The Return of Current Balance Relaying on The Montana Power Company System

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Introduction to Current Balance Relaying

When two parallel, nearly equal impedance transmission lines are bussed together at their ends, the lines can be relayed in the current balance or transverse differential mode. In this scheme, Phase A current in one-line is balanced against Phase A current in the other. The same applies to Phases B and C and the ground relay. External faults and load current results in balanced currents in the lines and the current balance relays do not respond to these. Only internal faults result in operation of the current balance relays.

Figure 1 is a simplified system one-line and relaying diagram. Current balance relaying is shown applied to Breakers P and Q. Not shown is equivalent relaying that would be applied to R and S. On short paralleled lines, 21Z1 and 67NI could be omitted.

Current balance relaying is generally applied in a pilotless system although a pilot system could be used with it to improve its performance. More will be said about this later.

Figure 2 shows a three-wire diagram of current balance relaying applied to all three phases and ground. In the interest of economy, this relaying could be applied to A, C and ground. Also current balance relaying can be applied to the ground relaying function only. This can greatly enhance the performance of the existing relaying since the great majority of faults involve ground.

A Brief History of Current Balance Relaying

Before vacuum tube electronics were applied to line relaying, current balance relaying was one of the few relaying schemes that promised high speed fault clearing. Over the years, current balance relaying has died out in favor of various pilot systems.

The only commercially available current balance schemes with which the author is familiar are the Westinghouse HD and the General Electric CFCB. Only the Westinghouse HD relay has been applied on the Montana system. Both of the above relays are now obsolete.

History of Current Balance Relaying on the Montana System

In the mid-sixties, current balance relaying was applied on three different sets of paralleled lines. All used the Westinghouse HD relay. Figure 3 is typical of the tripping schemes installed on the Clyde Park-Livingston 50 kV lines and the Hauser Lake-ASARCO 69 kV lines. Figure 3 shows the interlocking that is necessary between the breakers. Also notice a time delay relay which operates in the backup mode if one of the lines is out-of-service. On these two sets of lines, current balance relaying with the backup timer represent the only protection available. Over the years these relays have performed very well.

The third application of current balance relaying was on the Mill Creek-South Butte 161 kV lines. These lines have current balance ground relaying only and depend upon stepped distance relaying for other types of faults. The HD scheme was changed out early in 1983 to an electromechanical current balance scheme using conventional relays. We are in the process of trying to patent this system. To date, two ground faults have appeared on these lines and have cleared at high speed by the new relaying.

Sequential Instantaneous Tripping for End Zone Faults

Figure 4 shows a pair of parallel transmission lines on which end zones have been drawn. For faults in the middle zone, the ends will both clear instantaneously. For faults in the end zones, any current balance relaying scheme without using a pilot channel will have to clear sequentially. Breaker R nearest the fault will be first to trip. With the redistribution of fault current, Breaker P will then trip. A direct transfer-trip pilot could improve this situation. When Breaker R's current balance relay sees the fault, a transfer-trip could be initiated to trip P.

Tapped Loads and Lines

A transmission system with tapped loads and lines is shown in Figure 5. As long as the banks are delta connected on the high voltage side, no problems will be encountered with the current balance ground relaying. If the banks are quite large, a fault on their secondary may trip the current balance phase relaying. To remedy this situation the current balance phase relaying should be monitored by Zone 2 distance relays.

Zone 2 Monitoring of the Current Balance Phase Relaying

Figure 6 is a demonstration showing the necessity of monitoring phase current balance relays with a Zone 2 distance relay. The condition described has Breaker P tripped out on a close-in A-G fault. Breaker R is still closed but its ground relay is in the process of tripping R. Note that current in B and C phases of Breaker S is larger than current in B and C of Breaker R; therefore, S can trip falsely if not monitored by a Zone 2 distance relay.

Recommended Tripping Schematic

Figure 7 shows the recommended tripping schematic when using a modern current balance relaying system. Notice C.B. relaying is only applied on A and C phases and ground. Also time delayed backup relaying is provided by the Zone 2 distance relay and the directional ground relay in connection with the timer 62/X. The Zone 2 distance relay is shown monitoring the Phase C.B. relays.

Settings for C.B. Relaying

On the surface, very sensitive relay settings would seem to be in order on C.B. relay systems. However, one should remember that current transformers can perform differently for the same magnitude of primary current due to saturation effects. Therefore, very sensitive settings should be avoided. A relay with a range of 2-8 amperes should give enough sensitivity with the ground relay set somewhat more sensitively than the phase relays. The end zones of Figure 4 expand as the relay is set less sensitively.

Paralleled lines of unequal impedance can still use C.B. relaying. One method of achieving fairly well balanced secondary currents is to adjust the primary CT ratio. For instance, with 600/5 current transformer perhaps one could use the 120/1 tap on one breaker and the 100/1 tap on the other to achieve reasonable balance.

