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Negative Sequence Current Relays Types COQ and POQ

Generator Protection Against Unbalanced Fault Currents

The COQ relay is designed to protect turbine or engine driven generators from damage due to thermal heating caused by negative sequence currents which flow during unbalanced faults on the power system. These negative sequence currents, in turn, induce 120-cycle rotor currents which tend to flow in the surface of the rotor's solid forging, and in the non-magnetic wedges and retaining rings. The I^2R loss caused by these induced currents can raise the machine temperature sufficiently to cause metal flow and resultant machine damage.

The relay can also be used to protect motors, synchronous condensers, and frequency changer sets against prolonged contribution to unbalanced faults.

Its burden is sufficiently low to permit the use of existing current transformers. Potential transformers are not required.

Sensitive Instantaneous Detection of Unbalanced Currents on 3-Phase Systems

The POQ high-speed relay provides sensitive detection of unbalances or unbalanced faults in three-phase power systems. It is commonly used to detect unbalances on feeder or distribution circuits, or to detect single phasing in generator or motor circuits.

Type POQ's sensitive polar unit is energized by the output of a negative sequence current filter. It will pickup on ½ ampere of negative sequence current and will withstand 5 amperes of positive sequence current continuously. It can detect phase failure on motor circuits having a maximum to minimum load variation as great as 5 to 1. The minimum single phased load current that can be detected is 1.0 ampere.

However, since the POQ will also operate for external faults, a timing relay such as type TD-5 should be used to effect coordination between the primary line relays and the POQ.

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Type COQ Characteristics

Overcurrent Unit

The COQ negative sequence relay is available with the following negative sequence current taps:

3 3.25 3.5 3.8 4.2 4.6 5.0

These tap values represent the current transformer secondary amperes which correspond to one per unit generator current. At these values of negative sequence current, the moving contact will leave the time dial stop and reach the stationary contacts in a time as determined by the time dial setting and as shown by Figure 3. For example, with a time dial setting of 4 the relay will close its contacts in 30 seconds with the above tap currents applied to the relay.

As shown by the curves in Figure 4, the relay's characteristic is defined by a generator characteristic $I_2^2T=K$. The relay characteristic is such that it coincides with the generator characteristic at 1 per unit negative sequence current, but at higher values of negative sequence current the relay characteristic is substantially parallel and slightly less than the generator characteristic. In this manner, a suitable margin of safety is obtained between the two characteristics.

Figure 4 shows how the relay characteristic parallels the constant I_2^2t curves where products in excess of rating are to be allowed.

Figure 5 provides a means of selecting a time dial setting that will restrict unbalanced fault duration to the desired limit.

Figure 6 demonstrates the use of a tap setting lower than the full load current of the machine to accommodate I_2^2T limits of 7 and 10 while still providing wide contact spacing. For this figure, a tap setting of 3 is used with a machine full load current of 4 amperes.

Typical time-current curves of the relay are shown in Figure 3. Minimum pickup is approximately 0.6 of the tap value current.

Trip Circuit Data

Main contacts on the COQ induction disc unit will close 30 amperes at 250 volts d-c and will carry this current for sufficient time to trip a circuit breaker.

Burden Data and Thermal Rating

Phase	Rating: Cont.	Amps 1 Second	Watts at 5 Amps	Volt-Amps at 5 Amps	Power Factor Angle
1	5	100	5.3	5.3	0°
2	5	100	0.0	0.98	90° lag
3	5	100	4.0	7.25	56° lag

Type POQ

The POQ relay provides sensitive instantaneous detection of unbalanced currents in a three-phase power system. It is operated by negative sequence current, and has a high speed polar unit which can be used to initiate tripping, or to sound an alarm.

Common applications include its use to detect unbalanced loads on feeder circuits, or to avoid thermal damage to motors as caused by single-phasing.

Operation

The polar unit of the POQ is energized by the rectified output of a saturating transformer which is energized by the filter output. When the relay is energized by tap value negative sequence current, the polar unit contact closes to energize an auxiliary contactor switch (CS-1) coil which is connected across battery voltage. Operating time of the CS-1 switch is ¾ of a cycle, at the end of which time the trip circuit will be completed if the polar unit contact remains closed. Inclusion of the CS-1 switch, adds a desirable shock-proof feature to the relay.

Characteristics

The following negative sequence current taps are available on the Type POQ relay.

