TYPE CA-4 RATIO DIFFERENTIAL RELAYS

For Three-Winding Transformer and Bus Protection

Application

The protection of three-winding transformer banks or busses having more than two lines connected to the bus does not differ in principle from that which has long been used for the differential protection of a generator or transformer bank as explained in Catalog Section 41-205. That is, current transformers are located in all lines to the transformers or bus and a summation of all the secondary currents is made as shown in Figures 2 and 3. Under load conditions or for an external fault the summation of all the currents should equal zero, and therefore, no current should appear in the operating winding of any relay connected across that circuit. For an internal fault, however, assuming faithful current transformer response, the total amount of the short-circuit current should go through the operating winding of the protective relay.

There are two extreme conditions on which a differential relay is expected to perform correctly, (1) not trip on maximum external fault current, but (2) trip on minimum internal fault current. That is, the magnitude of an internal phase-to-ground fault, where a limited current exists, generally determines the minimum sensitivity for which the relay may be set. On the other hand, heavy external fault currents may produce A-C. and D-C. saturation in one or more current transformers, resulting in different secondary currents from the various lines. The resulting difference in performance of the current transformer response will cause some differential current to flow in the operating winding of the relay, even though the fault is not internal. To prevent improper operation, the relay either must be set to operate above the current resulting from this differential current or it must be of the ratio-differential type requiring that the current in the operating coil be above a certain percentage of the total short-circuit current flowing through the relay. Thus, the use of a ratio-differential relay would lower the tendency for incorrect relay operation for heavy external faults and still allow for very sensitive settings to take care of small internal ground fault currents.

In protecting three-winding transformers and busses having more than two lines connected to the bus with ratio-differential relays consideration must be given to using a relay or relays having a sufficient number of restraining windings

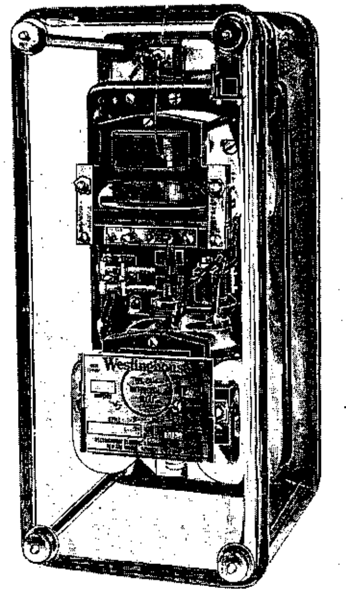

FIG. 1—TYPE CA-4 RELAY IN STANDARD PROJECTION TYPE CASE.

so that on an external fault, short-circuit current must pass through at least one restraining winding. That is, if current transformers are paralleled in such a manner that, with an external fault on one circuit the current would circulate between their secondaries, the difference in the outputs of the two current transformers would flow through a restraining winding and the operating winding in series, and the relay would operate as a sensitive overcurrent relay. The type CA-4 relay was designed, therefore, to provide a multiple number of restraining windings.

Three-Winding Transformer Protection

As has been described in Catalog Section 41-205, the CA relay was designed for two-winding transformer protection. It also can be used for protection of three-winding banks where there is one permanent source connected to the transformer, the current transformer in this source being balanced against the resultant current from the current transformers in the other two lines. However, where no one source can be considered as permanent, it is necessary to use the CA-4 relay which provides a restraint winding for each of the three lines to the transformer bank. The CA-4 is a single-phase relay and three are required for complete three-phase and ground protection.

The CA-4 relay also differs from the CA transformer type relay by having no internal current-balance taps. If the current transformers to be used with the relay will not give equal secondary currents in the correct phase relation, when properly connected, external auxiliary current balancing auto-transformers are required.

In a few cases power transformers give very high values of magnetizing current inrushes when the breaker is closed on a three-winding transformer, and this magnetizing inrush may be of too high magnitude and too long duration for the pickup value of the CA-4. To meet this condition, a combination of CA-4 relays plus a three-phase magnetizing inrush tripping suppressor can be supplied. The function of the magnetizing inrush tripping suppressor is to prevent the action of closing the breaker trip coil circuit until the magnetizing current inrush has diminished below the pickup of the relay. At the same time, however, the suppressor will still permit proper tripping if there is a fault in the transformer when the breaker is closed. Figures 13, 14 and 15 show connections for protection of transformers with the CA-4 relay.

