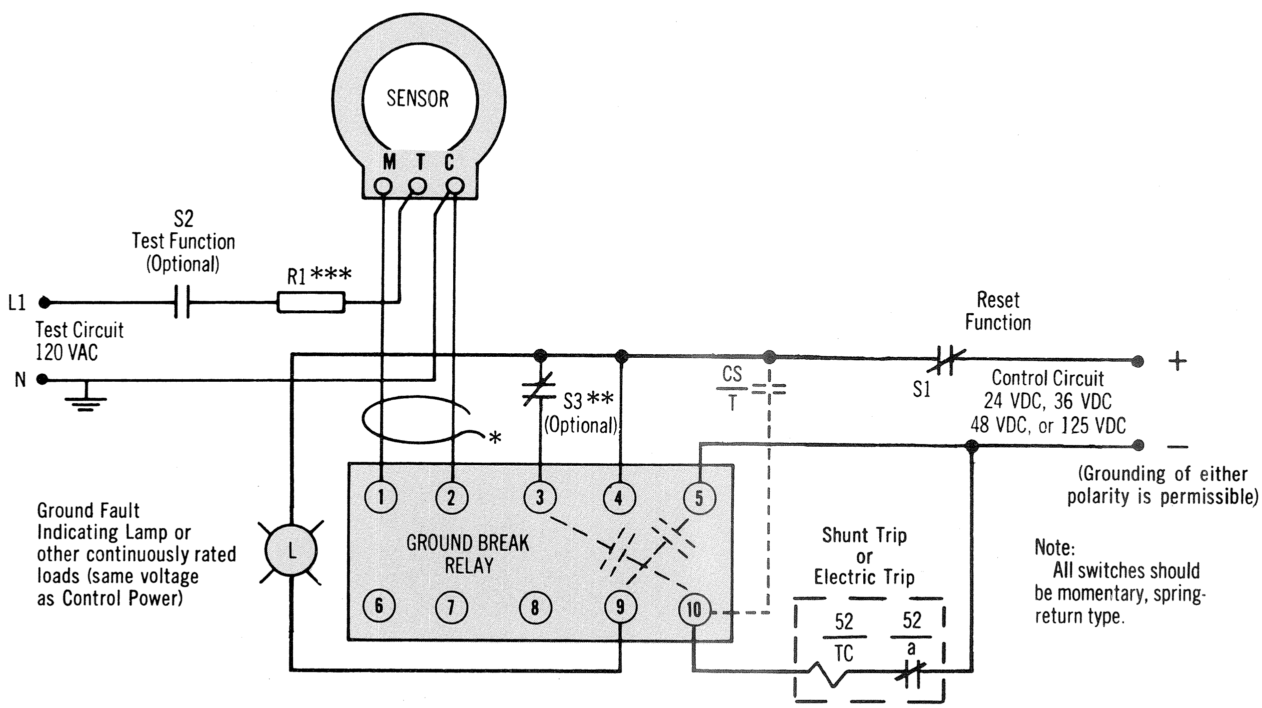


Figure 4-5

Wiring Diagram for Ground Break without Monitor Panel using ac Control Voltage.



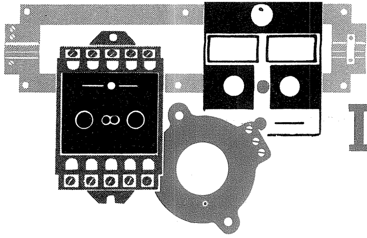
*Wires, #14 AWG min., routed together for 100 ft. max. run. Wires should not be harnessed with power conductors.

**The function of S3 is to inactivate the Trip Coil, if desired, during the Test function and until after Reset has been accomplished.

***Other values of R1, if used, will simulate ground faults. See Fig. 6-1

Figure 4-6

Wiring Diagram for Ground Break without Monitor Panel using dc Control Voltage.