.5 .6 .8 .1 1.5 2.0 2.5

These taps represent the negative sequence current that will operate the relay. At these values of negative sequence current, the polar unit will close its contacts to pickup the time delay switch.

Operating Time

POQ operating time is 1 to 2 cycles (60 hertz base).

Burden Data

60 cycle burden of the filter with positive sequence current applied (no output to polar unit) is:

Phase	A-c Rating in Amps Cont.	1 Second	Watts at 5 Amps	Volt-Amps at 5 Amps	Power Factor Angle
1	5	100	5.3	5.3	0°
2	5	100	0.0	0.98	90° lag
3	5	100	4.0	7.25	56° lag

Construction – COQ and POQ in FT-21 Case

1 Filter Reactor

The negative sequence current filter consists of a three-winding mutual reactor and a wire resistor assembly with adjustable sliders. It is factory-adjusted so that its output is proportional to the negative sequence current input.

2 Tap Block

Taps provided on the tap block allow selection of the minimum negative sequence current input to the filter which will just cause the relay contacts to close (pickup is approx. 0.6 of tap value for the COQ).

3 Time Dial (COQ Only)

Positioning of the time dial at its various numbered settings determines the setting of the relay for the permissible $(I_2)^2t$ thermal characteristic of the protected machine.

4 Stationary Contact

COQ
Made of silver. Has sufficient wipe to assure positive contact action.

POQ
The right hand contact of the POQ polar unit (see "P" in figure 0) is wired into the relay trip circuit. The lefthand stationary contact serves as a backstop for the moving contact assembly.

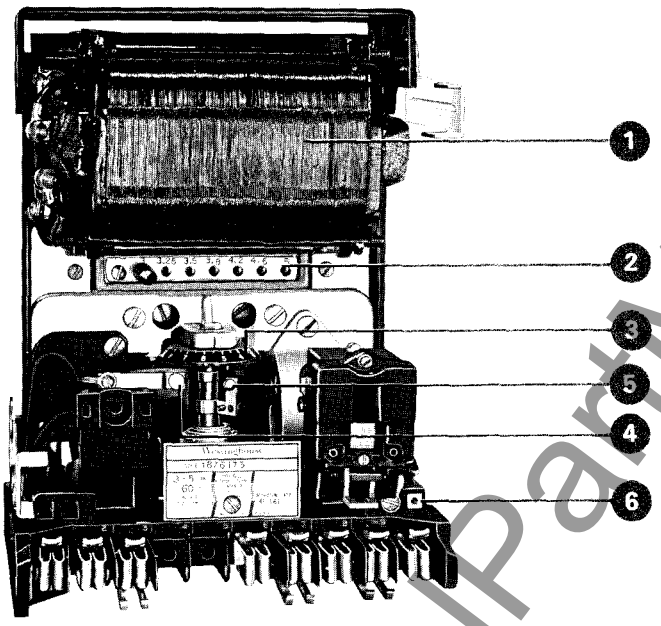
5 Moving Contact

COQ
Clamped to an insulated section of the COQ's induction disc shaft. Current passes through a spiral spring to the moving contact.

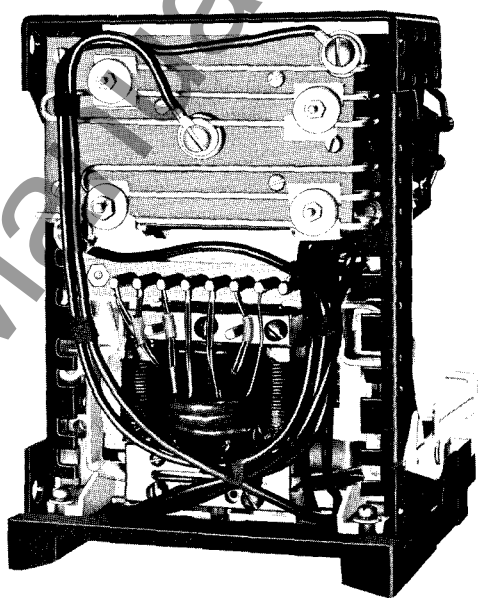
POQ
The contacts of the polar unit are connected in series with an auxiliary contactor switch (CS-1) to avoid the possibility of undesired tripping due to vibration or accidental shock.

