Westinghouse Electric Corporation
Relay-Instrument Division
Coral Springs, FL 33065

November, 1981
New Information
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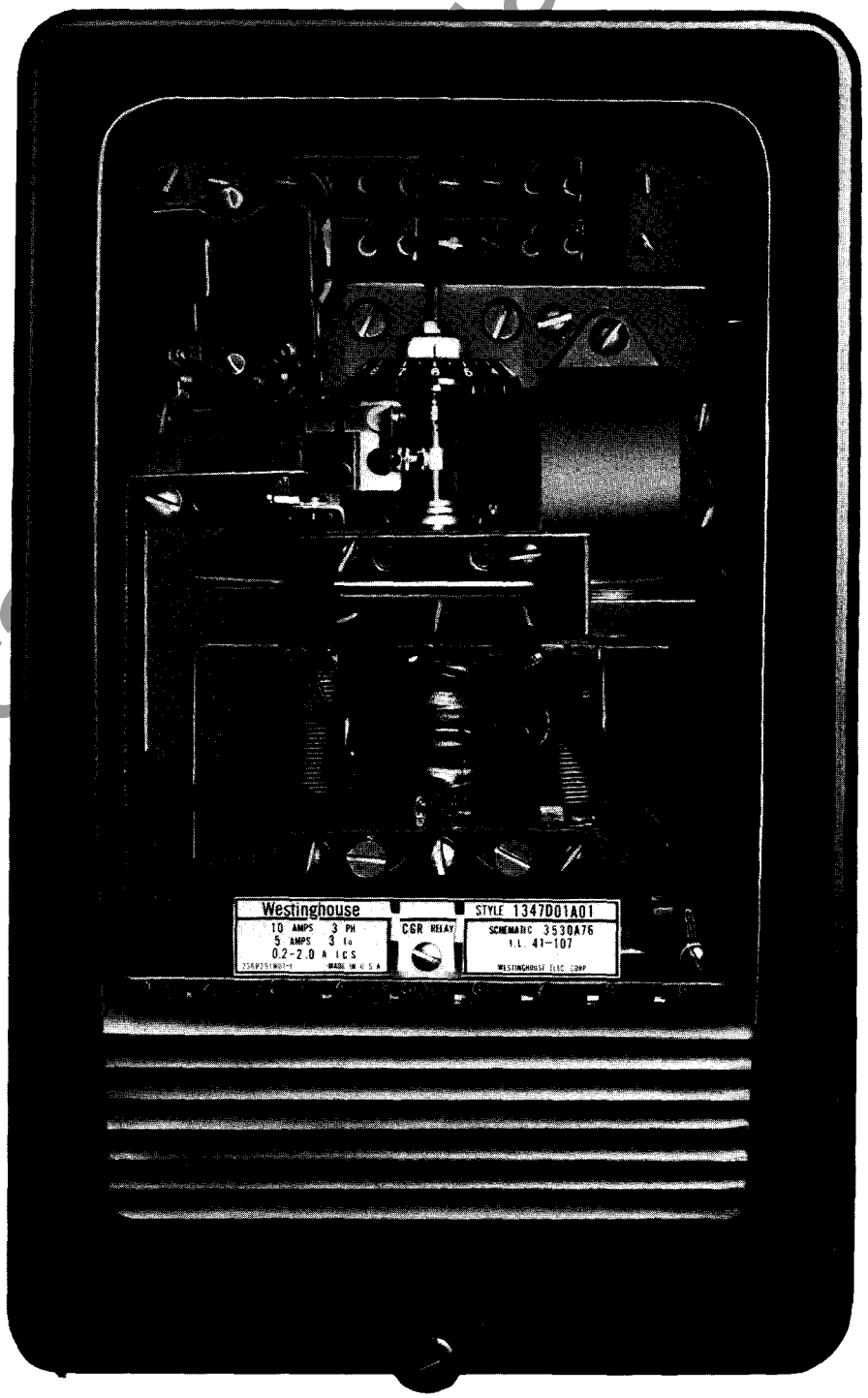
Type CGR Ratio Ground Relay



Application
Three phase four wire distribution feeders serve both three phase and single phase loads through a variety of load connections and protective devices **(Figure 13).** Some degree of single phase load unbalance is to be expected. Conventional ground relays must be set above the expected level of residual current due to this unbalance. An additional margin must be provided in the settings to cover a blown fuse on a single phase lateral. The setting of these relays must be based on maximum load levels even though the load varies during the day and year.

The CGR downed conductor relay has been designed to provide extra protection during situations when conventional ground relays fail to detect a fault. The CGR offers the following advantages:

- Greater sensitivity at lighter loads.
  1) Greater sensitivity for high resistance faults.
  2) Greater sensitivity for open conductor detection.

The ratio characteristics of the CGR relay give it an advantage over conventional relays because its sensitivity varies inversely with load current. The fixed setting of conventional ground relays limit them to faults equivalent to full load conditions.

The feeder duty cycle curve in **Figure 1** shows that the actual load varies considerably during the day. In addition, the peak value varies throughout the year and during the life of the feeder. The net result is that a residential feeder may operate below sixty percent of peak load as much as ninety percent of the time. The CGR offers added protection during this period when conventional relays provide little or no protection against open conductors or high resistance faults.

Loss of Load Comparison
A ground relay requires a flow of unbalanced current to recognize a broken conductor. The magnitude of the current depends on the portion of the faulted phase still feeding load after the line has opened. The higher sensitivity of the CGR relay permits it to detect an open conductor with less loss of load than that required by conventional relays. Its sensitivity varies inversely with the load current as described in **Figure 2.**

Figure 3 compares the CGR versus a $3I_o$ relay for an open conductor condition. The conventional $3I_o$ relay is unable to detect loss of even 100% of the load on one phase at load levels below its setting.

Sensitivity To Open Conductors
At different tap selections, the relative sensitivity of the CGR vs conventional relays is shown in **Figure 4.** It gives coverage against open conductors at a greater distance out along the feeder than that of ordinary methods.