On lines with a moderate impedance imbalance, compensation can be made by not choosing sensitive settings.

Case with Source at One End and Load at the Other

Referring back to Figure 1, if there was no source at the Breakers R and S location, then C.B relaying cannot be applied there. It can still be used on P and Q however. On R and S very sensitive directional or directional distance relays can be used. End zones of sequential instantaneous tripping will exist in this system just as was described in Figure 4.

Current Balance Relaying in Ring Buses or Breaker and One-Half Schemes

Figure 8 shows how C.B. relaying can be applied even in complicated breaker configurations like breaker-and-one-half schemes. Notice that the "X" auxiliary relay trips Breakers P and Q and blocks the "Y" auxiliary relay.

Summary of Advantages and Disadvantages of C.B. Relaying

Advantages of C.B. Relaying:

1. Requires no pilot.
2. Works well for highly coupled lines.
3. Can be set quite sensitively.
4. Inexpensive.
5. Very reliable.

Disadvantages of C.B. Relaying:

1. Out-of-service if paralleled line is out for maintenance. Scheme then reverts to time delayed backup relaying.
2. Does not allow three terminal line operation unless the matched impedance lines terminate at all three busses and each bus is a strong source.

Future of C.B. Relaying on The Montana Power Company System

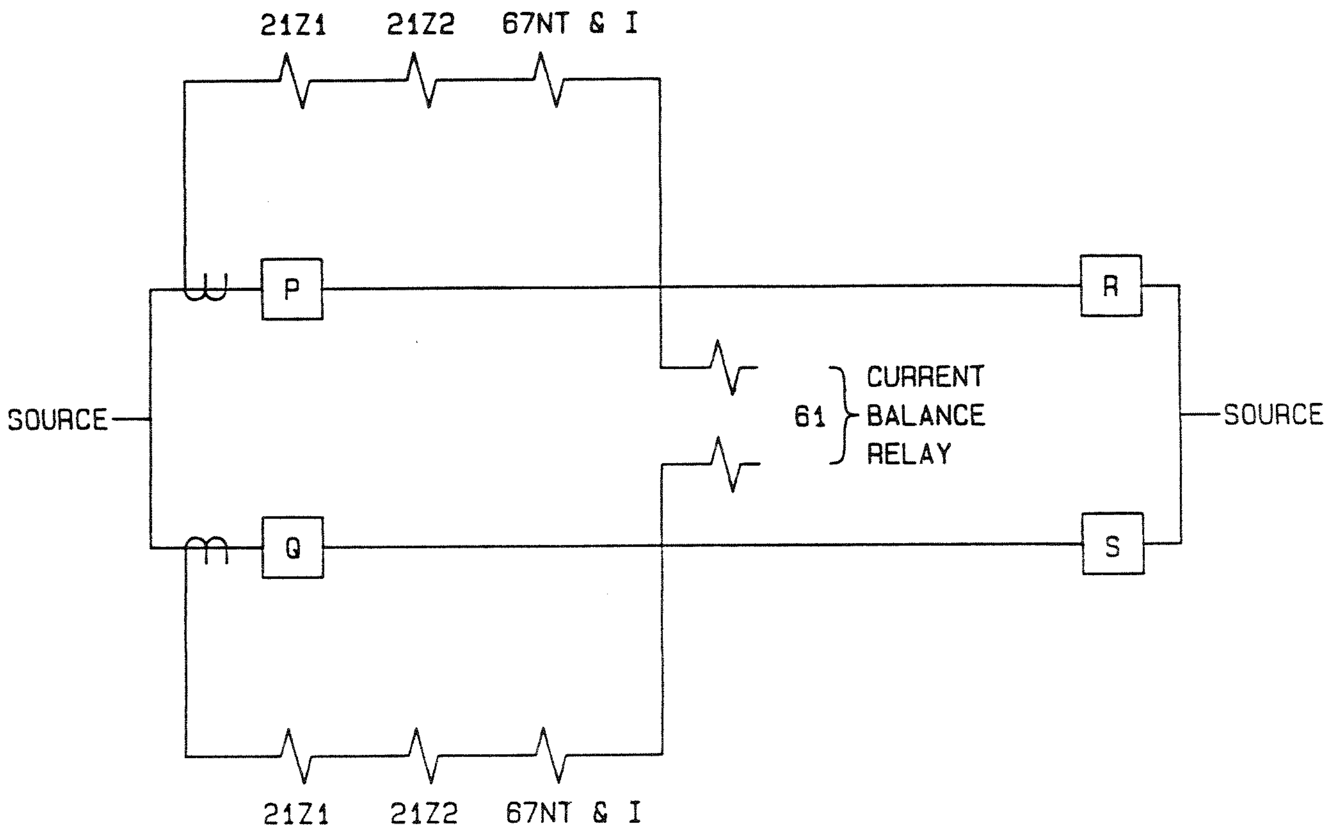
We at Montana Power are embarking on a new course in protective relaying. The new policy will be to apply fewer pilot schemes than we are currently using. We are doing this because of the high cost of pilots whether we build them ourselves or lease them from Bell. Another reason is the questionable reliability of many pilot schemes.