IV Application Tips

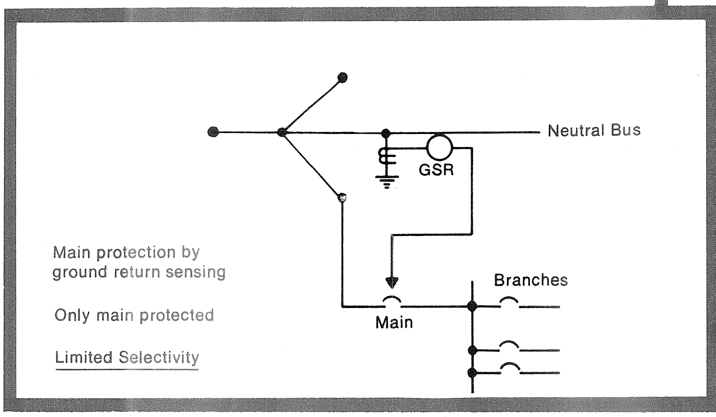


Figure 5-1

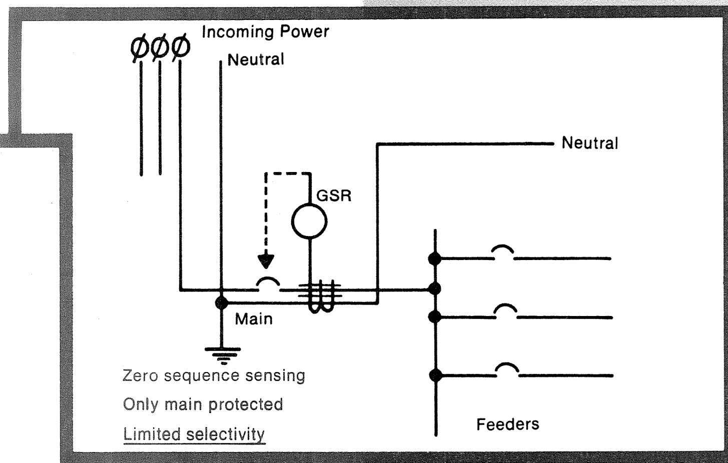


Figure 5-4

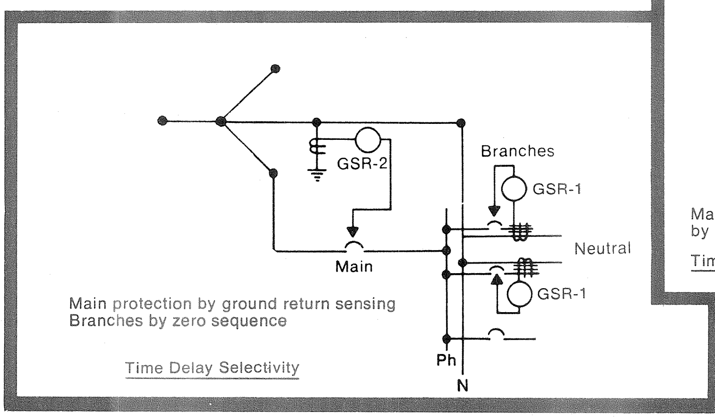


Figure 5-2

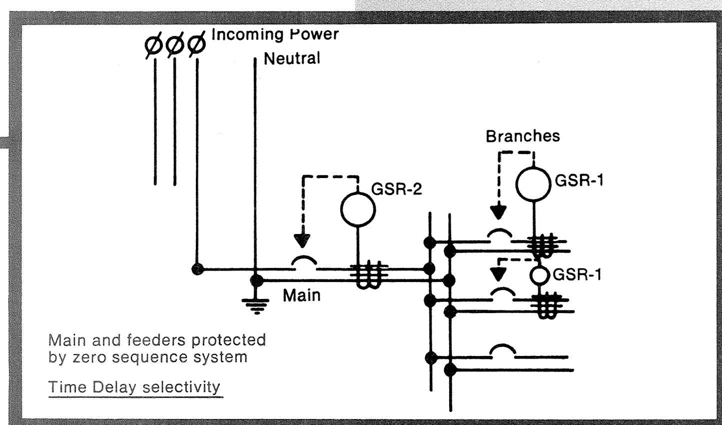
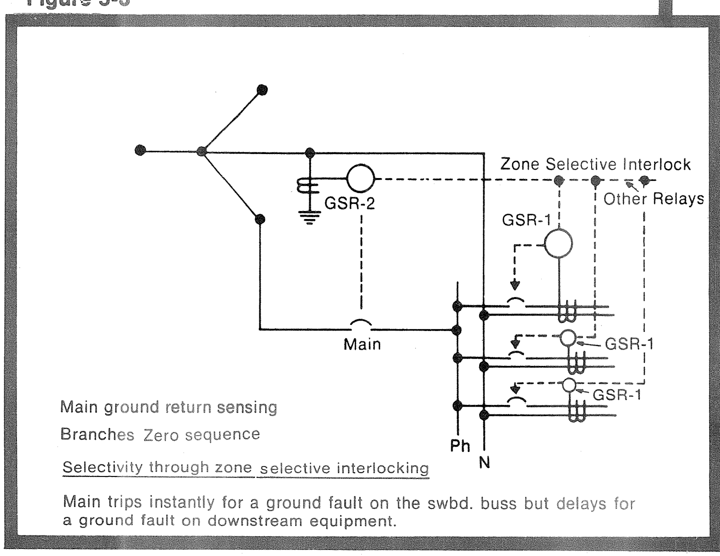