Typical Residential Feeder Loading

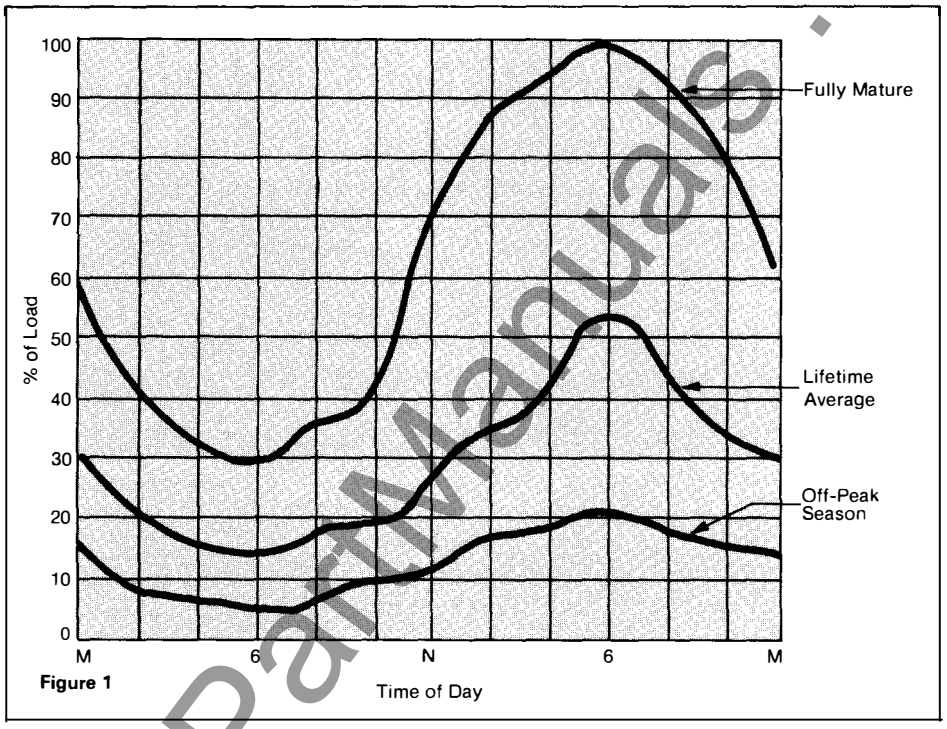


Figure 1

Characteristics of Type CGR Relay—One Phase Current Low

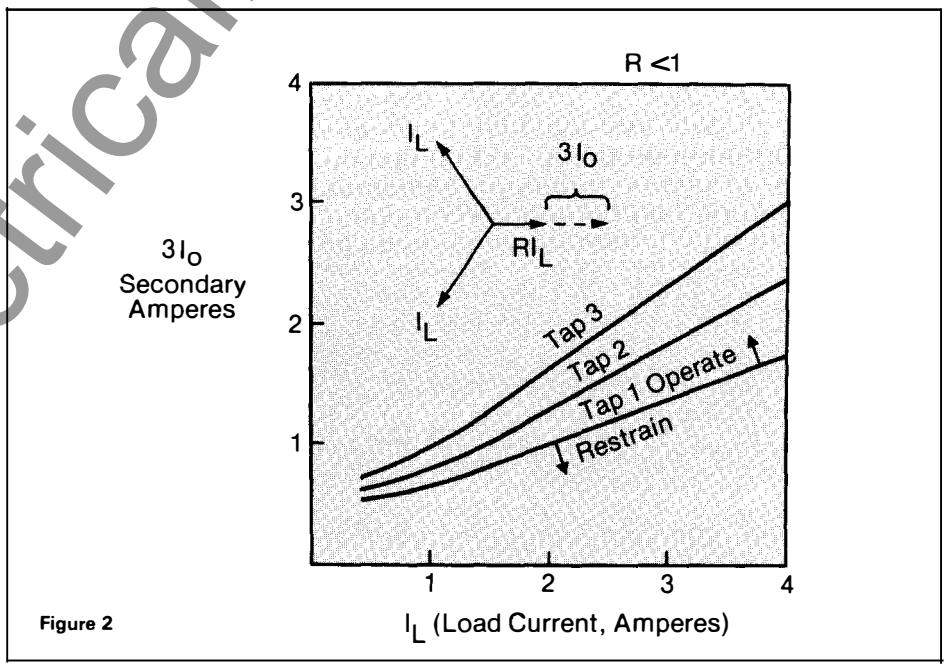


Figure 2

Broken Conductor Detection—Relay Response

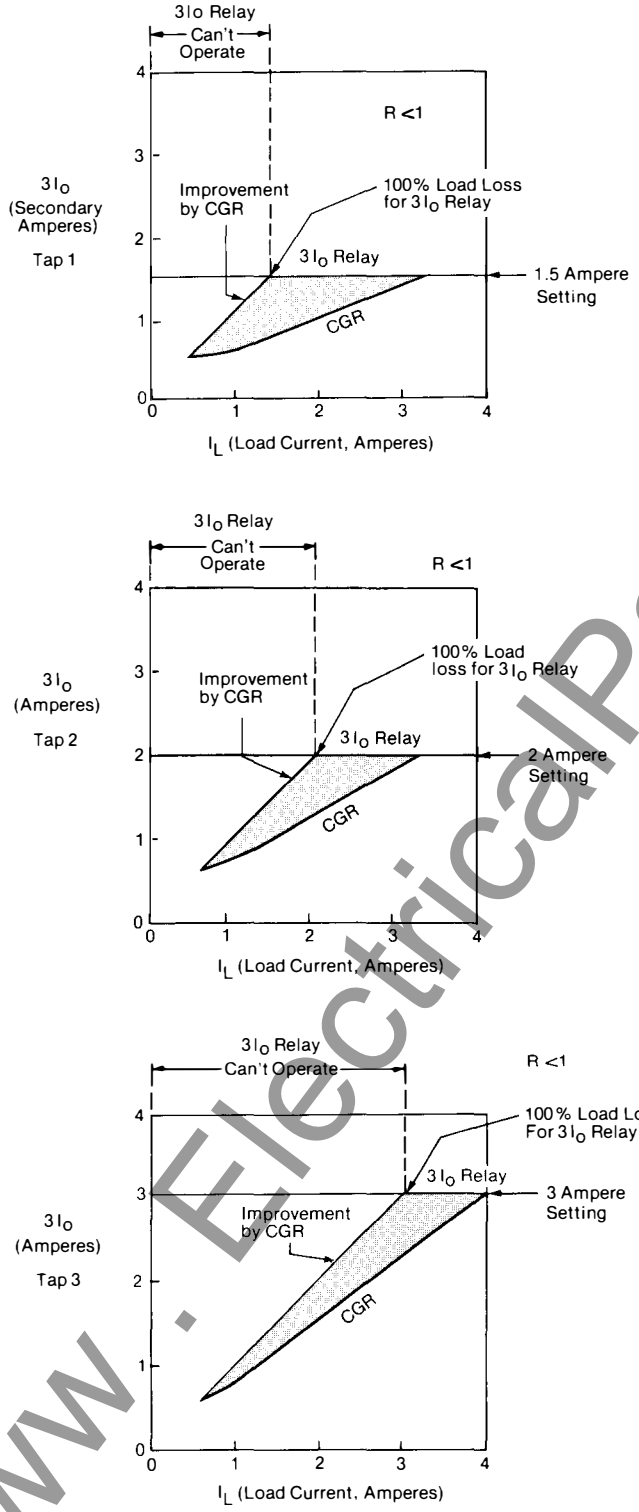


Figure 3

Broken Conductor Detection—Comparison of Effectiveness

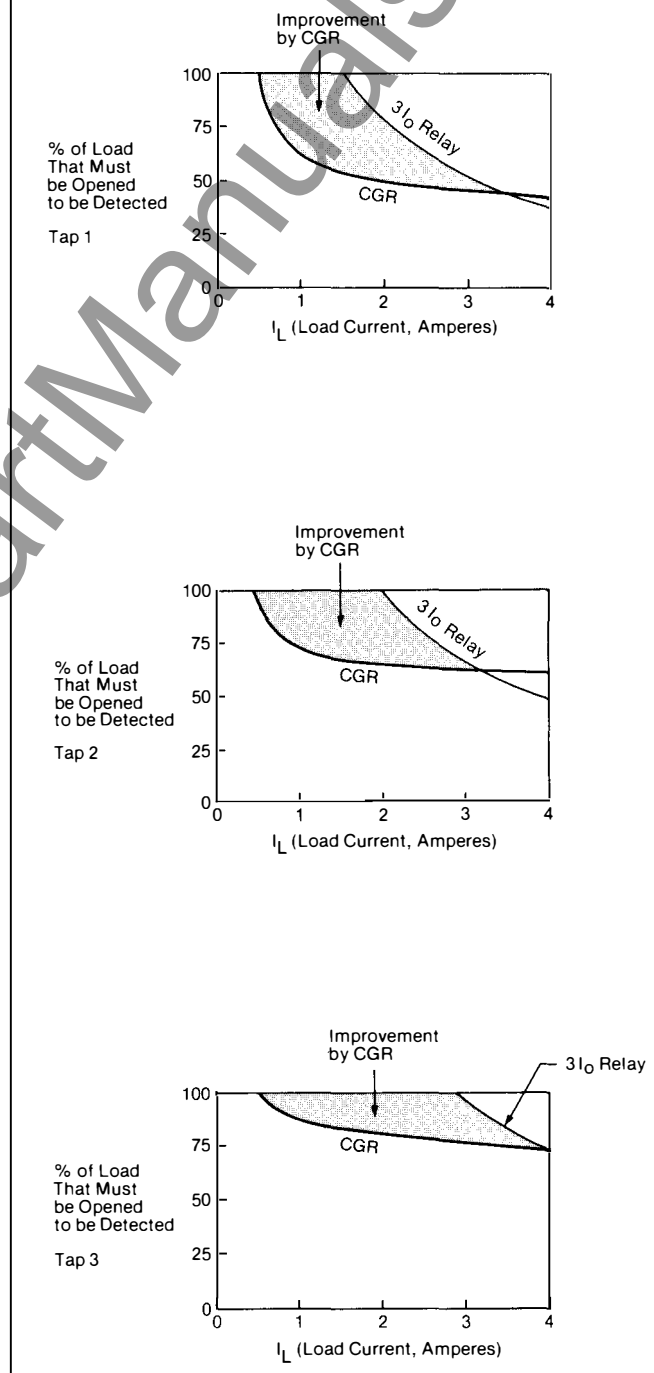


Figure 4

High Resistance Fault Detection
Another inherent benefit of the CGR relay is its ability to recognize very high resistance faults **(Figure 5 through 7)**. The fault resistance values shown in **Figure 6** are in per unit based on feeder full load current. A ground fault with a fault resistance as high as 8 per unit (120 ohms on a 12470/7200 volt feeder with 480 amperes full load) is detectable by the CGR relay. (This is approximately 4 times the maximum resistance fault that a ground CO relay can detect.)

Best protection can be achieved by a combination of the CGR and a CO residual ground relay