Current balance relaying fits nicely into this policy of fewer pilots because it doesn't need a pilot to work well.

In 1984, two sets of paralleled lines will get new current balance relaying. These will be electromechanical C.B. relays. Tetragenics, a wholly-owned subsidiary of Montana Power, will be designing a solid state C.B. relay for our own use as well as for sale commercially.

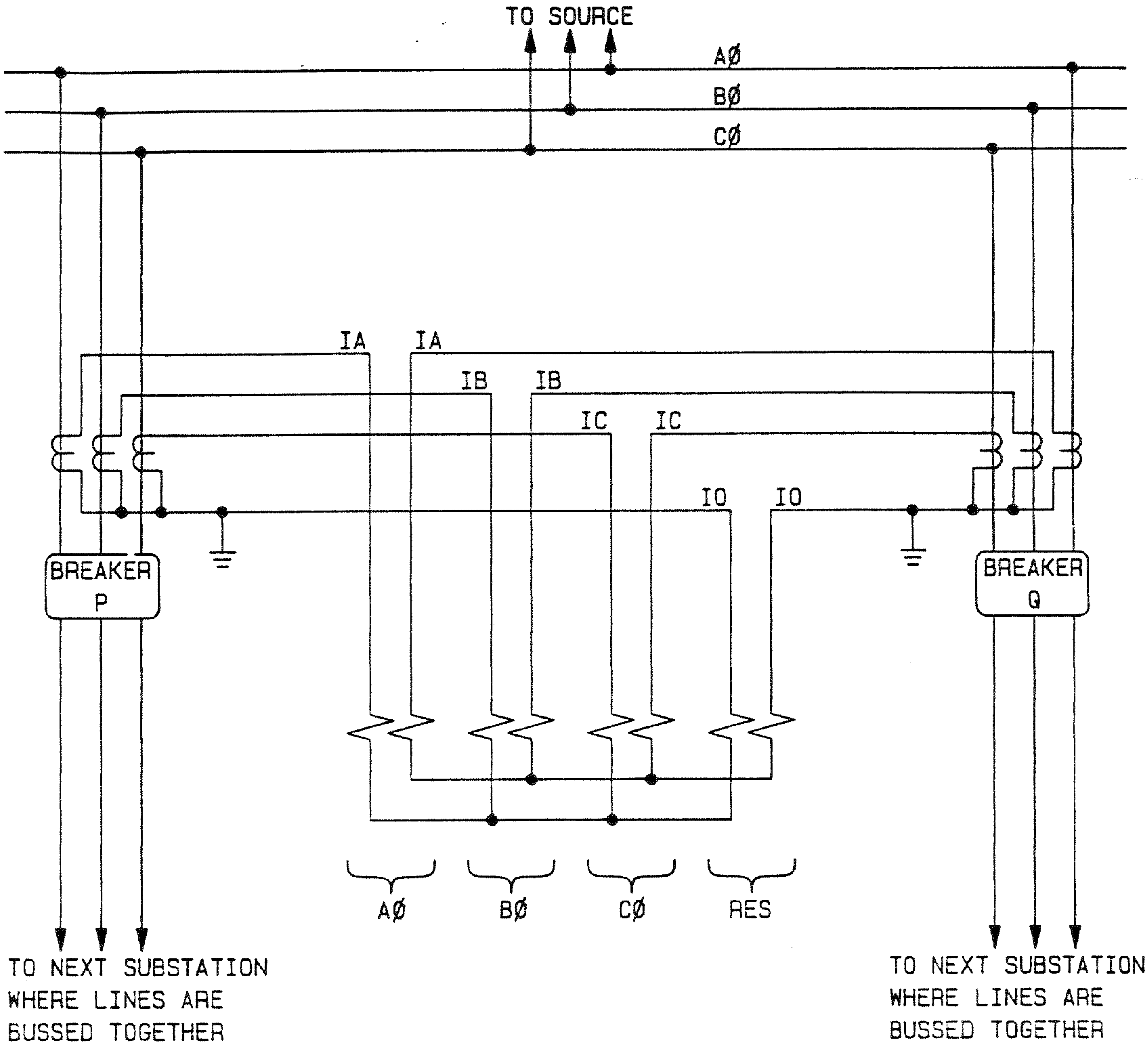
Reference:

The Relay Protection of High Voltage Networks; GI Atabekov, Pergamon Press, 1960



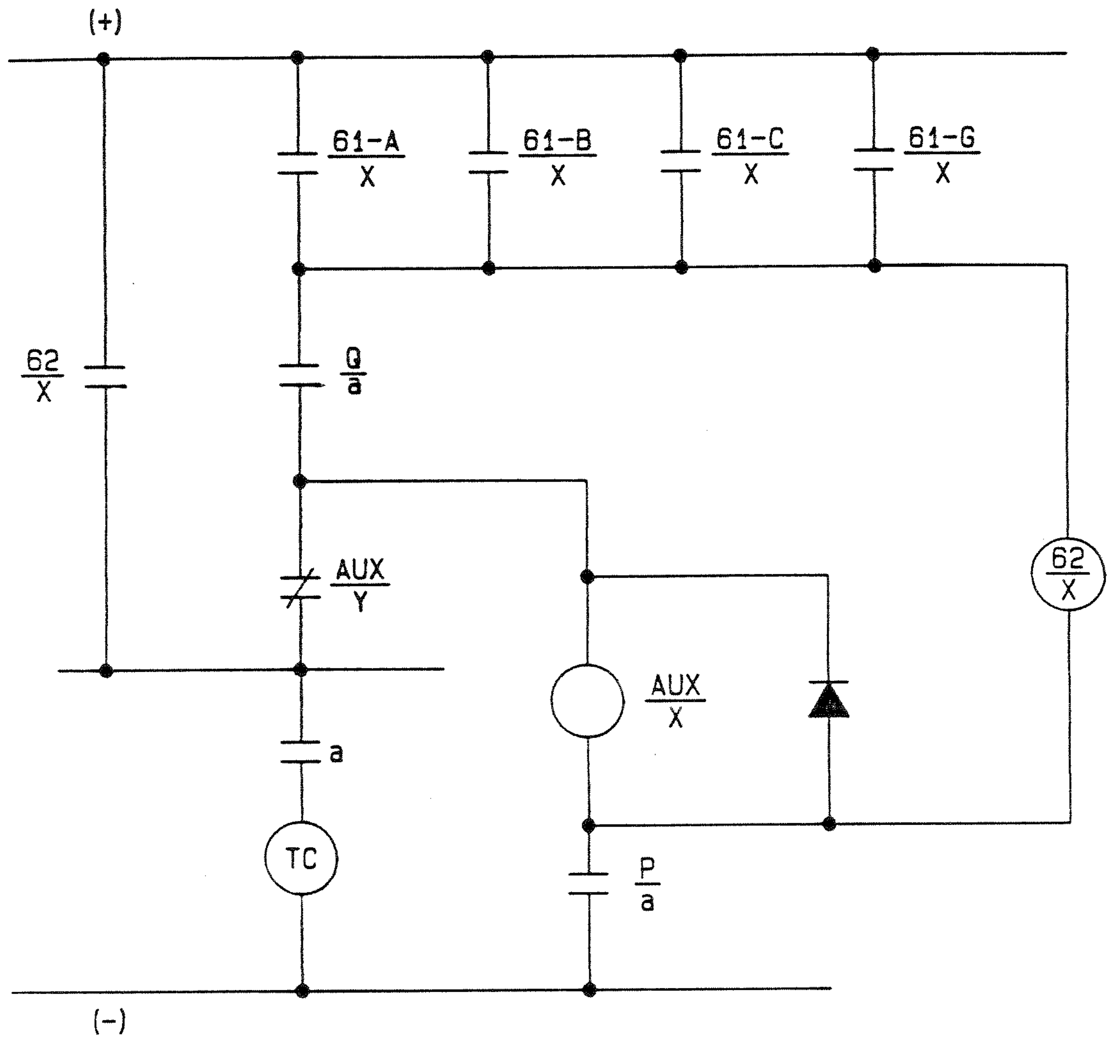
SIMPLIFIED SYSTEM ONE LINE AND RELAY DIAGRAM