Bus Protection

Figure 3 shows a typical installation for protecting a multiple-circuit bus with a differential scheme. It is seen that this does not differ in any respect with the principle of differential protection of a three-winding transformer. The CA-4 also can be used on busses having more than three circuits, as shown in Figure 4, providing some of the lines can be grouped into three resultant restraint currents. However, in grouping the lines due consideration must be given the prob-

TYPE CA-4 RATIO DIFFERENTIAL RELAYS—Continued

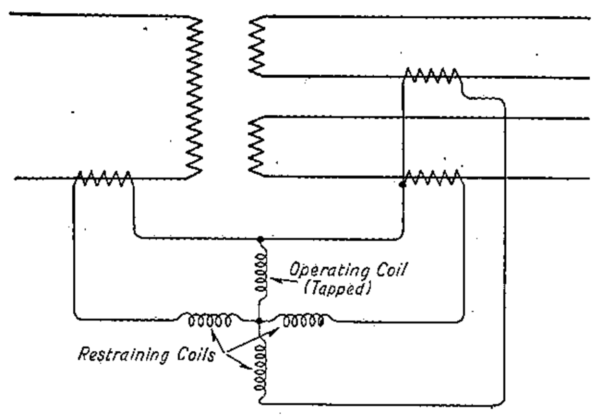

Fig. 2—Schematic (1 Line) Diagram Showing Protection of a 3-Winding Transformer Bank with a CA-4 Relay.

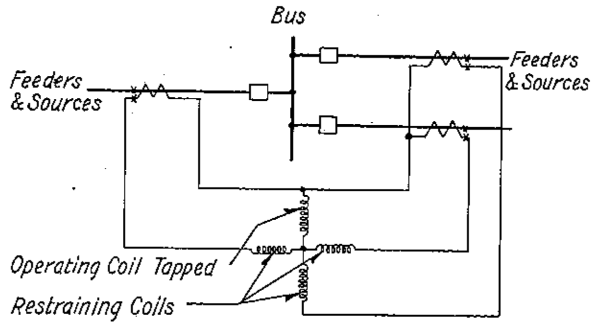

Fig. 3—Schematic Diagram of Connections for Protecting a Circuit Bus with the Type CA-4 Relay.

lem of obtaining adequate restraint. Some of the total fault current may be allowed to circulate between the secondaries of paralleled current transformers without producing restraint if the remainder of the total fault current does produce sufficient restraint for the conditions.

In many cases it is impossible to group the lines into three resultant restraining circuits, and for these cases the use of two CA-4 relays per phase is required as shown in Figure 5. In this figure it is seen that the CA-4 relays are so connected that one restraining coil is available for each circuit and both CA-4 relays must close their contacts to complete the breaker trip circuit. The operating coils of both CA-4 relays are connected in series so that on an internal fault both relays will close their contacts. Consideration of the minimum number of sources that can be connected to the bus at any one time may allow the paralleling of certain current transformers so that for all possible bus set-ups the means of providing a sufficient amount of restraint can be made available to prevent false tripping on external faults.

General Considerations for Bus Differential Protection

In applying bus differential protection, each application should be considered carefully with respect to the amount and distribution of fault currents, sizes and ratios of current transformers, number of generating sources, and consequently the number of restraining coils needed, relationship of the protected bus to power sources as affecting the amount and extent of the D-C. component, and other important factors. The problem becomes more severe as the ratio of maximum through fault current to minimum internal fault current increases. Catalog Section 41-211 presents a further discussion of considerations for bus differential protection and should be studied before any definite decision is made on more complex bus problems.

Distinctive Features

1. **Ease of Inspection**—The standard case has a full glass cover which, when removed, leaves the complete relay accessible for inspection.

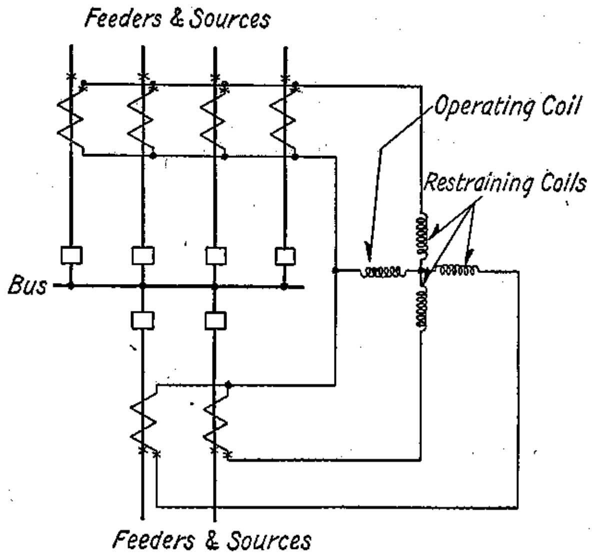

Fig. 4—Schematic Diagram of Connections for Protecting a 6-Circuit Bus (by Grouping the Circuits into 3 Resultants) with the Type CA-4 Relay.