Characteristics of Type CGR Relay—One Phase Current High

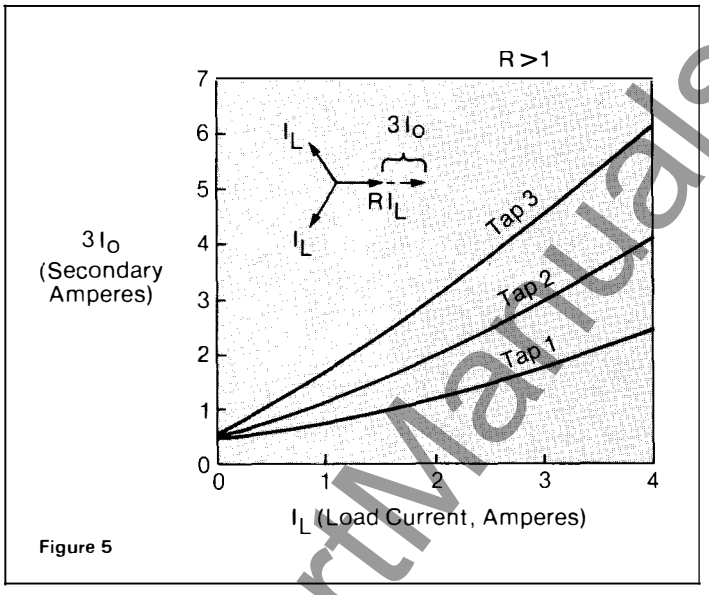


Figure 5

Ground Fault Detection—Comparison of Effectiveness

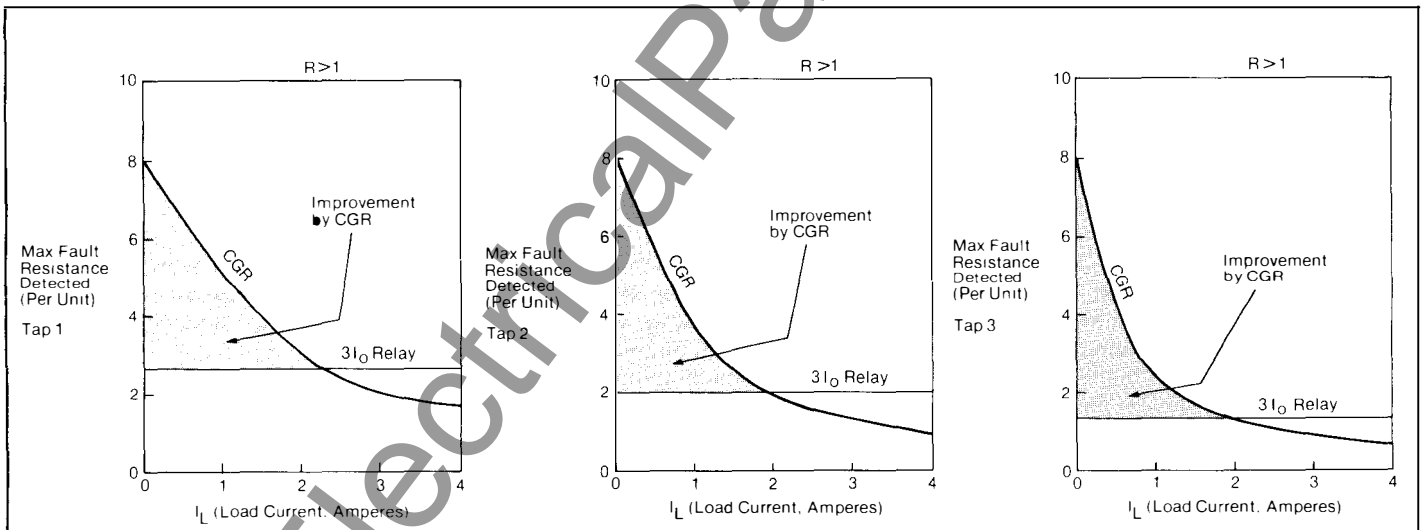


Figure 6

Ground Fault Detection—Relay Response

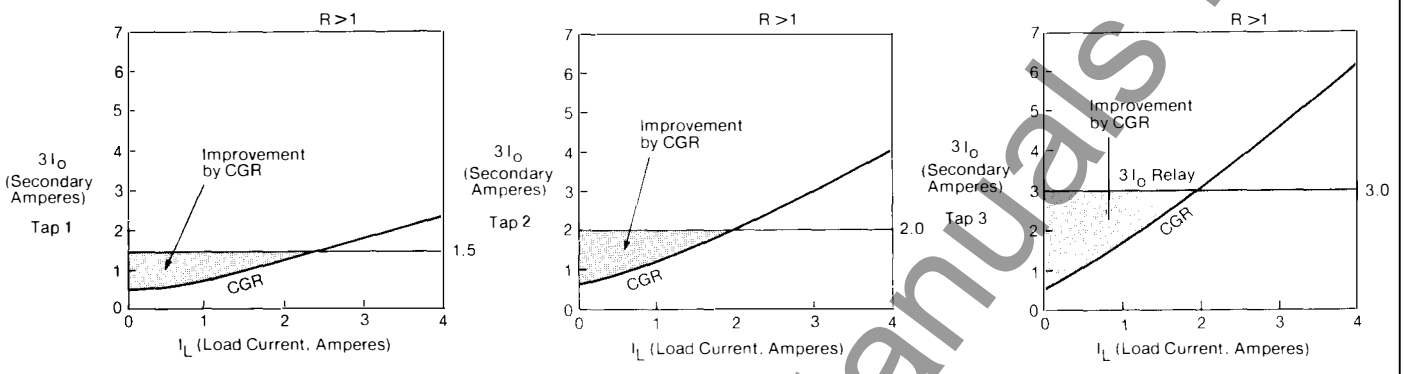


Figure 7

Construction and Operation
The Type CGR relay, in an FT-21 case contains a ratio ground (RG) unit which consists of an induction disc with two electromagnets (a restraint electromagnet and an operate electromagnet) and an Indicating Contactor Switch (ICS).

Electromagnets: The restraint electromagnet has four tapped coils. Two coils are located on each of the outer legs of an "E"-shaped laminated structure. One leg is energized by current $I_A - I_B$ and the other by $I_C - I_B$. These coils produce out-of-phase fluxes in the air gap and cause a contact-opening torque on the disc of the ratio ground unit. This torque is a function of the difference of the positive sequence current squared and the negative sequence current squared $(|I_1^2| - |I_2^2|)$.

The operate electromagnet has a main coil which receives $3I_o$ current and a secondary winding which drives current through a coil on each of the side legs. Current flowing through this electromagnet produces contact-closing torque which is a function of the square of current $|3I_0^2|$.

When the RG unit contacts close, the flow of trip circuit current activates the Indicating Contactor Switch.

Indicating Contactor Switch: The dc Indicating Contactor Switch is a small clapper type device. A magnetic armature, to which leafspring-mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the circuit-breaker trip circuit. During this operation, two fingers on the armature deflect a restraint spring located on the front of the switch, allowing the operation-indicator target to drop.