Figure 5-5

Figure 5-3



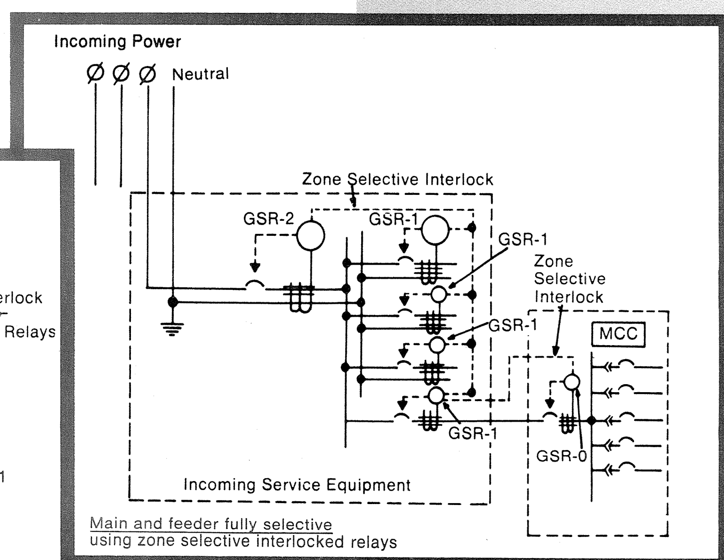
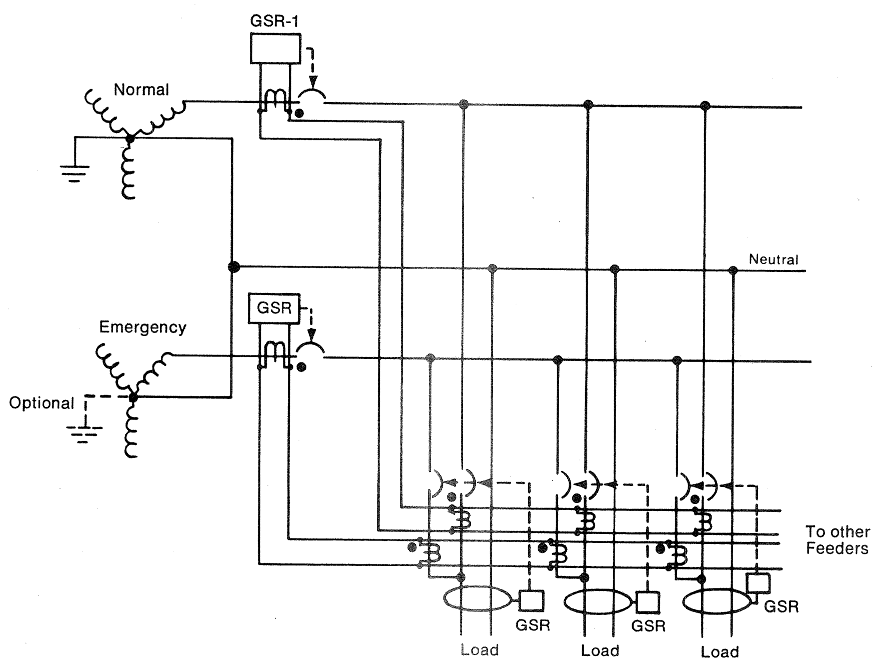
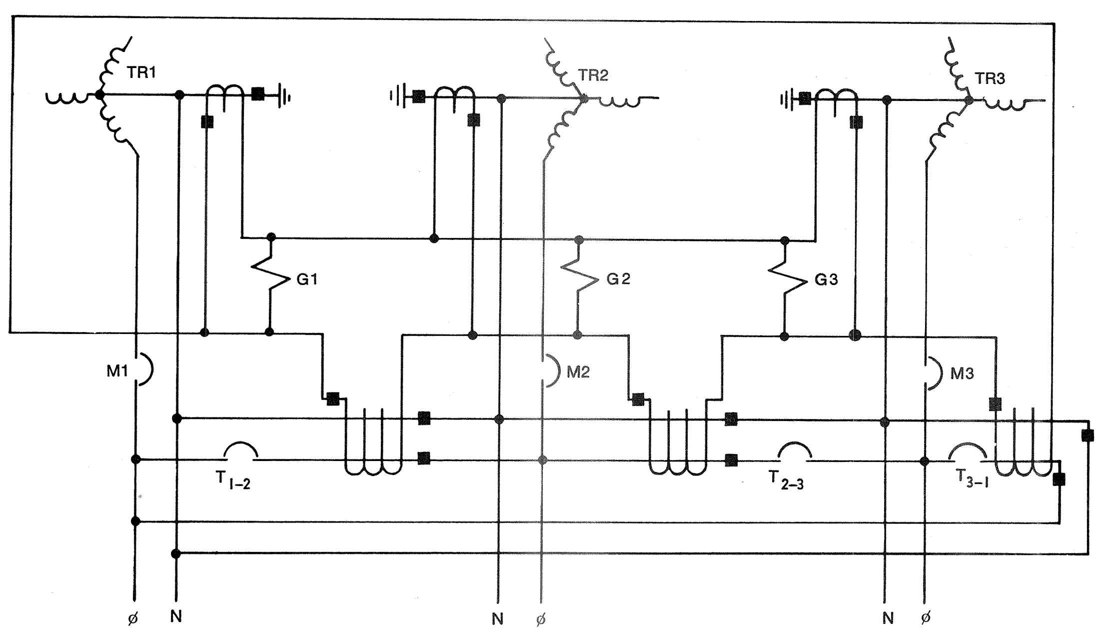


Figure 5-6

Double Bus,Double Breaker Emergency Power Systems



Ring Bus (Transformer, Generator or both)



G1 Trips M1, $T_{1\text{-}2}$, $T_{3\text{-}1}$ — G2 Trips M2, $T_{1\text{-}2}$, $T_{2\text{-}3}$ — G3 Trips M3, $T_{2\text{-}3}$, $T_{3\text{-}1}$

Double-ended unit substations or switchboards (Fig. 5-7) present a special case, which is one of obtaining selectivity between the tie and main protective devices and between the two mains under arcing fault conditions.