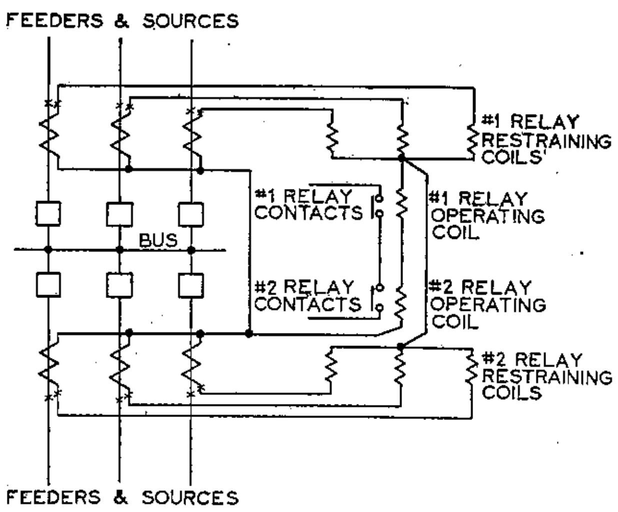

Fig. 5—Schematic Diagram of Connections for Protecting a 6-Circuit Bus with Two Type CA-4 Relays Per Phase.

TYPE CA-4 RATIO DIFFERENTIAL RELAYS—Continued

2. **Standard Case**—Designed for most commonly used relays for uniform appearance and similar wiring and mounting details. Similar construction except for flush mounting can be supplied when desired.

3. **Universal Studs**—For mounting equally well on slate or steel panels.

4. **Universal Shock-Proof Indicator**—Not affected by vibrations. The term "Universal" is used to indicate that a 0.2 or 2.25 ampere minimum setting can be obtained merely by changing one connection.

5. **Three-Point Contactor Switch**—Mounted in the relay and used in the trip circuit to shunt around and protect the main contacts of the relay. When the switch operates, instantaneously upon the closing of the main relay contacts, it seals itself in and remains positively closed until the breaker operates and the pallet switch opens the trip circuit. The use of the contactor switch makes it possible for the relay to handle trip circuit currents up to 30 amperes at 250 volts D-C.

6. **Adjustable Ratio**—Taps are provided to permit adjustment of the unbalance required to operate the relay to 15%, 25% or 40%.

7. **Adjustable Pure Silver Contacts**—Assembled in the front of the relay for convenience in test and inspection.

Construction and Operation

The type CA-4 relay operates on the induction disc principle and consists of four electromagnets operating on two discs which are fastened to the same shaft. Three of the electromagnets are restraining elements and are connected to receive the secondary currents from the various current transformers. The fourth electromagnet element is connected to receive the differential or unbalance current. The operating winding is tapped so that the relay will just operate on 15, 25 or 40 per cent balance. An extra connector block screw is provided so that taps on the relay can be changed without opening the current differential circuit.

The currents in the three restraining elements, Figure 9, produce an opening torque proportional to the currents in the various windings of the protected transformer, assuming faithful current transformer performance. The current in the difference or operating element produces a closing torque proportional to the difference of the three restraining currents when these currents are flowing through the power transformer. The necessary quadrature flux to produce torque is supplied by the upper pole coil of the electromagnet. These coils are excited by transformer windings on the main poles of the various electromagnets.

Because of the restraint which exists in the relay during through faults when the load is heavy, the current transformer characteristics need not be accurately matched, since there is a restraining torque on the relay disc that permits a certain discrepancy of current transformer ratio characteristics without resulting in faulty tripping. This is illustrated in Figure 6 which shows typical operating characteristics for a through fault. Figures 7 and 8 show typical time of operation curves of the CA-4 relay.

The Magnetizing Inrush Tripping Suppressor contains a small synchronous timer element with contacts designated T_2 (Fig. 10) which are closed at the end of a time interval adjustable up to five seconds. The timer element consists of a synchronous motor energized by the potential transformers through contacts S_1, S_2, S_3. The synchronous motor drives a moving contact through a gear train, the moving contact completing the circuit by bridging the contacts on the adjustable contact block. The synchronous motor has a floating rotor which is in mesh with the gear train when the motor is energized. When the motor is de-energized, the rotor drops out of mesh allowing the spiral spring to quickly reset the moving contact. Three auxiliary voltage switches, S_1, S_2, S_3 having front and back contacts are provided. These are energized from the three phase-to-ground or phase-to-phase voltages as shown in Figures 14 and 15. In addition, three D-C. voltage contactor switches, T_1, T_3, and T_4, are provided and are energized from the control battery.