Negative Sequence Current Relays Types COQ and POQ

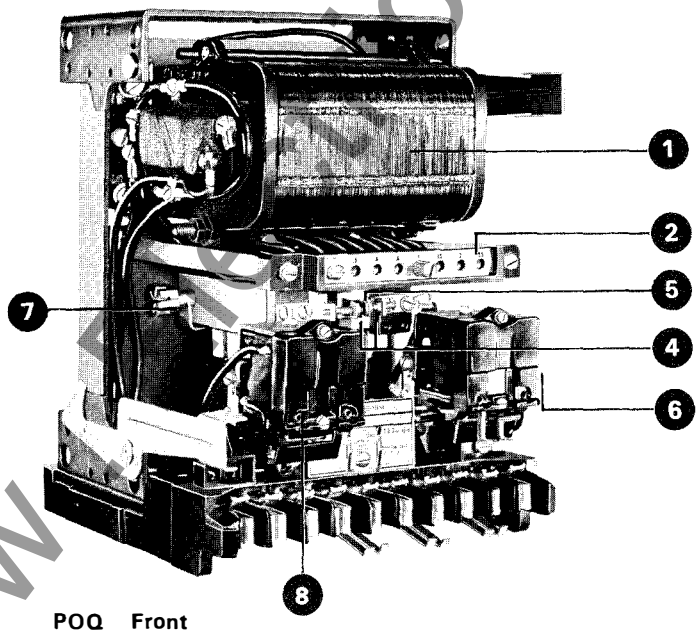
Construction



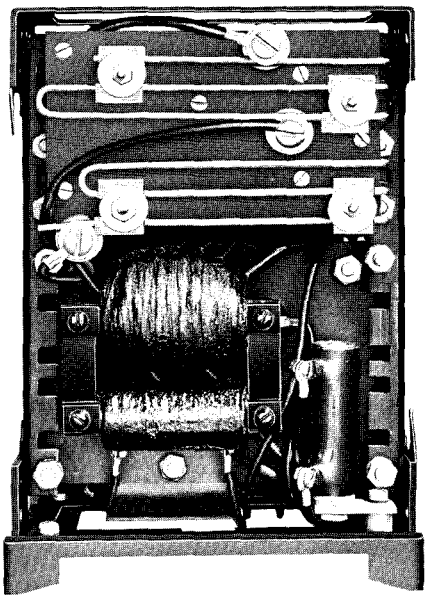
COQ Front



Rear



POQ Front



Rear

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Construction, continued

6 Indicating Contactor Switch

When energized, the ICS causes an operation indicator target to drop into visible position – indicating that the relay has operated.

Resetting is manual, by means of a pushrod external to the case.

ICS Unit Burden and Rating

ICS Tap: Amps	Coils Rating in Amps Cont.	1 Second	Resistance in Ohms
0.2	0.4	11.5	6.5
2.0	3.2	88.0	0.15

7 Magnetic Shunt Screws

POQ Only

Sensitivity of the polar unit assembly is adjusted by means of two screw assemblies; one on each side of the unit's magnetic frame. Drawing out of the left shunt increases the amount of current required to close the polar unit contact. Drawing out of the right hand shunt decreases the minimum trip current. Both shunts are held firmly in position by a spring-type clamp.

8 Auxiliary Contactor Switch (CS-1)

POQ only (not shown on photo)

Energized by the closing of the polar unit contact. Prevents accidental closing of the relay contacts due to jarring of the relay panel. Operates in about ¾ of a cycle. Has a coil resistance of about 170 ohms. The assembly does not include an operation indicator target.

ANSI Standards and Limitations

This material is reproduced from the "American Standard Requirements for Salient Pole Synchronous Generators and Condensers," C50.12-1965 and "American Standard Requirements for Cylindrical Rotor Synchronous Generators," C50.13-1965, copies of which may be purchased from the American National Standards Institute, 1430 Broadway, New York, N. Y. 10018.

C50.12

6. Short-Circuit Requirements

A machine shall be capable of withstanding, without injury, a 30-second, three-phase short circuit at its terminals when operating at rated kva and power factor, at 5 percent over-voltage, with fixed excitation.② The machine shall also be capable of withstanding, without injury, any other short circuit at its terminals of a 30-second duration or less, provided the machine phase currents under fault conditions are such that the negative phase sequence current (I_2), expressed in terms of per unit stator current, at rated kva, and the duration of the fault in seconds (t), are limited to values which give an integrated product (I_2^2t) equal to or less than the values shown below, and provided also the maximum phase current is limited, by external means to a value which does not exceed the maximum phase current obtained from the three-phase fault.