FIG. 1



THREE-WIRE DIAGRAM SHOWING CURRENT BALANCE RELAYING

FIG. 2



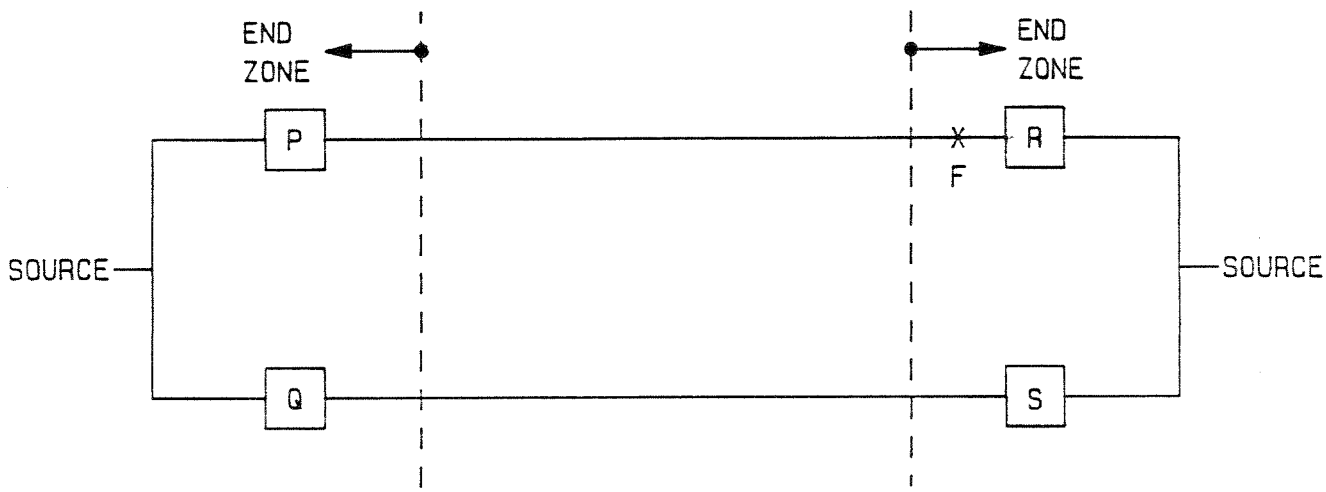
TRIP CIRCUIT FOR BREAKER P

NOTES:

1) "X" CONTACTS TRIP P AND BLOCK Q
2) "Y" CONTACTS TRIP Q AND BLOCK P

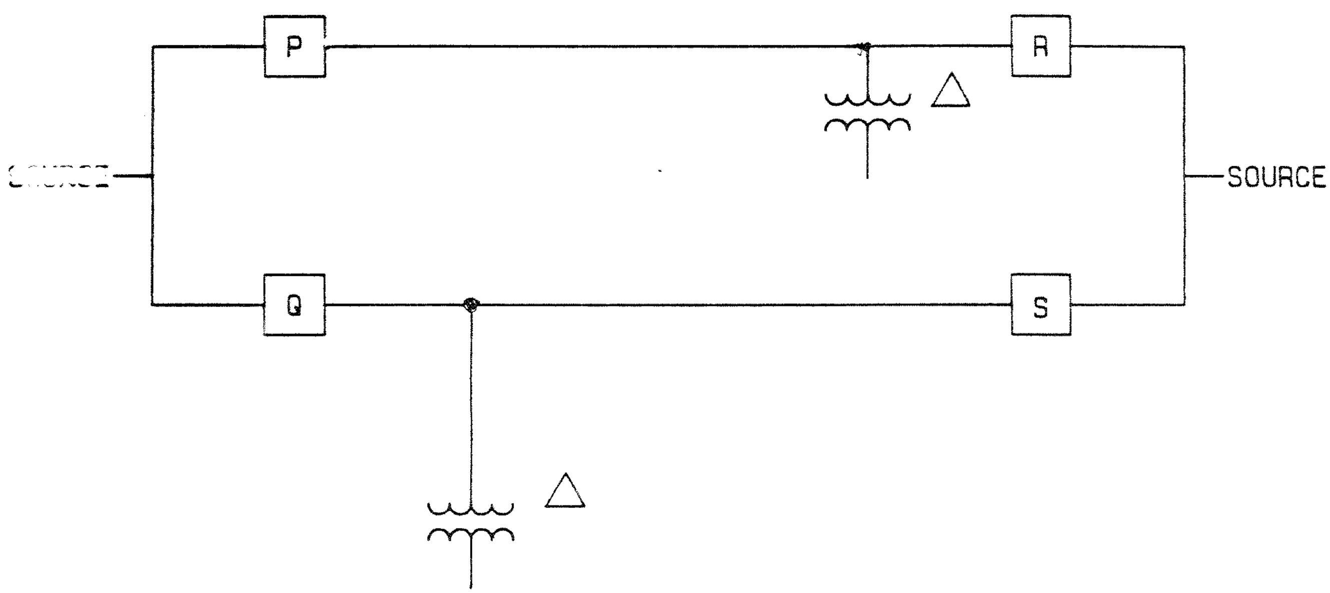
TRIPPING SCHEME USED WITH HD CURRENT BALANCE RELAYS

FIG. 3



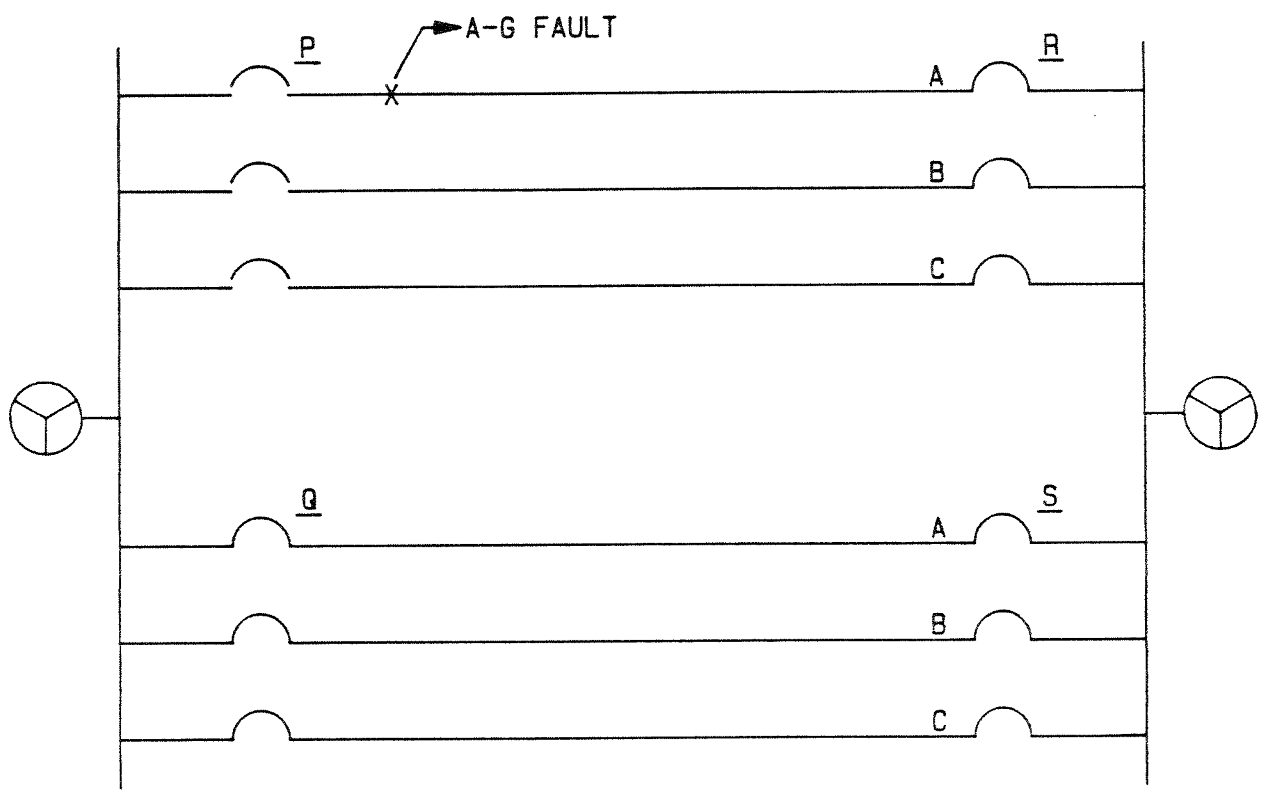
END ZONES WHERE CURRENT BALANCE TRIPPING TURNS OUT TO BE SEQUENTIAL INSTANTANEOUS