These various elements described operate together as follows, with reference to Figures 14 and 15. When the transformer bank is energized, the voltage operated switches, S_1, S_2, and S_3, pick up, opening their back contacts before the differential CA-4 and T_1 contacts close, thus preventing tripping by means of T_1 contact on magnetizing inrush. The make contacts of these switches are in series and energize the synchronous timer. At the end of the time interval (adjustable up to five seconds) which gives the magnetizing inrush time to subside and allows the opening of the CA-4 and T_1 contacts, the T_2 contact closes. This energizes the auxiliary contactor switches T_3 and T_4. T_3 operates to seal around T_2 contact, and T_4 closes to complete the tripping circuit to the CA-4 contacts. Now, if a fault, which is not severe enough to drop the voltage below the drop-out of the A-C. voltage switches, S_1, S_2, S_3 (approximately 60 volts), occurs within the transformer bank, tripping occurs through the CA-4 and T_4 contacts in series. If the fault is severe, and the voltage drops below the drop-out voltage of S_1, S_2, or S_3 and T_4 resets before the CA-4 contacts close, tripping will occur through T_1 contact and the back contact of the A-C. voltage switch that dropped out. Here the CA-4 contacts serve only to energize the T_1 coil, and tripping occurs through S_1, S_2, or S_3 back contacts in series with T_1 contact.

The seal-in contact T_3 is provided as a safeguard to make certain that a tripping circuit will always be available, regardless of the magnitude of the fault. Thus, there will be no critical voltage which might open the tripping circuit through T_4 contact (which was set up by T_2) without providing another tripping path through the back contacts of S_1, S_2 or S_3. If a faulty transformer bank is energized, one or more of the A-C. voltage switches will fail to pick up due to low voltage and tripping will immediately be accomplished through the T_1 contact and the S_1, S_2 or S_3 switch that failed to pick up.

External current balancing auto transformers are required where the main current transformers do not provide equal secondary currents with the correct phase relation for the CA-4 restraining windings. Figures 13, 14 and 15 show the auxiliary auto-transformers and CA-4 relay external connections for three typical installations. Usually two sets of auto-transformers are required as shown in Figures 13 and 14. Figure 13 shows the external connections of the type CA-4 relay when the Magnetizing Inrush Tripping Suppressor Relay is not required.

When two or more CA-4 relays per phase are used as shown in Figure 5, a multi-contact auxiliary relay is required to trip the number or breakers involved. Such a relay may be of the type that interrupts its own coil circuit and thus

TYPE CA-4 RATIO DIFFERENTIAL RELAYS—Continued

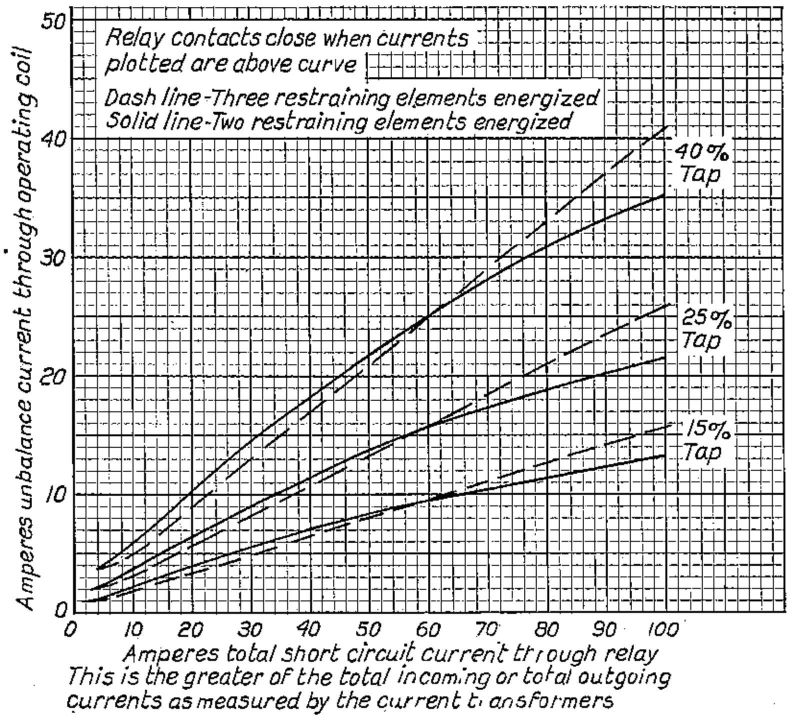

FIG. 6—OPERATING CHARACTERISTICS FOR A THROUGH FAULT.

obviate the necessity of using a number of pallet switches for that purpose. In any case, the trip circuit of the relay should be loaded up to draw 3 to 5 amperes D-C. to insure positive action of the contacts.

Operation Indicator

The CA-4 relay is equipped with a universal gravity-type indicator which is positive in operation and suitable for all tripping currents above 0.2 ampere.

Auxiliary Contact Switch

A self-aligning auxiliary contactor switch is connected in the circuit to relieve the main contacts when the current is above 2.25 amperes. A tripping current as high as 30 amperes may be safely carried without fear of contact trouble.