Type of Synchronous Machine	Permissible I_2^2t②
Salient pole generator	40
Synchronous condenser	30

② Machines subjected to faults between these limits may suffer varying degrees of damage: for faults in excess of 200% of these limits serious damage should be expected.

C50.13

6. Requirements for Abnormal Conditions

6.1 Armature Winding Short-Term Thermal Requirements

The generator armature shall be capable of operating a 130 percent of rated armature current for at least one minute, starting from stabilized temperatures at rated conditions.

Note 1: The permissible armature at currents times up to 120 seconds, based upon the same increment of heat storage as defined in 6.1, will be:

Time (seconds)	10	30	60	120
Armature current (percent)	226	154	130	116

Note 2: It is recognized that armature temperatures will exceed rated load values under these conditions and, therefore, the machine construction is based upon the assumption that the number of such operations at armature currents to the limits of Note 1 will occur not more than two times per year.

Characteristics

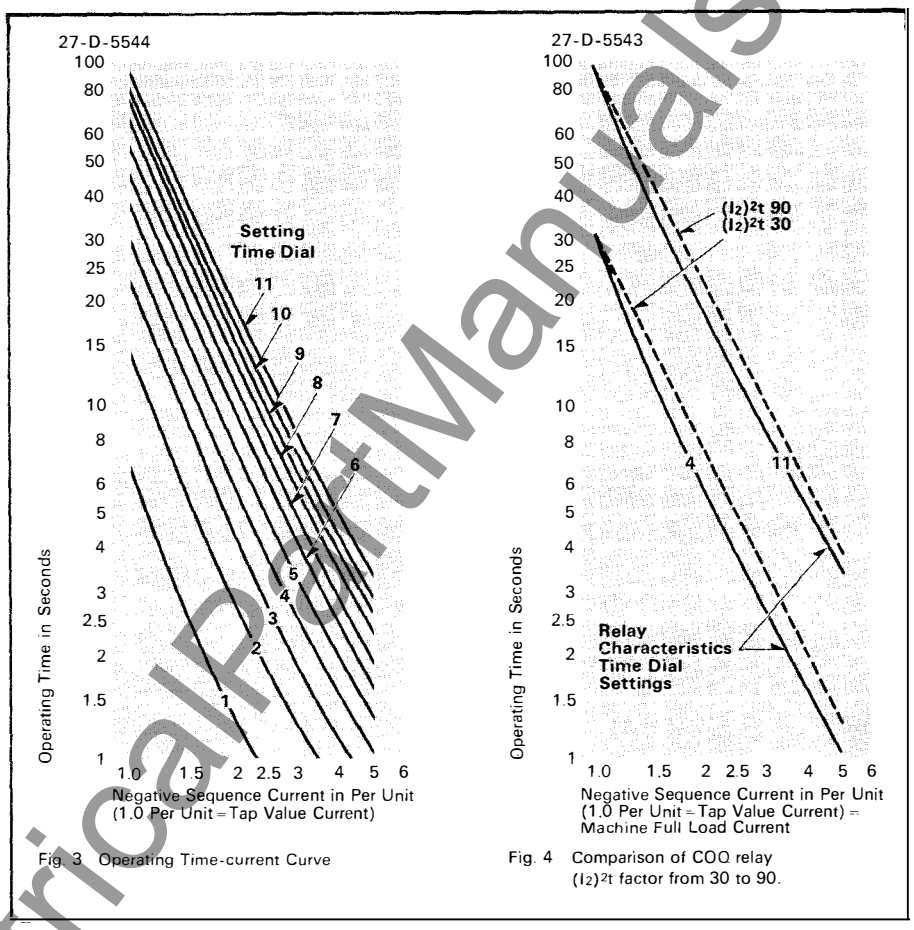

Fig. 3 Operating Time-current Curve

Fig. 4 Comparison of COQ relay $(I_2)^2t$ factor from 30 to 90.