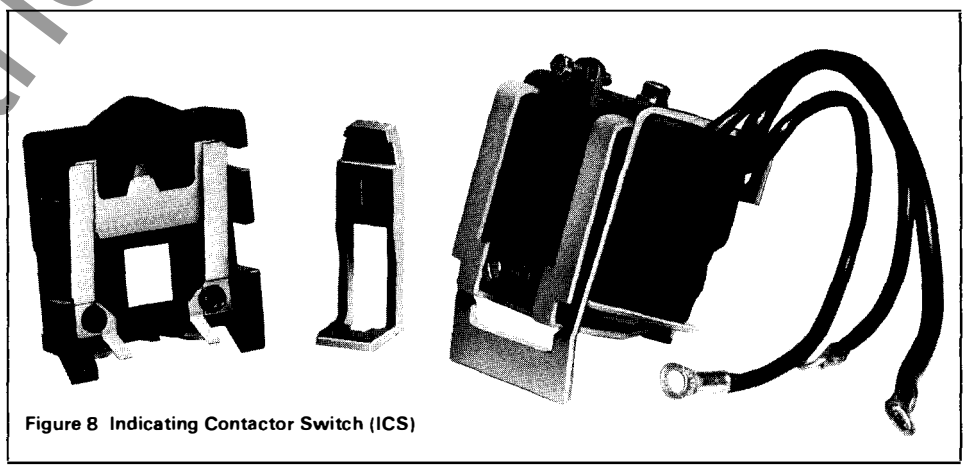


Figure 8 Indicating Contactor Switch (ICS)

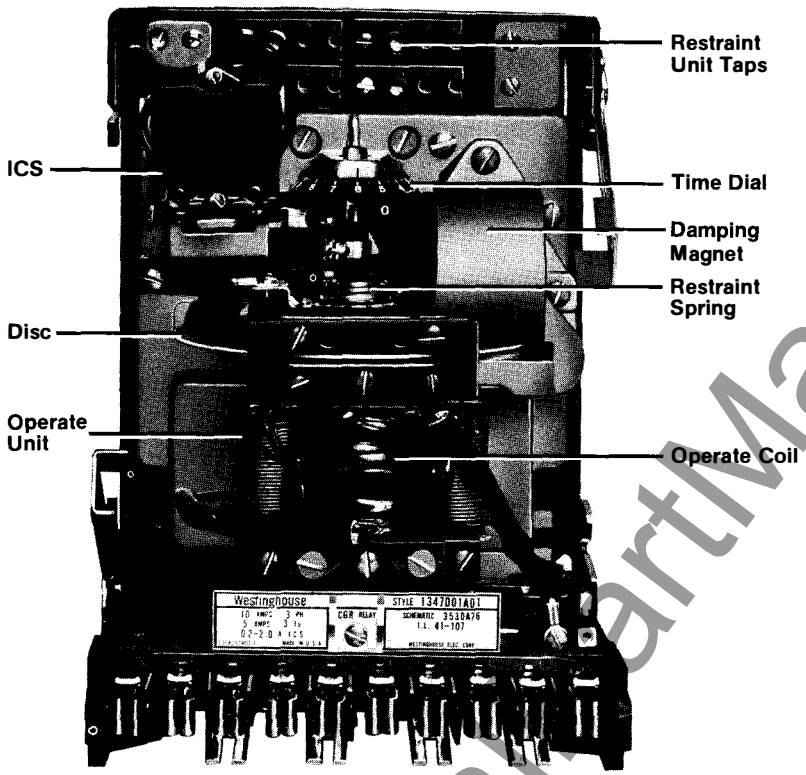


Figure 9
Type CGR Relay Without Case
Front View

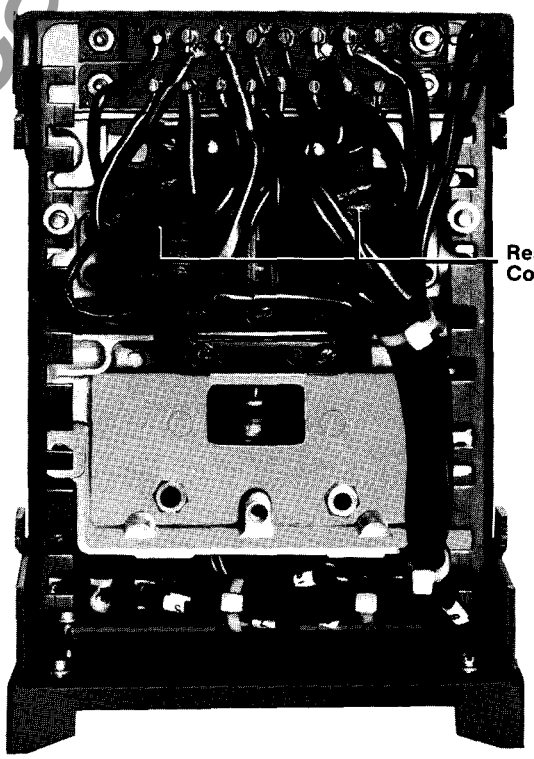


Figure 10
Type CGR Relay Without Case
Rear View

Ratio Ground Unit
With no restraint current applied, a nominal current of 0.5 amperes in the operate coil will cause the contacts to close. This sensitivity may be adjusted to any value from 0.25 to 0.75 amperes by changing the spring restraint.

The spring serves only to open the contacts. It does not reset the moving contacts to the time dial settings.

The speed of operation of the CGR relay is affected by:

1) Tap setting
2) Time dial setting
3) Restraint current (I_L)
4) Operate current ($3I_O$)

Trip Circuit
The main contacts will safely close 30 amperes at 250 volts dc and the indicating contactor switch contacts will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide a pick-up setting of 0.2 or 2 amperes. To change taps, connect the lead located on the front of the tap block to the desired setting. The ICS resistance is:

0.2 ampere tap ..... 6.5 ohms dc
2 ampere tap ..... 0.15 ohms dc

Time Dial
When properly coordinated with conventional relays, the CGR relay will operate only for those open or ground faults that will not be detected by other devices. The procedure for determining the proper time dial setting is explained below. This will allow other equipment to function normally for all faults which they can detect. To prevent reclosing after the CGR operates, an external auxiliary lockout relay must be applied.

