INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

SELECTIVE POLE CARRIER RELAYING AND RECLOSING

OPERATION

The selective-pole carrier relaying scheme operates in the same manner as the standard carrier scheme described in I.L. 41-600.5 or 41-600.6 except that additional elements have been added and modifications made to provide selective single-pole tripping. That is, for all internal phase A-to-ground faults, only the phase A pole of the circuit breakers of both ends of the protected line will be opened to isolate the fault. In a like manner, only phase B pole will operate for phase B-to-ground faults, and only phase C pole for phase C-to-ground faults. For all internal two phase-to-ground faults the correct phases are selected to open the circuit breaker poles of the faulted lines at both ends of the line. Thus, for example, on an internal B-to-C-to-ground fault only the phase B and phase C poles of the circuit breakers at both ends of the line will open. On an internal phase-to-phase fault one phase of the two faulted phases is selected to open the correct circuit breaker pole. On a phase A to phase B fault, only the phase A pole will be opened, and on a phase C to phase A fault only the phase C pole will be opened.

On any three phase fault, grounded or ungrounded, all three circuit breaker poles will be opened. However, for any faults external to the line section being protected by the power line carrier the back up protection incorporated in this relaying scheme will in the event of an external fault initiate the tripping of the poles of all three phases of the circuit breaker regardless of the type of external fault.

When using the Selective Pole Carrier Relaying and Reclosing Scheme, the voltage rating of the circuit breakers should be carefully considered in line with NEMA rule SG-6-83.

The scheme utilizes three type HZ or HZM relays, one type HRK or HRP relay, one type HQS relay, one type RS or RSN relay, one type TS relay, one or two type SG relays as required, and one type MG relay. Where the type HZM relay is used a type HZM-3 relay is required.

The connection of these relays and their operation in the scheme is as follows with reference to figures 1 to 3. The directional and impedance elements of the type HZ or HZM relay are energized with star current instead of the usual delta current. Thus for a phase A to ground fault, only the phase A relay will receive fault current which would not be the case with delta current. This assures that phase B and C relays will not operate to cause incorrect tripping. However this connection requires that Z1 be set for less than the usual 80 or 90% of the protected line section, to prevent it from over-reaching on external double-line-to-ground faults. The setting will vary for different systems, since it is determined by the relative magnitude of the negative and zero sequence impedances.

Delta voltage on the impedance element provides the operation of only one relay on inter-phase faults. On a phase AB fault, the phase A relay receiving AB voltage operates because of the low voltage and high phase A current. Phase B relay, while it receives a high phase B current, does not operate except under extreme conditions because it receives BC voltage which is essentially uncollapsed. Similarly, phase B relay operates on a phase BC fault, and phase C relay on a phase CA fault.