Negative Sequence Current Relays Types COQ and POQ

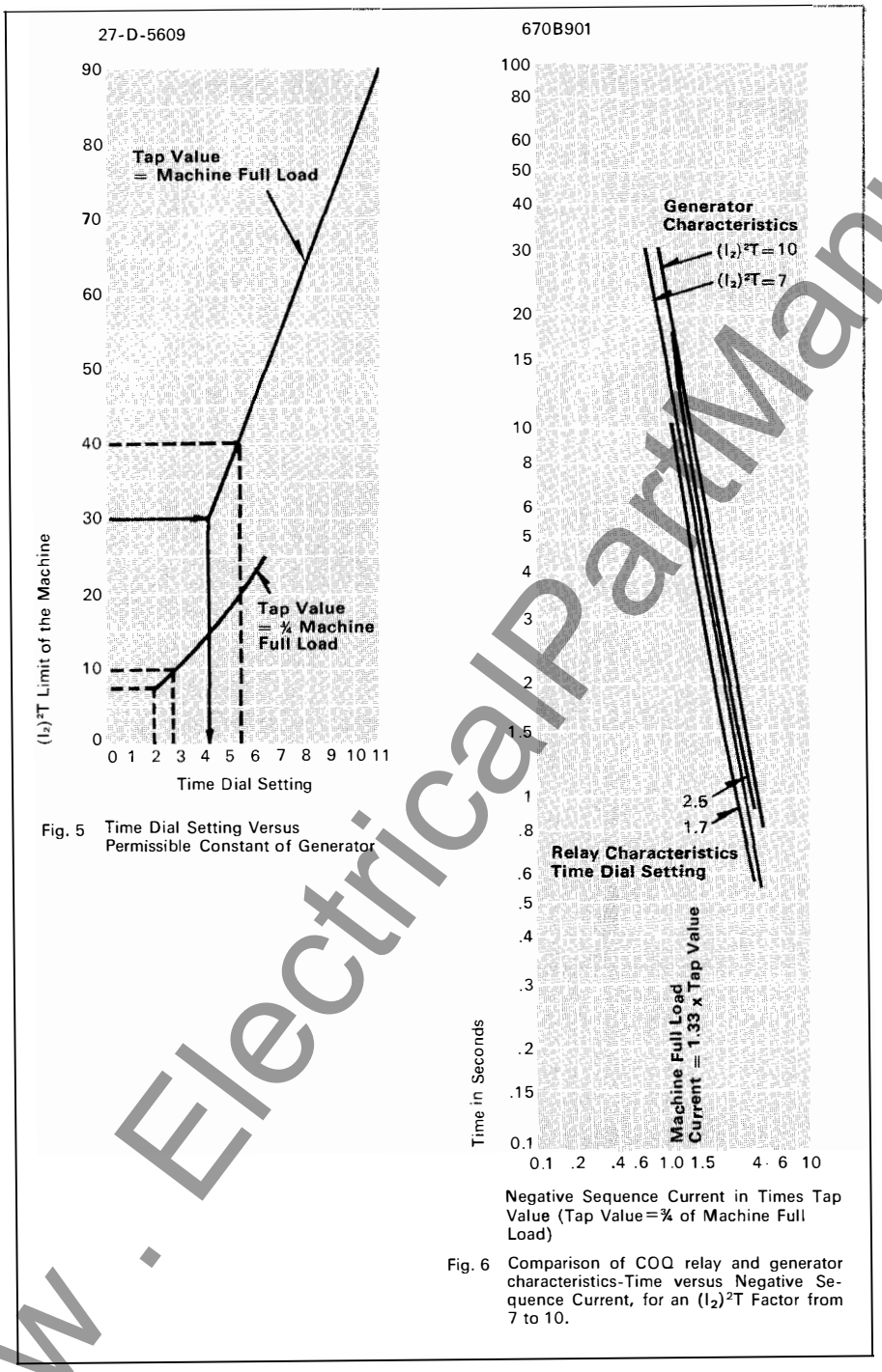

Fig. 5 Time Dial Setting Versus Permissible Constant of Generator

Fig. 6 Comparison of COQ relay and generator characteristics-Time versus Negative Sequence Current, for an $(I_2)^2T$ Factor from 7 to 10.

6.2 Field Winding Short-Time Thermal Requirements

The generator field winding shall be capable of operating at a field voltage of 125 percent of rated-load field voltage for at least one minute starting from stabilized temperatures at rated conditions.

Note 1: The permissible field voltages at times up to 120 seconds, based upon the same increment of heat storage as defined in 6.2, will be:

Time (seconds)	10	30	60	120
Field voltage (percent)	208	146	125	112

Note 2: It is recognized that field winding temperatures under these conditions will exceed rated-load values and, therefore, the machine construction is based upon the assumption that the number of such operations at field voltages to the limits of Note 1 will occur not more than two times per year.