Method of Calculating Trip Current

It is not safe to assume that the current carried by the contactor switch and target coil can be calculated by Ohm's law, using the voltage of the circuit and the resistance of the breaker trip coil. The first objection to this is that the voltage may be low at the time the relay is tripped because of a heavy load on the battery and circuits of several breakers are being operated at once. The other objection to the single calculation is that the current builds up slowly in the trip coil and the breaker may be opened and the trip circuit opened by the pallet switch before the current has reached its calculated value. This is due to the inductance of the coil.

A safe rule is to assume that only half the calculated value of the current will be available to operate the contactor switch and the operation indicator.

Energy Requirements

The burden of the CA-4 restraining windings with 5 amperes flowing is 3 volt-amperes per element. With 5 amperes flowing through the operating winding its burden is as follows:

15% Tap	24.0 Volt-Amperes	58° lag
25% Tap	8.5 Volt-Amperes	53° lag
40% Tap	3.3 Volt-Amperes	45° lag

The burdens of the Magnetizing Tripping Suppressor are as follows:

Auxiliary Switch T_1	—7.25 watts at 125 volts D-C. (Intermittent duty)
Auxiliary Switches T_3 and T_4	—4.40 watts at 125 volts D-C.
Synchronous Timer T_2	—2.5 volt amperes, 55% P. F. at 115 volts 60 cycles
A-C. Voltage Switches S_1, S_2, S_3	—3.1 volt amperes, 98% P. F. at 115 volts 60 cycles

List Prices

CA-4 Relay, Single-Trip Contacts, Universal Operation Indicator*, 15%—25%—40% Unbalance Taps

Frequency —Cycles**	Standard Case Style No. *** (Fig. 9)	List Price Discount Symbol FC
60	1 056 084	$170 00

Magnetizing Inrush Current Tripping Suppressor, 115 Volt, 60 Cycles**, Control Voltage 125 Volts D-C.

Standard Case Style No.*** (Fig. 10)	List Price Discount Symbol FC
1 101 427	$150 00

Note: A set consisting of 6 auto-balance Current Transformers can be supplied, for use with the CA-4 relays as shown in Figures 13, 14, and 15, by the Sharon Transformer Division at $100.00 list less FC discount.

* Resistance of universal gravity target coil: 2.8 ohms; in parallel with contactor switch coil: 0.25 ohms.

** 25 and 50 cycle relays and suppressors can be supplied. Specify "Similar to Style ....(give 60 cycle style) except 25 cycle (or 50 cycle)." Add 10% to price of 60 cycle relay or suppressor as the case may be.

*** These styles have dimensions in line with the figures shown on page 6. This is known as the projection type case. If a similar case is desired excepting for flush mounting (for flush mounting a shallow glass cover and steel case are used), it can be supplied by ordering the relay or suppressor "Similar to Style............(give style of corresponding projection type) except for flush mounting." For price refer to Catalog Section 41-070.