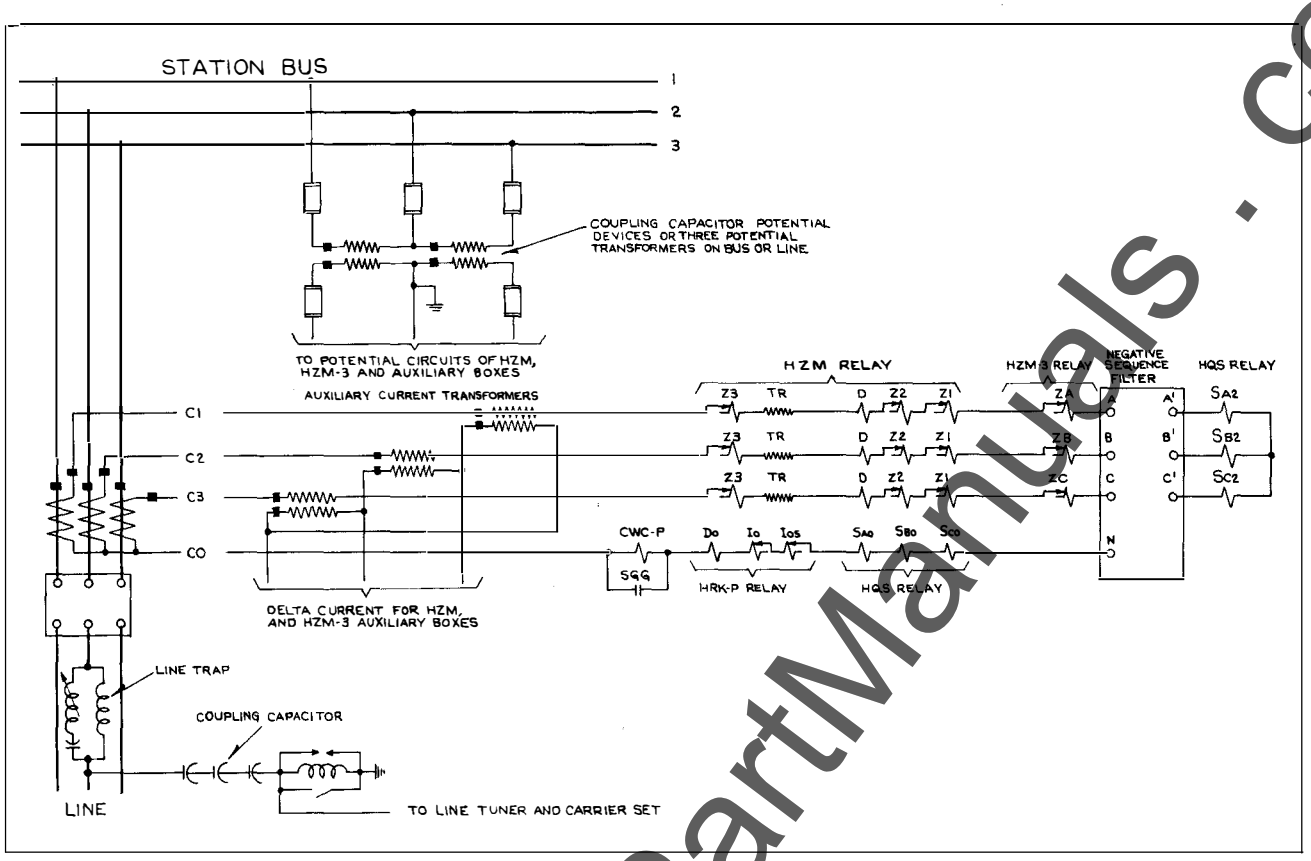

Fig. 1—Simplified A-C Schematic of the Selective Pole Carrier Relaying Scheme.

By using delta current on the HZM auxiliary box, there is no shift for various type faults in the angular position and displacement of the impedance circle. The star current in the impedance element does cause a change in the impedance circle diameter for various types of faults.

The type HQS phase selector relay is connected to receive negative sequence current from a three-phase negative sequence filter energized by the current transformers and the residual current from the neutral circuit of the current transformers. On all single line-to-ground faults, the zero sequence components of all three phases are essentially in phase with the negative sequence component of the faulted phase. This means on a phase-A-to-ground fault, for example, the phase A phase selector element, which has directional characteristics, will have contact-closing torque while the phase B and C elements will have contact-opening torque, since the B and C components of negative sequence current are essentially 120° out of phase with the negative sequence component of the unfaulted phase. For example, consider a phase B-C to-ground fault. In this case the phase A phase selector element will receive contact closing torque while the phase B and C elements will not, because the negative sequence components of these two phases are essentially 120° out-of phase with the respective zero sequence phase B and C components.

For phase faults not involving ground, the type HQS relay does not operate as the zero sequence currents are zero.

The three poles of the breaker are tripped as follows with reference to figures 2 and 3. On a single line-to-ground faults, the respective phase selector contacts, S_A, S_B, or S_C, of the type HQS relay closes its make contact and opens its associated back contact. The make contact thereby selects the proper