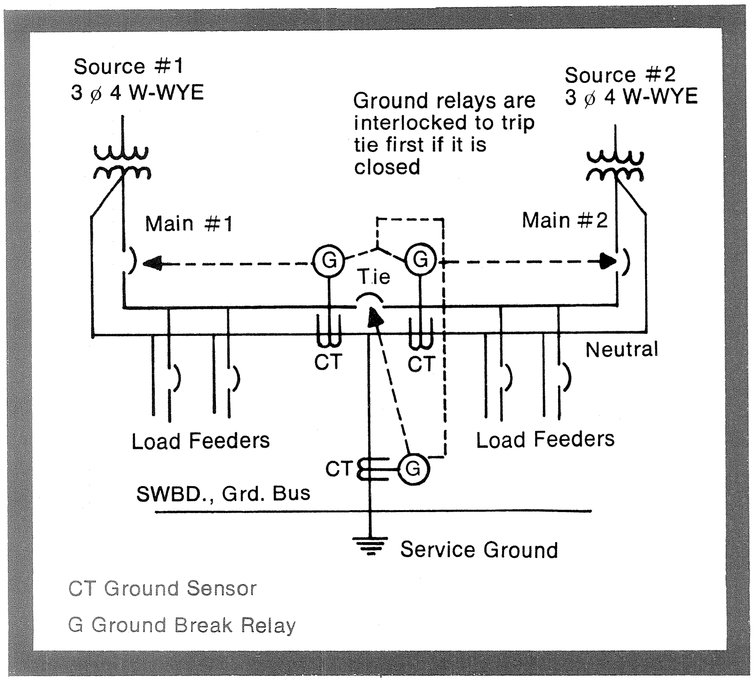
Selectivity is obtained by grounding the neutral at only one point, at the center of the switchboard, and placing a sensor on a ground strap between this point and the switchboard ground bus. The GROUND BREAK relay associated with this sensor trips the tie device. Sensors for tripping each main device are located on the neutral, on each side of the point where the ground strap is connected. All feeder neutral connections are made on the source side of these sensors.

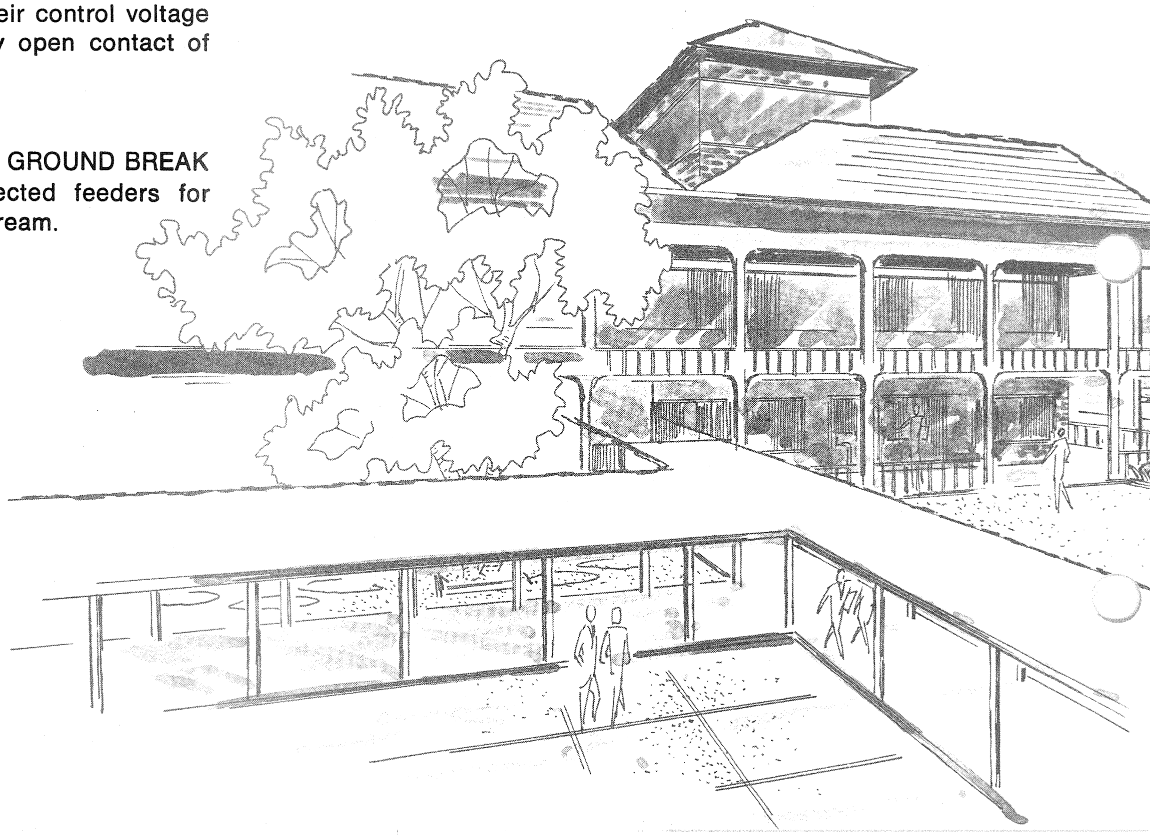
The GROUND BREAK relays are interlocked to trip the tie device first, if it is closed. When the tie is open, ground fault current returns to the transformer that is energizing the fault by flowing from the switchboard enclosure and ground bus through the single ground strap to the neutral bus, and through one neutral sensor back to the transformer neutral point.