FIG. 4



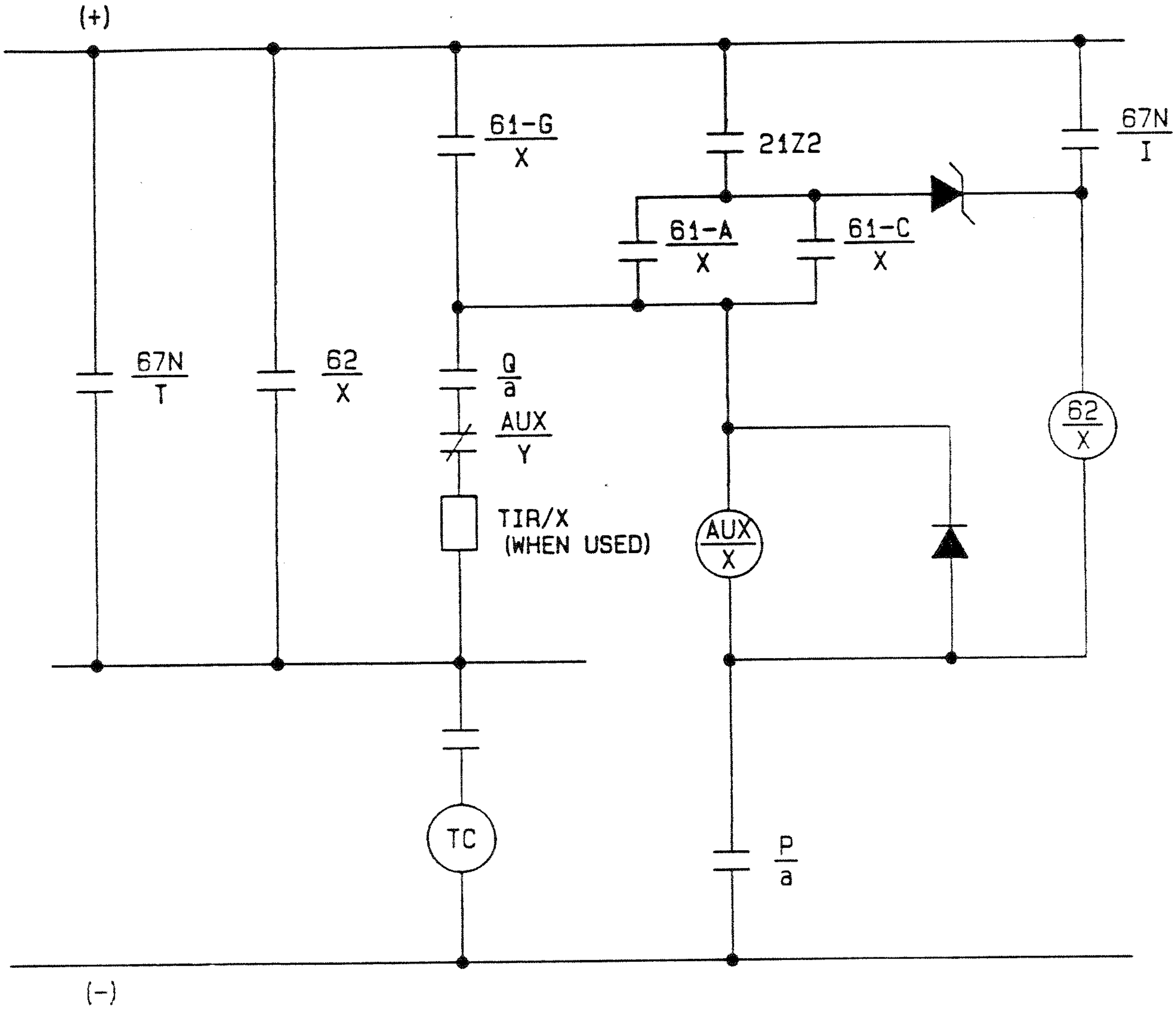
TAPPED LOADS AND LINES ON LINES
PROTECTED BY CURRENT BALANCE RELAYING

FIG. 5



THE NECESSITY OF MONITORING PHASE C.B.
RELAYS WITH A ZONE 2 DISTANCE RELAY

FIG. 6



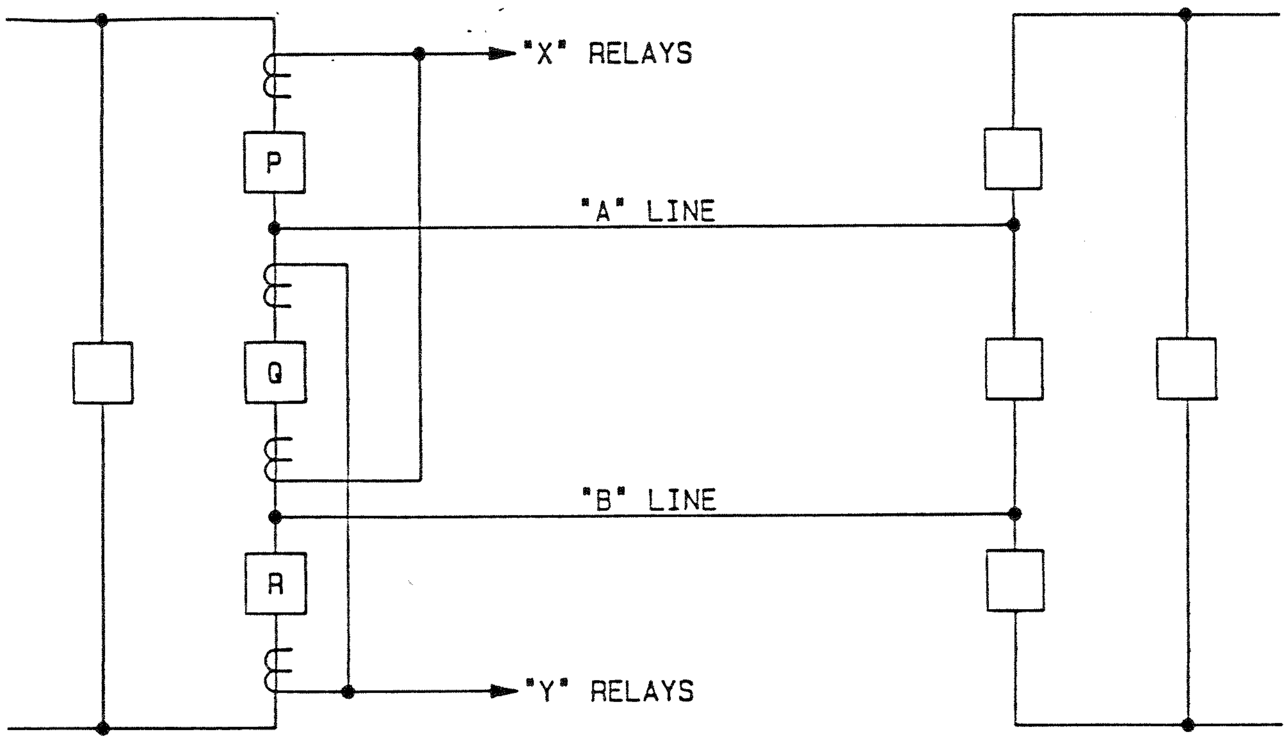
TRIP CIRCUIT FOR BREAKER "P"