TYPE CA-4 RATIO DIFFERENTIAL RELAYS—Continued

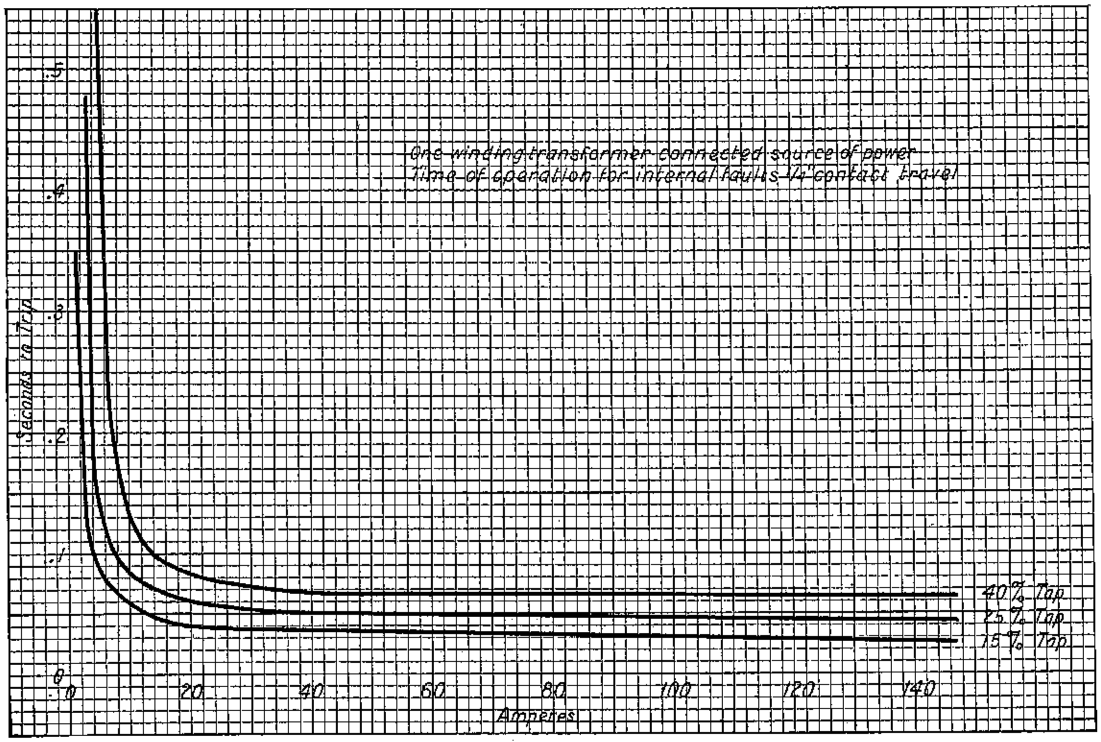

Fig. 7—Time-Ampere Curve of the Type CA-4 Relay, Protecting a Three-Winding Transformer When One Winding of the Transformer is Connected to the Source of Power.

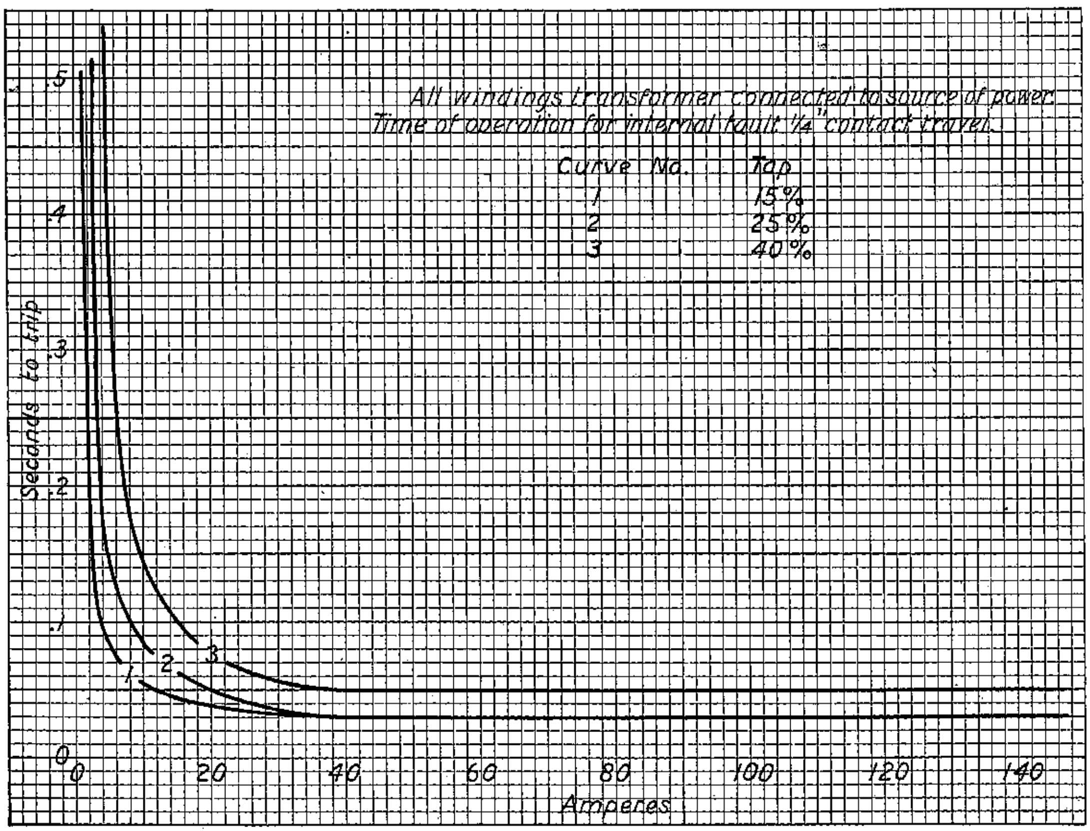

Fig. 8—Time-Ampere Curve of the Type CA-4 Relay, Protecting a Three-Winding Transformer When All Windings of the Transformer are Connected to the Source of Power.