6.3 Rotor Short-Time Thermal Requirements for Unbalanced Faults

The generator rotor shall be capable of withstanding, without injury, the effects of unbalanced short circuits at the armature terminals for times up to 120 seconds, based upon a constant rate of heat being generated and negligible heat dissipation, provided the integrated product (I_2^2T) of generator negative phase-sequence current (I_2) and time (T) does not exceed the values listed below. Negative-phase-sequence current shall be expressed in per unit stator current at rated kva and time shall be expressed in seconds.

Type of Cylindrical Rotor Synchronous Generator	Permissible I_2^2T①
Conventionally-cooled	30
Conductor-cooled	10

① Generators subjected to faults between these limits and 200 percent of these limits may suffer varying degrees of damage; for faults in excess of 200 percent of these limits, serious damage may be expected.

6.4 Mechanical Requirements for Short Circuit

The generator shall be capable of withstanding, without mechanical injury, any type of short circuit at its terminals for times not exceeding short-time thermal requirements, when operating at rated kva and power factor and five percent overvoltage, provided the maximum phase current is limited by external means to a value which does not exceed the maximum phase current obtained from the three-phase fault.

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Internal Wiring (Front View) Type COQ

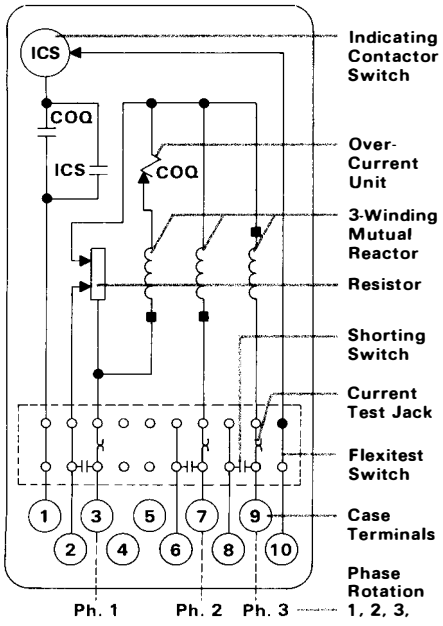


Figure 6: Neutral Connection of Three Phases Formed Within The Relay

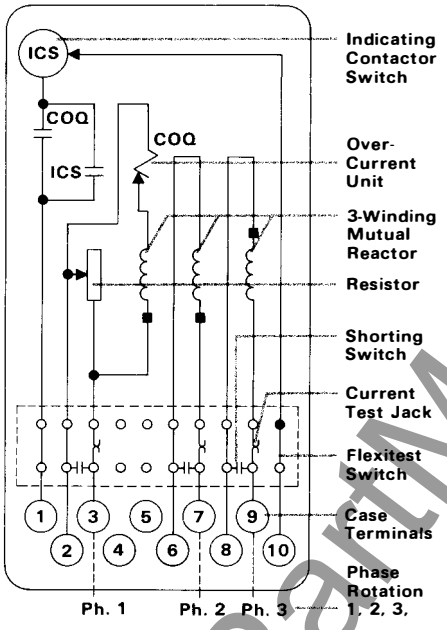


Figure 7: Neutral Connection of Three Phases External to The Relay

Internal Wiring (Front View) Type POQ

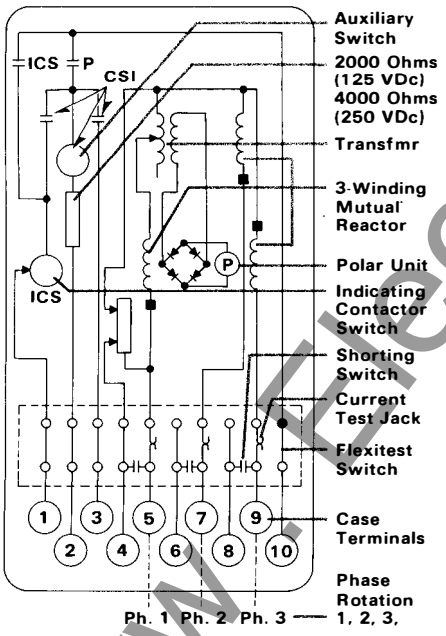


Figure 8

Note: Terminals 4, 6, and 8 are to be Jumped at Relay Case.