Since only one neutral sensor sees the fault current, only one main device trips and unnecessary disruption of service is prevented. The main breaker relays will not operate when load current flows in the neutral because their control voltage is obtained through a normally open contact of the tie breaker relay.

Referring to Fig. 5-7, additional GROUND BREAK relays may be added to selected feeders for ground fault protection downstream.

Figure 5-7

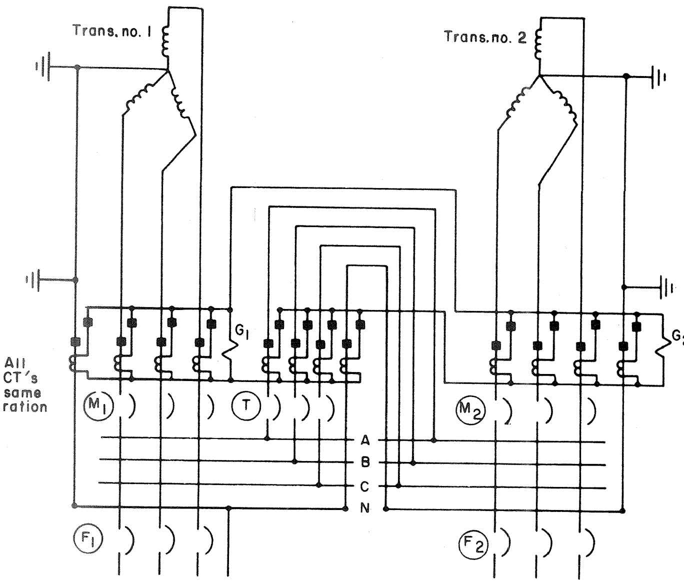




Double-ended Equipment

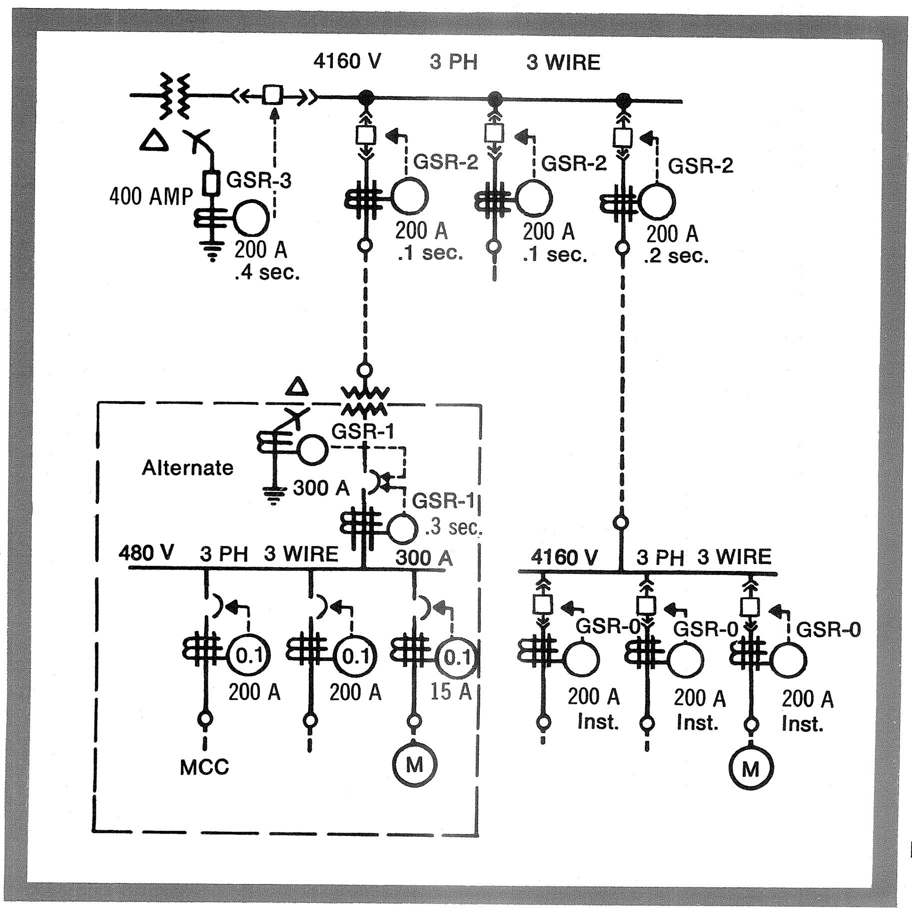
Relays G1 and G2 may be selectively coordinated with the ground-fault protection relays applied on the feeder breakers by the selection of suitable current and time-delay settings. With relays G1 and G2 connected as shown, maintaining proper polarity markings, there will be no current flow through the relay coils for three-phase, phase-to-phase, or phase-to-neutral currents. Furthermore, the line-to-ground fault current may return over either of the ground paths and the neutral conductor, or it may be divided between the two in any proportion, without upsetting the proper flow of the current through the relay coils. Also, the line-to-neutral load caused by unbalanced line-to-neutral current on a feeder circuit has two parallel paths by which it may return to its source at one or both of the transformers. One path is by means of the neutral conductor, the other is partially by the neutral conductor to the ground point near one transformer and then by ground to the neutral of the source transformer. With the current transformers and relays connected as shown, these extraneous currents flowing in the neutral conductors will cause no adverse action on either of the relays. That is, it will not add to or subtract from the required ground fault current flow in the relay coils, nor will it introduce any current flow in the relay coils for non-ground fault conditions. These conditions are true for any combination of breaker positions (open or closed) of (M1), (M2) and (T).