Coordination is complicated somewhat by the nature of the time variation of the CGR relay operation produced by the variable restraint effect of different load levels. Conventional residual relays are not influenced by load level, but are responsive to zero—sequence current only.

Settings
The ratio ground settings of the CGR relay are chosen to be above the normal residual ($3I_O$) current that is present in a circuit having single phase loads connected phase to neutral.

The taps are on the coils of the restraint electromagnet and are numbered 1, 2 and 3. The identical tap must be selected for each of the 4 restraint coils. Tap selection can be made from the following table:

Tap	R_L	R_U	$3I_O/I_L$
1	0.57	1.6	0.4
2	0.4	2.0	0.6
3	0.23	2.9	0.8

R is the value of per unit current in one phase with the other two phases carrying balanced currents of I_L, with all currents 120 degrees apart. R_L is approximately the value of R below which the relay will operate and R_U is approximately the value of R above which the relay will operate for the tap selected. **(See Figure 2 and 5)**

$3I_O/I_L$ is also shown in the table. The values are, for the tap selected, the approximate ratio of zero sequence current to I_L above which the relay will operate.

Burden
The burden seen by the phase current transformers is a function of the degree of unbalance with the center phase, phase B, having the greatest burden connected in every case. Assuming that the restraint coils are connected in "Y" (terminals 4, 6 and 8 connected together) with the operate connected in neutral (terminal 3 connected to terminal 4), the voltampere burden seen by each ct for several different conditions is tabulated in **Figure 11.**

CGR Relay Burden

PHASE CURRENTS	CT VOLTAGE Across Terms	CT VOLTAGE Tap 1	CT VOLTAGE Tap 2	CT VOLTAGE Tap 3	VOLT AMPERES Tap 1	VOLT AMPERES Tap 2	VOLT AMPERES Tap 3
I_A = 5A	5-2	0.191	0.365	0.619	0.96	1.83	3.10
I_B = 5A	7-2	0.389	0.689	1.13	1.95	3.45	5.65
I_C = 5A	9-2	0.194	0.466	0.742	0.97	2.33	3.71
I_A = 5A	5-2	3.83	3.57	3.18	19.2	17.9	15.9
I_B = 15A	7-2	4.80	5.25	5.91	72.0	78.8	88.7
I_C = 5A	9-2	3.87	3.75	3.66	19.4	18.8	18.3
I_A = 5A	5-2	7.05	6.82	6.43	35.3	34.1	32.2
I_B = 30A	7-2	8.74	9.41	10.34	262.2	282.3	310.2
I_C = 5A	9-2	7.28	7.07	6.94	36.4	35.4	34.7
I_A = 5A	5-2	11.39	10.23	9.97	57.0	51.2	49.9
I_B = 45A	7-2	13.62	13.76	15.27	612.9	619.2	687.2
I_C = 5A	9-2	11.49	10.82	10.59	57.5	54.1	53.0

Circuit Conditions for CGR Burden

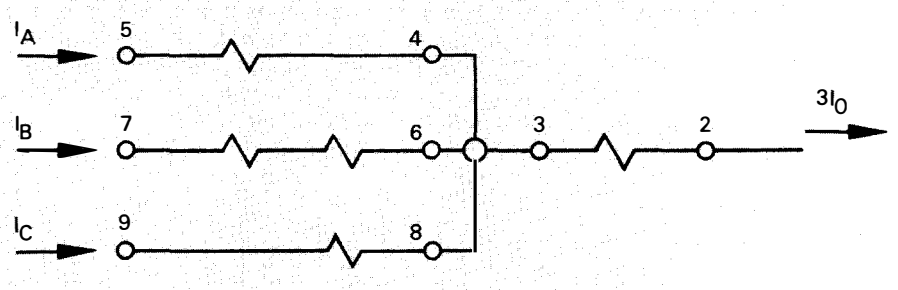


Figure 11

Coordination With Other Devices

Figure 12 shows a representative set of curves of operating time for the CGR relay versus R (the per unit current in the "odd" phase as shown in the phasor diagram of **Figures 2 and 5.** The characteristic of a CO, $3I_0$-only relay can readily be translated to this same plot by the knowledge that $3I_0=(1-R)I_L$ for R less than 1 and $3I_0=(R-1)I_L$ for R greater than 1. For selected values of R and I_L load current, $3I_0$ current values can be easily determined. Knowing the CO relay tap setting, the multiple of tap value that this current represents can identify the operating time for the CO relay for the particular time dial in use. It is assumed that this ground CO has been previously coordinated with all other current responsive devices on the feeder. In the absence of a ground overcurrent relay, a similar procedure may be used to assure coordination with downstream reclosers and lateral fuses. Phase current for a device in the 3-phase main, is simply RI_L for R greater than 1 and need not be considered for R less than 1. For a lateral protective device, phase current is $(K+R-1)I_L$ where K is the portion (in per unit) of the total load on the lateral.