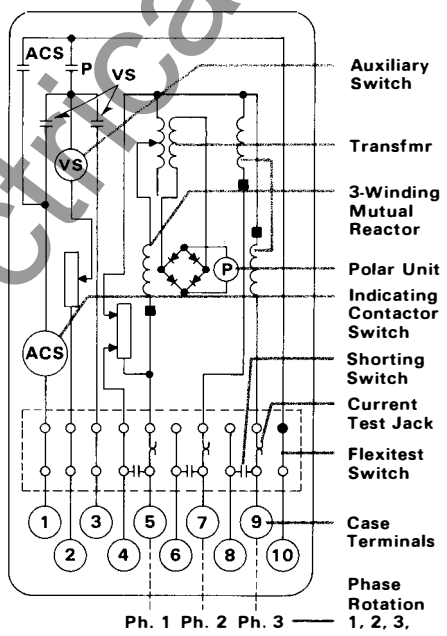


Figure 9: Type POQ for Ac Controlled Trip Circuit

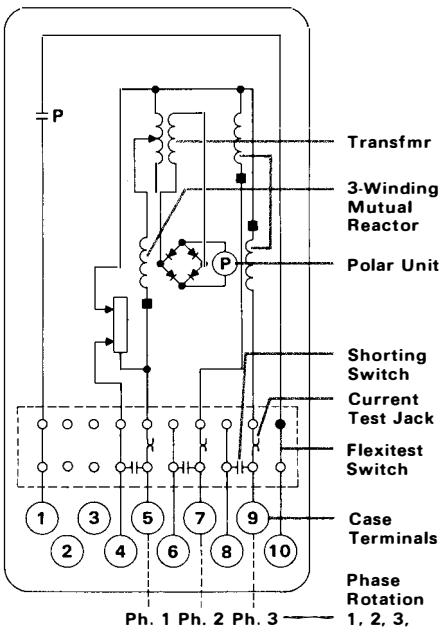


Figure 10: Type POQ Without ICS and Auxiliary Switch

Negative Sequence Current Relays Types COQ and POQ

External Wiring (Type COQ)