This summation scheme can be applied with the proper modifications on multi-feed systems; namely, three or more transformers and/or generators each with its own ground connections, feeding a switchgear or switchboard line-up and each switchgear or switchboard grounded on the line side of the main protector and intertied through tie breakers. Consult factory if sensor leads must exceed 100 feet.



Relays G1 & G2 must trip the tie CB as well as their respective mains.

Medium Voltage



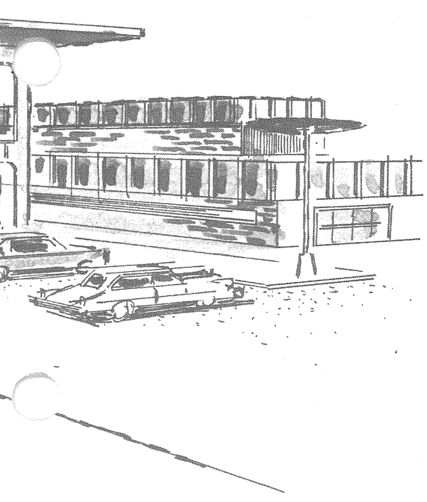
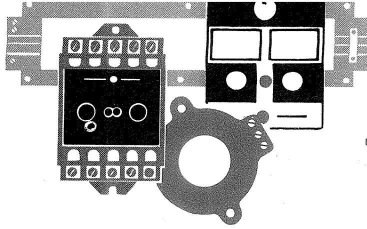


Figure 5-9



V Testing

TESTING

The reliability of the ground break system is excellent. However, since testing is so convenient, it is recommended that a test be performed monthly, or after the breaker has experienced a fault of any kind.

ON-SITE TESTS

The complete Ground Break System consisting of Sensor, Relay and Monitor Panel incorporates all the testing facilities which would be normally required by any planned maintenance/test program.

The system provides the following two types of tests.

I. System test *without* interruption of service. This test subjects the Ground Break System to a 1600 ampere ground fault at the sensor providing a test of the sensor, sensor wiring, relay, relay to Monitor Panel wiring, and Monitor Panel but disconnects the shunt trip from the circuit thereby preventing the protective device from tripping.

II. System test *with* interruption of service. Same as above but without disconnecting shunt trip, thereby providing a test of the complete system including the shunt trip wiring, shunt trip and circuit protective device.

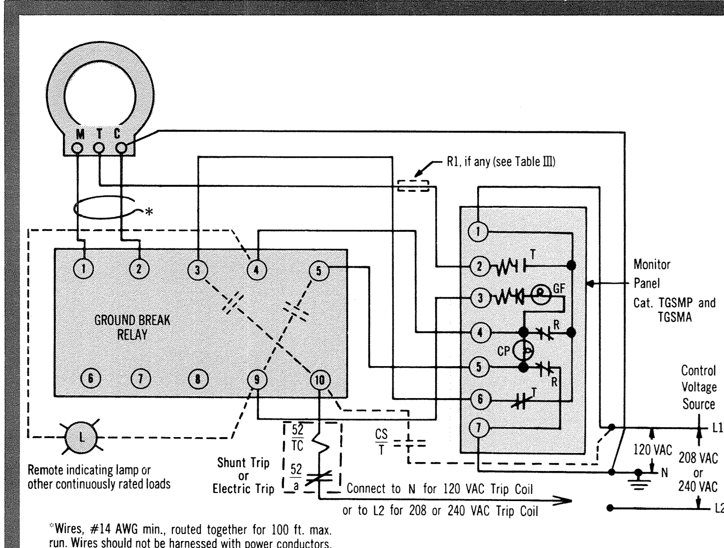
If a simulated current of other than 1600 amperes is desired, a resistor chosen from the chart below should be added to the test circuit and connected to terminal "T" on the current sensor.

Ground Break Test Resistors (Wirewound)

It is recommended a resistor be selected to give simulated ground fault signals at least 20% higher than pick-up setting of Ground Break relay.

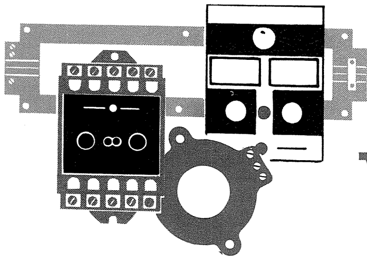
TGM Sensors Sim. Ground Fault Current	TGS Sensors Sim. Ground Fault Current	If Monitor Panel Figure 6-2 R1 Added Resistor	If Monitor Panel Wirewound Resistor, Min. Wattage	No Monitor Panel R1 Resistor Figure 4-2	No Monitor Panel Wirewound Resistor, Min. Wattage
190	1600A	no addition		50Ω	100W
130	1200A	20Ω	50W	70Ω	100W
120	1000A	30Ω	50W	80Ω	100W
96	800A	50Ω	50W	100Ω	50W
68	600A	90Ω	25W	140Ω	50W
48	400A	150Ω	25W	200Ω	25W
24	200A	350Ω	25W	400Ω	25W
12	100A	750Ω	20W	800Ω	20W
6.6	60A	1400Ω	12W	1400Ω	12W
4.8	40A	2000Ω	8W	2000Ω	8W
2.4	20A	4000Ω	5W	4000Ω	5W