TYPE CA-4 RATIO DIFFERENTIAL RELAYS—Continued

WIRING DIAGRAMS

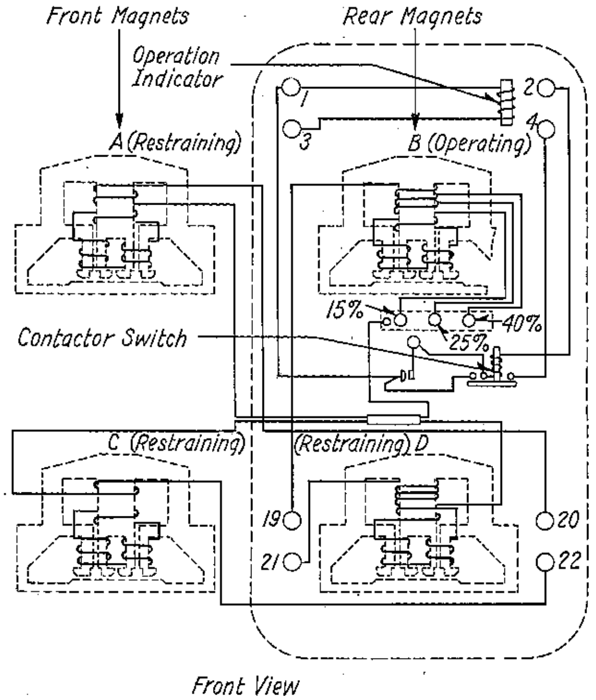

Fig. 9—Internal Wiring Diagram of the Type CA-4 Relay.

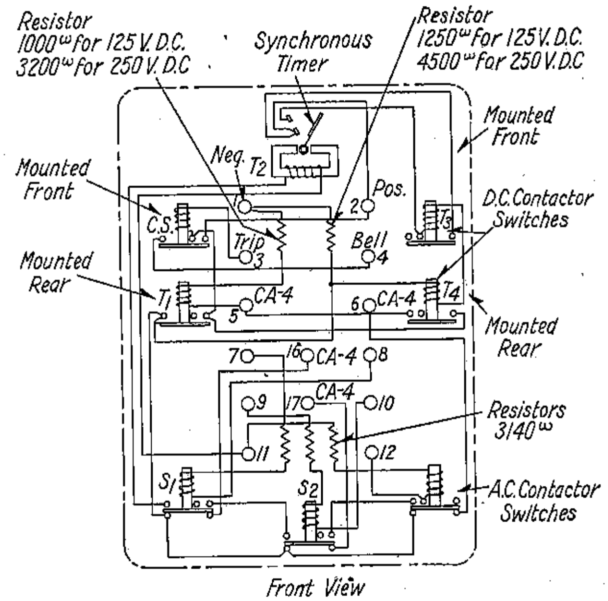

Fig. 10—Internal Wiring Diagram of the Magnetizing Inrush Tripping Suppressor.

OUTLINE DIMENSIONS IN INCHES

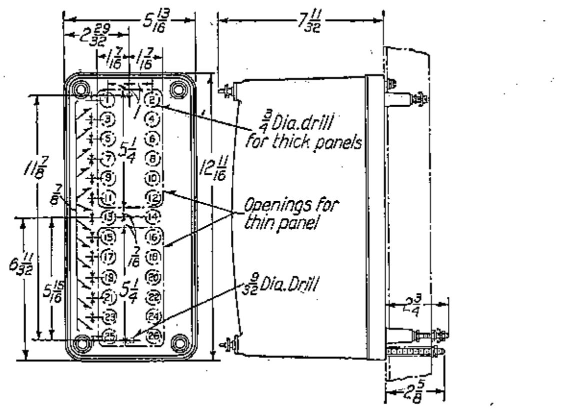

Fig. 11—Outline and Drilling Plan of the Type CA-4 Relay.

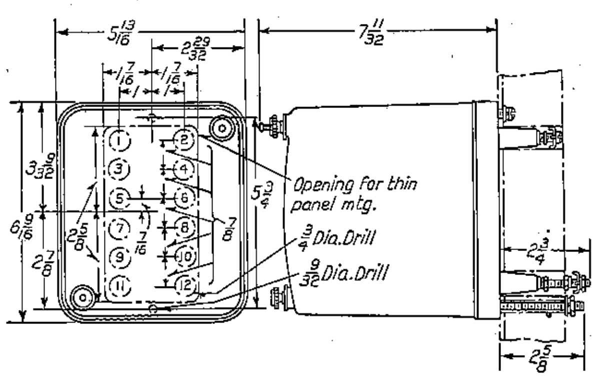

Fig. 12—Outline and Drilling Plan of the Magnetizing Inrush Tripping Suppressor.

Dimensions are for reference only. For official dimensions refer to nearest Westinghouse Sales Office.