NOTES:

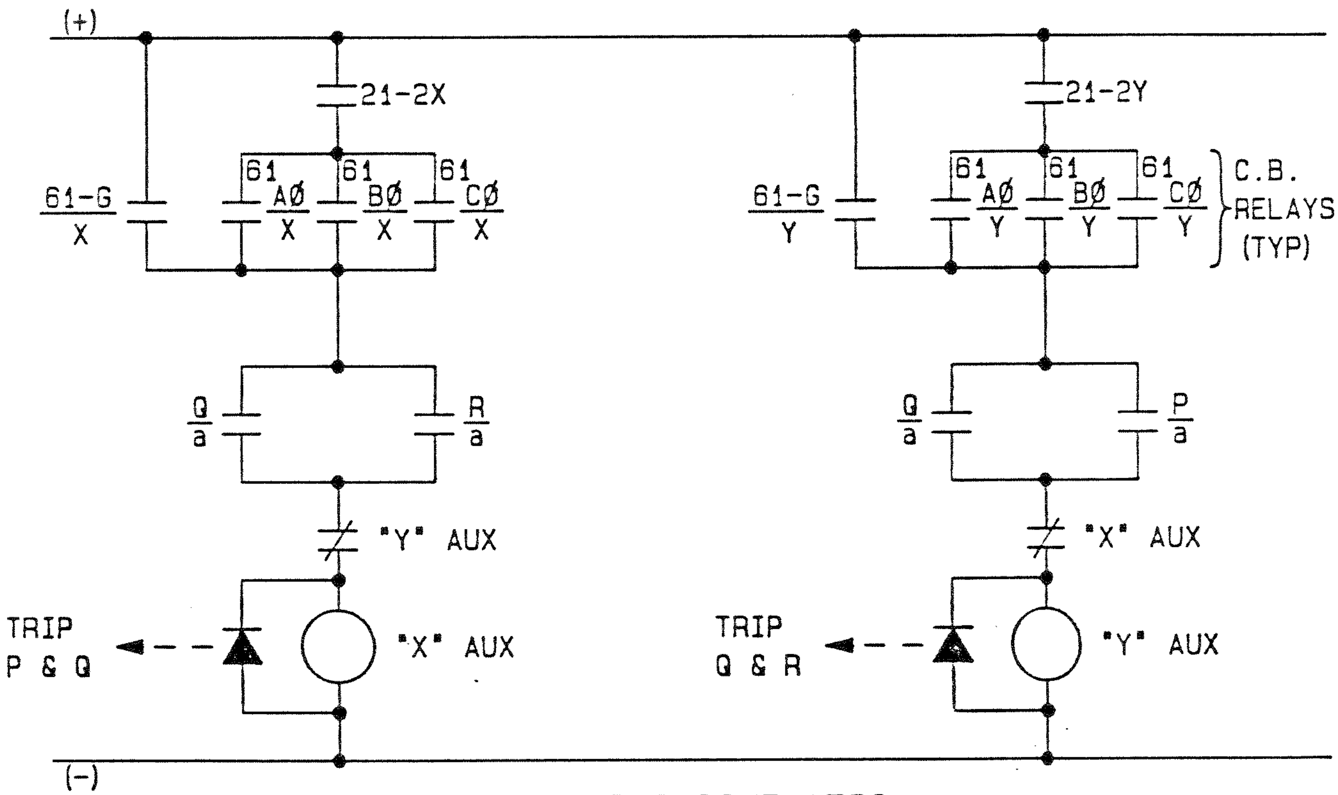
1) ON LONG LINES 67N/I COULD BE SET FOR DIRECT TRIPPING.

RECOMMENDED TRIPPING SCHEMATIC

FIG. 7



SYSTEM ONE-LINE DIAGRAM



TRIPPING SCHEMATIC

USING CURRENT BALANCE RELAYING IN RING BUSSES OR BREAKER AND ONE HALF SCHEMES

FIG. 8