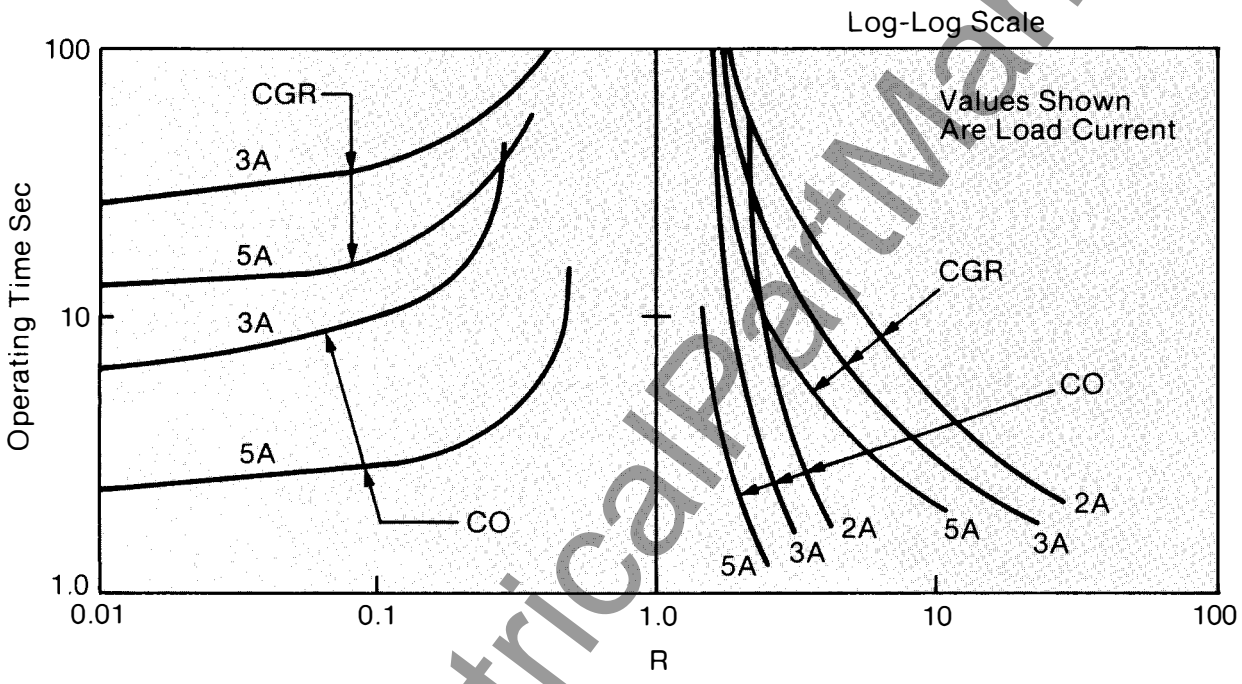


Figure 12 Typical Coordination of CGR Relay with Ground CO (CGR Tap 1, TD 11, CO-9 Tap 1.5; TD 5)

Figure 13 Schematic Diagram of Typical Distribution Substation and Circuit

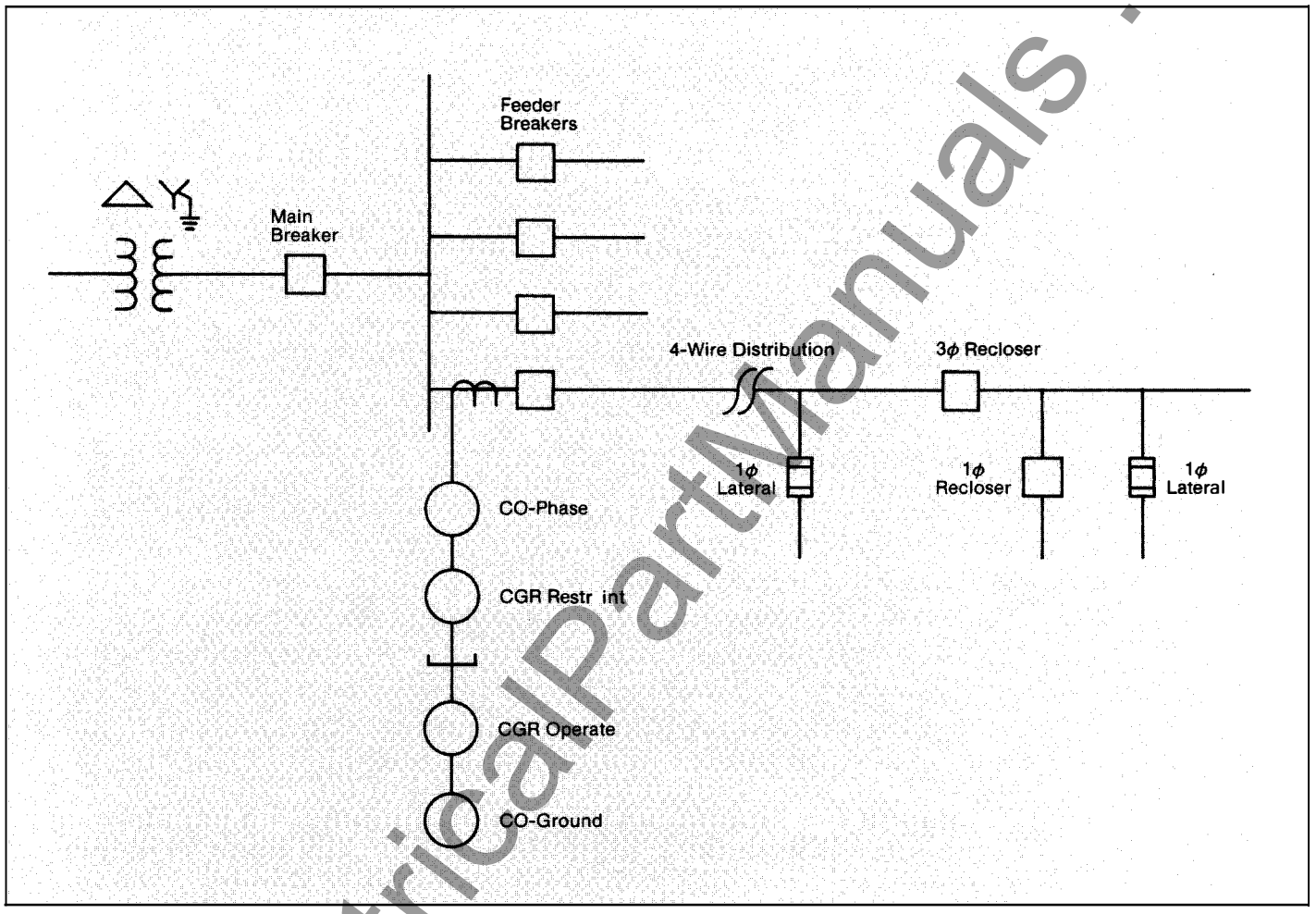
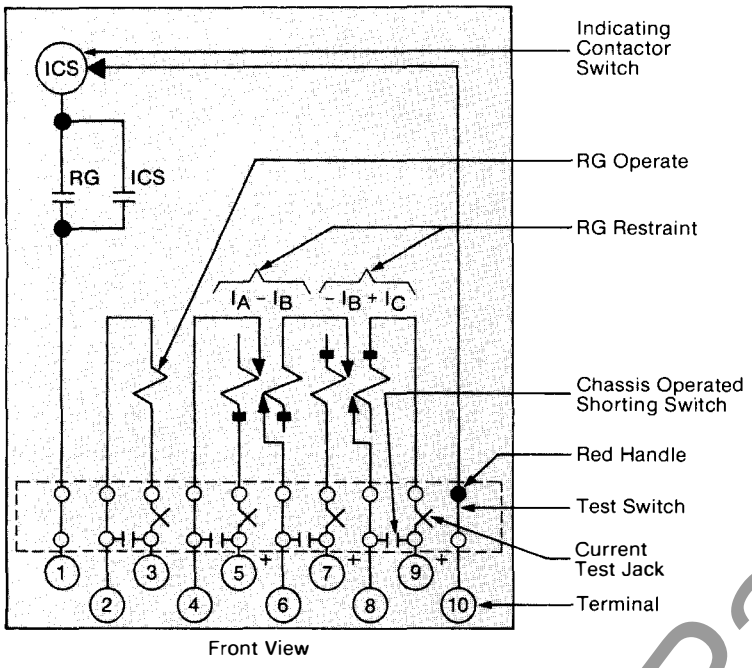