TYPE CA-4 RATIO DIFFERENTIAL RELAYS—Continued

WIRING DIAGRAMS

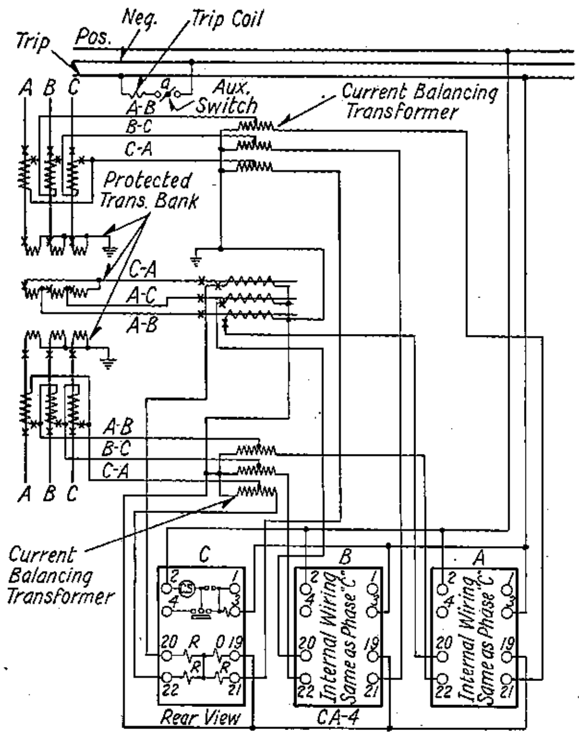

FIG. 13—EXTERNAL CONNECTIONS OF THE CA-4 RELAY WITHOUT THE MAGNETIZING INRUSH TRIPPING SUPPRESSOR FOR THE DIFFERENTIAL PROTECTION OF A STAR—DELTA—STAR TRANSFORMER BANK.

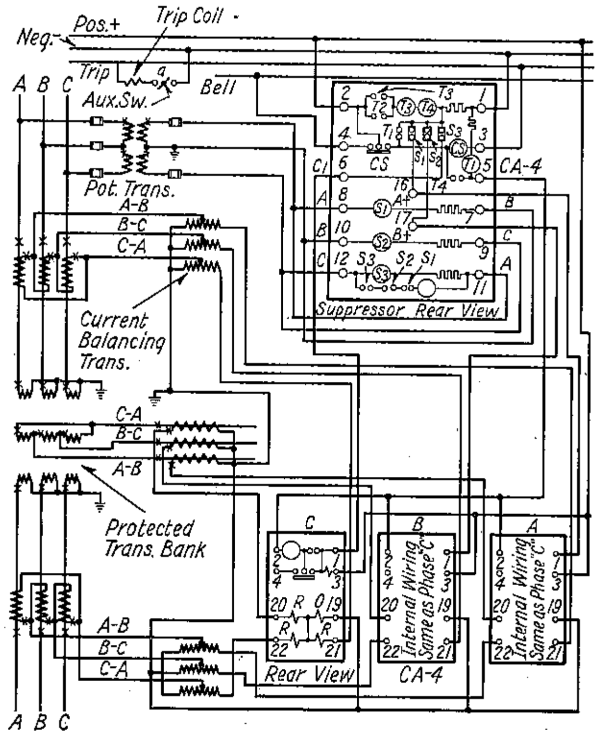

FIG. 14—EXTERNAL CONNECTIONS OF THE CA-4 RELAY AND THE MAGNETIZING INRUSH TRIPPING SUPPRESSOR FOR THE DIFFERENTIAL PROTECTION OF A STAR—DELTA—STAR TRANSFORMER BANK.

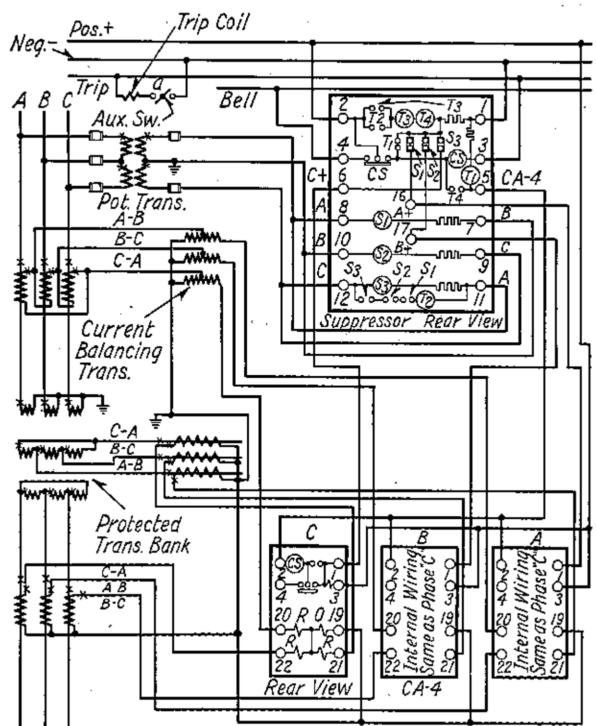

FIG. 15—EXTERNAL CONNECTIONS OF THE CA-4 RELAY AND THE MAGNETIZING TRIPPING SUPPRESSOR FOR THE DIFFERENTIAL PROTECTION OF A STAR—DELTA—DELTA TRANSFORMER BANK.

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