Figure 6-1



Wiring diagram for Ground Break Relay and Monitor Panel using ac control voltage and Optional Resistor

Figure 6-2



VI Guide Form Specifications

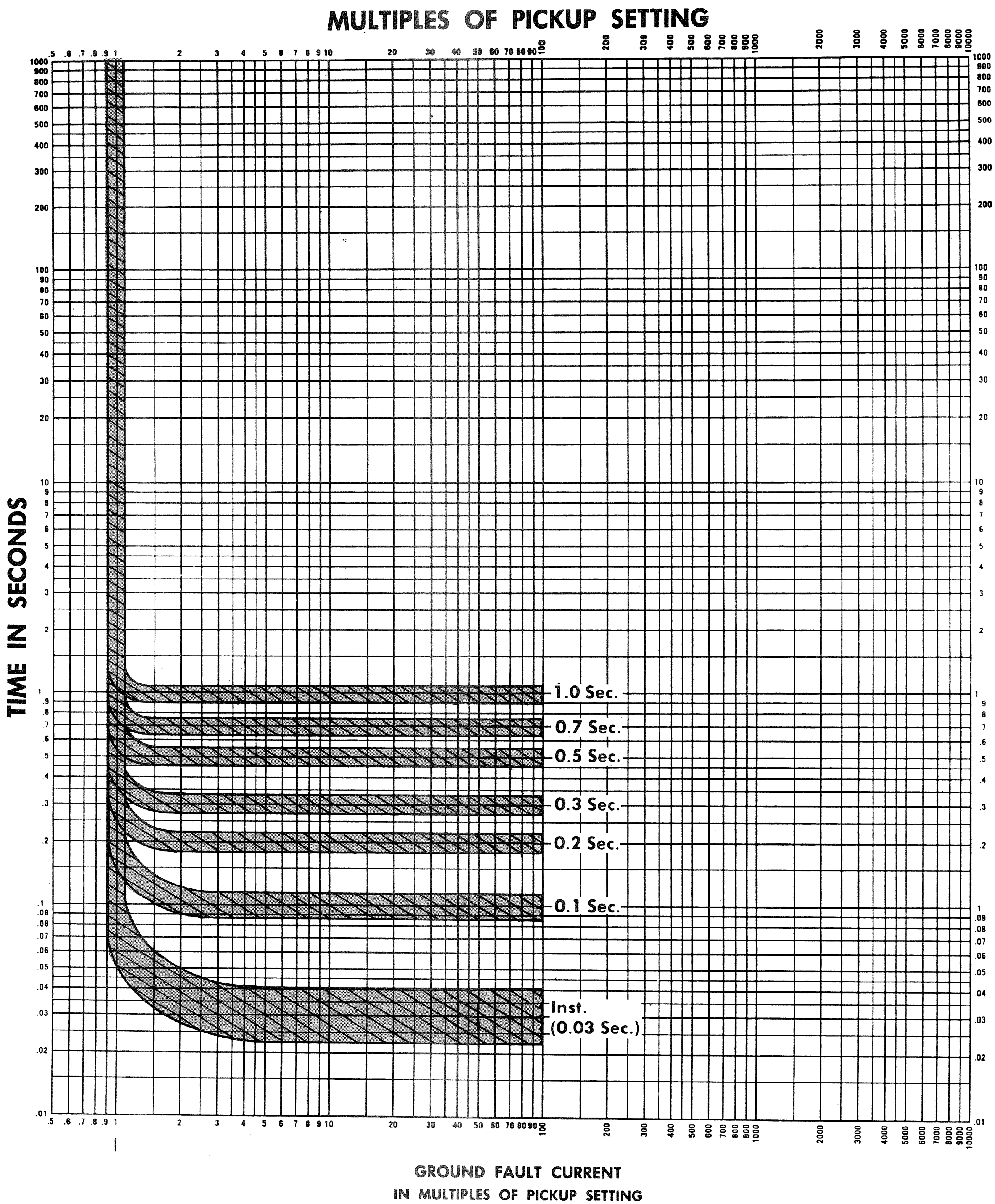
Furnish and install UL recognized ground sensor relay (GSR) system with Ground Break components for each of the protective devices indicated on the plans. Each unit shall consist of a coordinated ground sensor (CT) with integral test winding, solid state relay to operate the shunt trip circuit on the circuit protective device and Monitor panel.

The relay shall be of the (standard time delay) (Zone selective interlock) type and have continuously adjustable current pick-up settings of (5-60 amperes) (100-1200 amperes) and continuously adjustable time delay setting from Inst. (.03 sec.) to 1.0 second. It shall provide two independent output contacts each rated 5 amperes continuous and 30 amperes inrush at (24, 36, 48, 125V dc or 120, 120/208, 120/240V ac). The Relay shall include a memory function to recognize and initiate tripping on intermittent ground faults. The Monitor Panel shall indicate relay operation and provide means for testing the system with or without interruption of service and must not permit the ground fault system to be inadvertently left in an inactive or OFF state.