Figure 14 Internal Schematic (3530A76)

Type CGR Ratio Ground Relay in FT-21 Case.



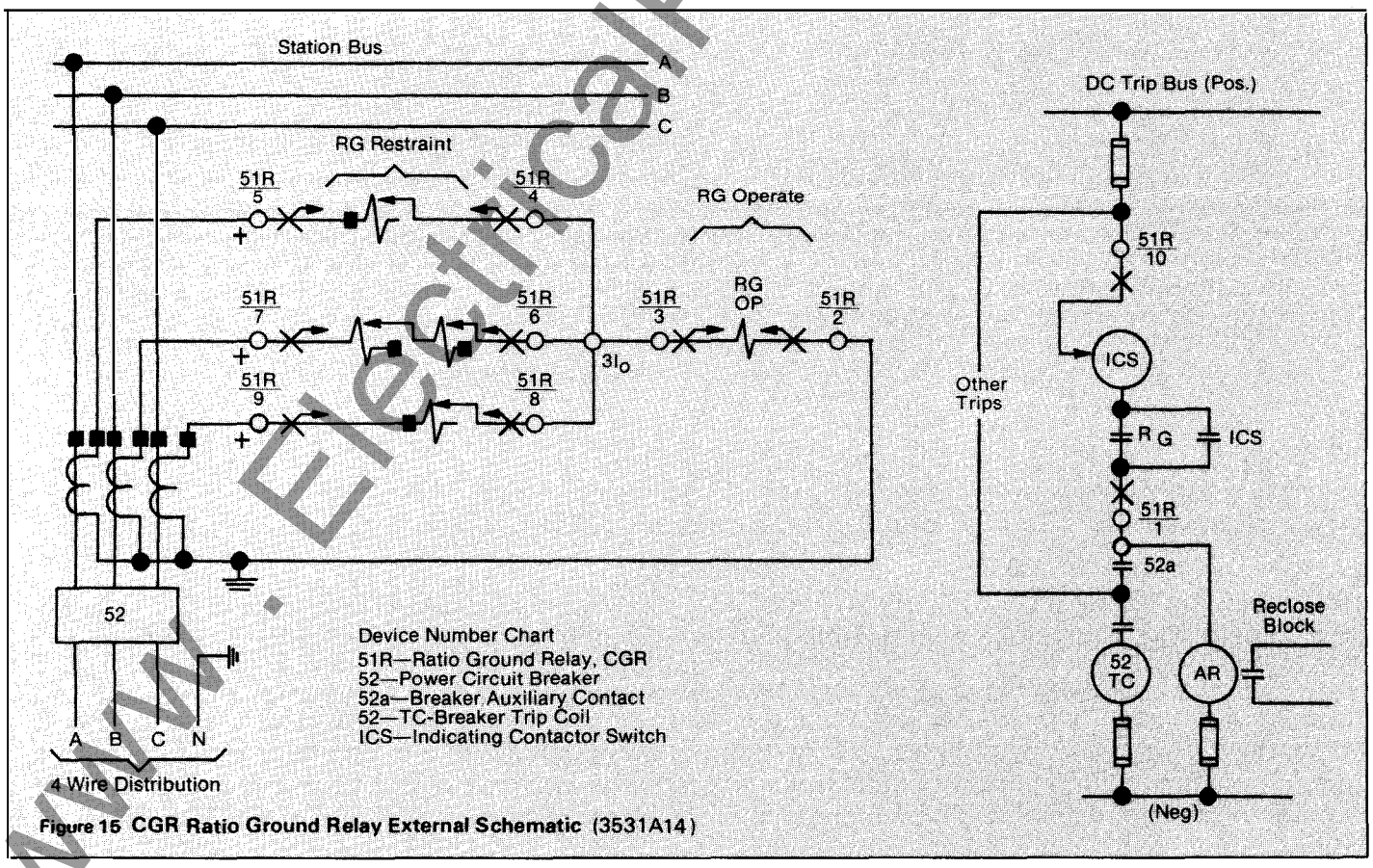


Figure 15 CGR Ratio Ground Relay External Schematic (3531A14)

Shipping Weights and Carton Dimensions

Case Type	Weight Net Shipping	Domestic Shipping Carton Dimensions
FT-21	17 lbs 37.48 kg	9 x 12 x 13 inches 23 x 30 x 33 cm

Further Information

Prices: PL 41-020
Case Dimensions DB 41-075
Instructions: IL 41-107, RPL-81-1 (Silent Sentinels)
Other Protective Relays: Selector Guide 41-000 A, B, C

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