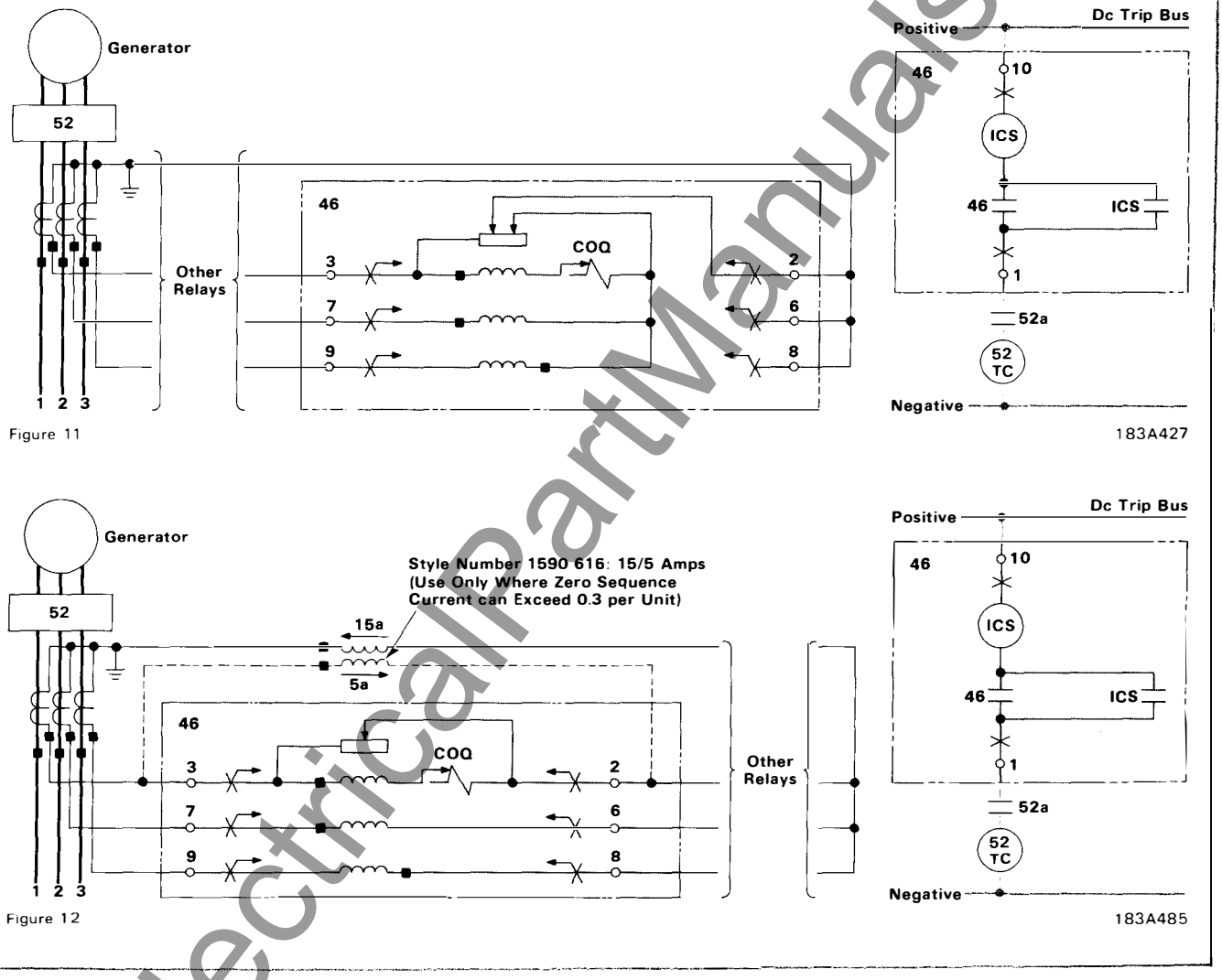
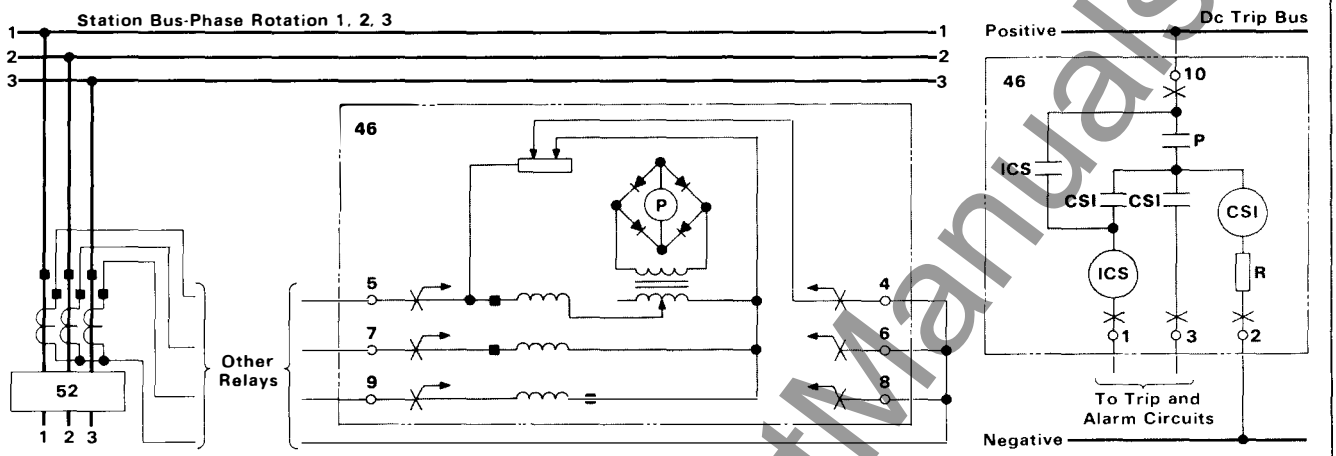


Figure 11

Figure 12

Negative Sequence Current Relays Types COQ and POQ

External Wiring



Legend:

46 — Type POQ Relay
P — Polar Unit
ICS — Indicating Contactor Switch
CSI — Auxiliary Switch

Figure 13

Further Information

Prices: Price List 41-020
Instructions:
COQ: Instruction Leaflet 41-161
POQ: Instruction Leaflet 41-162.2
Other relays: Protective Relay Index 41-000
Flexitest case: Descriptive Bulletin 41-075
WL switches: Descriptive Bulletin 37-250
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