The ground sensor shall be installed for ground return or zero sequence arrangement as required on the main service device. On feeder and branch devices, furnish zero sequence sensor arrangements.

Double-ended switchboards or switchgear shall be furnished with a combination of ground return and neutral mounted sensors for coordinated tripping of tie and main device. Interlocking of the relays for selective tripping of the tie and main breaker shall be accomplished without additional components other than the Ground Break relays.

Time Current Curves



GENERAL ELECTRIC

Relay Ranges (Amperes)
5 to 60A. and 100 to 1200
Time Delay Range:
Inst. (0.03 Sec.) to 1.0 Sec.
System Voltage Rating
600 v.a.c.
Frequency Rating
50 to 60 Hertz

GROUND BREAK™ SYSTEM

Type TGSR

Ground Fault Pickup Settings and Delay Time-Current Curves
(Curves apply from −20°C to +55°C ambient)

GES-6135

Adjustments

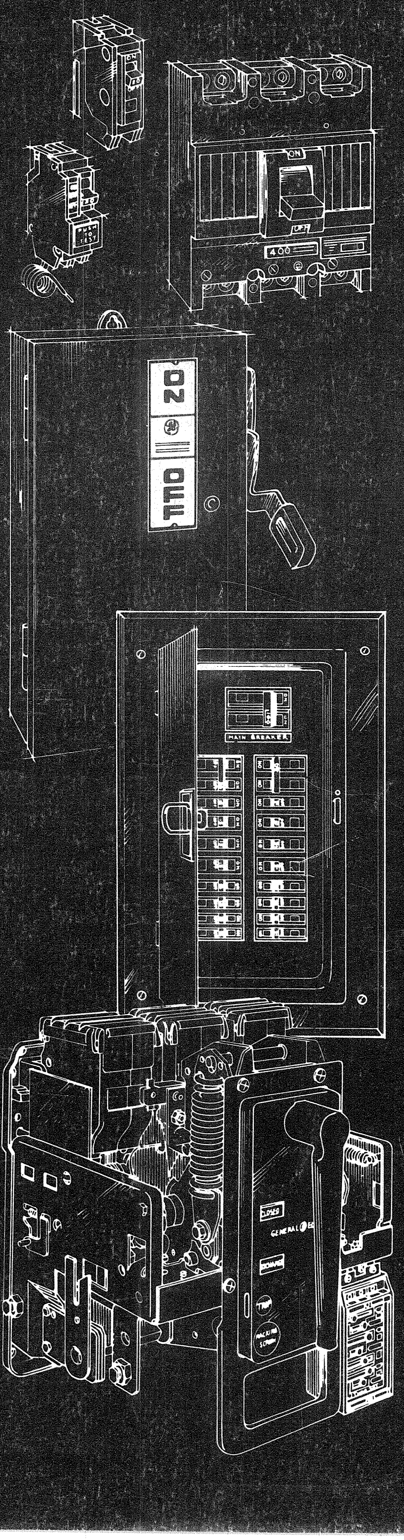
Pick-up Unit: Continuously adjustable.
Time Delay: Continuously adjustable.

Pick-up current does not exceed 1200A at any setting.

GENERAL ELECTRIC CO., CIRCUIT PROTECTIVE DEVICES DEPT., PLAINVILLE, CONN.

K215-128

General Electric literature for premium protection



molded case circuit breakers

Q-Line Molded Case Circuit Breakers	GEA-8481
THQE Circuit Breakers and Terminations	GEA-9755
Application and Selection Molded Case Circuit Breakers	GET-2779
VersaTrip® for Molded Case Circuit Breakers	GET-6202
Mag Break® Motor Circuit Protectors	GEA-7498
Tri-Break® Integrally Fused Circuit Breakers	GEA-7477
Mine Duty Circuit Breakers	GET-6207
Testing and Maintenance of Molded Case Circuit Breakers	GET-2963

insulated case circuit breakers

Power-Break® Insulated Case Circuit Breakers, Product Information	GEA-9752
Power-Break® Insulated Case Circuit Breakers, Technical Information	GET-9732
VersaTrip®, for Insulated Case Circuit Breakers	GET-6202

low voltage power circuit breakers

Application and Selection for Type AK Low Voltage Power Circuit Breakers	GEA-8733
Power Sensor® Test Set	GEK-7301
Power Sensor® Testing Instructions	GEK-7309
SST ECS Test Set	GEK-64454
Type AK Breaker Installation and Operation Instructions	GEK-7302
Maintenance Manuals	
AK-25	GEI-50299
AK-50, -75, -100	GEK-7303
AKR-30, -50	GEK-7310
Renewal Parts Bulletins	
Renewal Parts Price Bulletin	GEP-1675
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ground fault protective products

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panelboard components

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circuit breaker load centers

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PowerMark +® Riser Panels, Series Type	GIZ-2362-17
Lightning Protector	GEA-9756
Meter Mod II and Mini Mod II Modular Metering	GEA-9757
Load Center Renewal Parts	GEF-4453

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GENERAL ELECTRIC

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