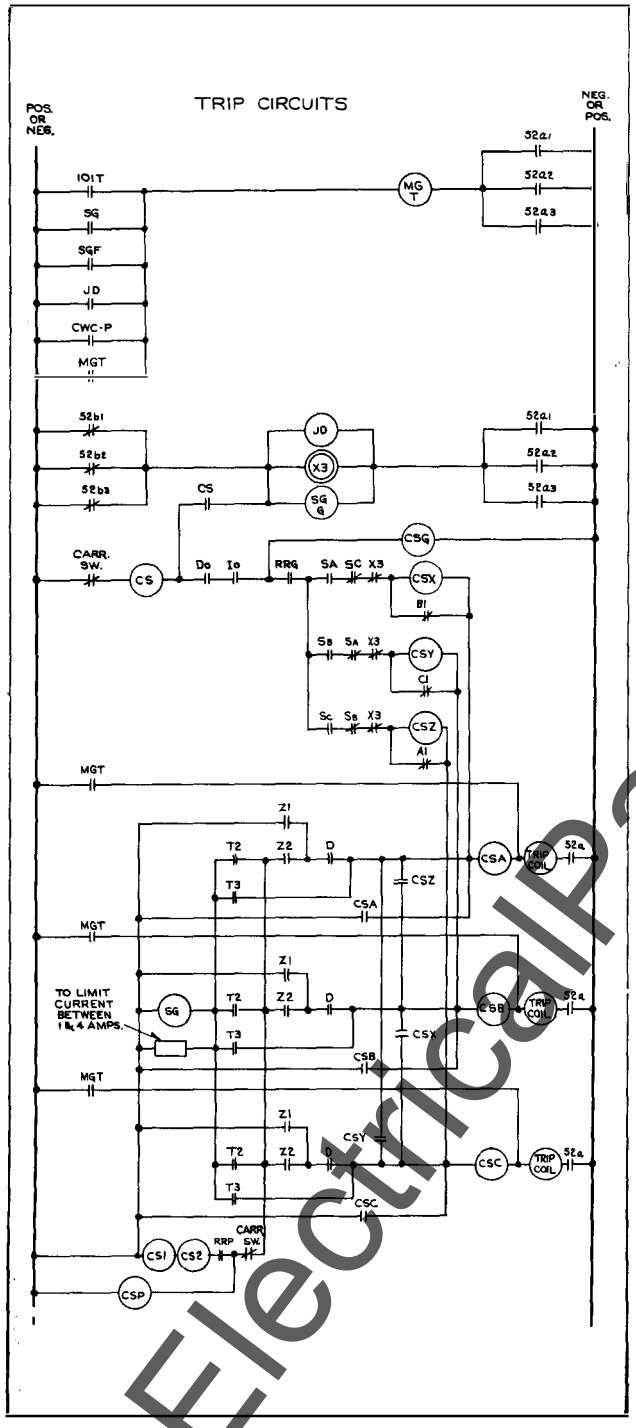

Fig. 2—Simplified D-C Trip Circuit Schematic of the Selective Pole Carrier Relaying Scheme.

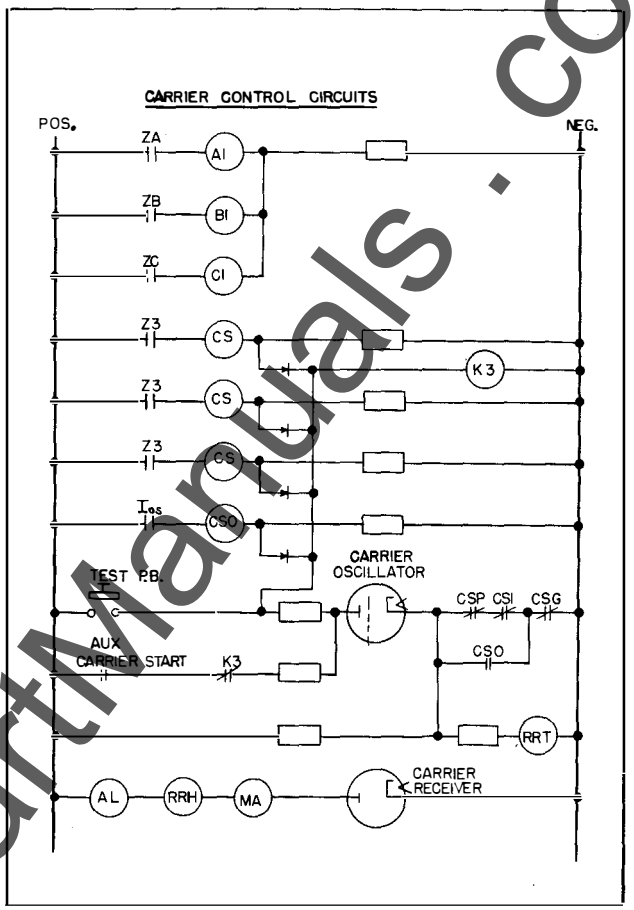

Fig. 3—Simplified Carrier Control Circuit Schematic for the Selective Pole Carrier Relaying Scheme.

phase to be tripped by the D_o and the I_o contacts of the type HRK or HRP ground relay and the carrier ground trip contacts, RRG, of the type RS relay. For example, on a phase A to ground internal fault, the following operations take place to select the correct pole of the circuit breaker. In the trip circuit the contacts D_o and I_o of the type HRP or type HRK relay, the contact S_A of the type HQS relay all close to trip phase A breaker. Make contacts S_B and S_C of the type HQS relay remain open and the trip coils of phase B and phase C poles of the circuit breaker are not energized. Relay type HZ or HZM phase A contact Z1 may trip under the conditions of a phase A-to-ground fault thereby tripping simultaneous through the ground relays and the phase relays phase A pole of the circuit breaker. Thus in a single phase to ground fault only the phase involved with the fault is cleared from the system.

On double line to ground internal faults, for example, a B-to-C ground fault, the phase B type HZ or HZM relay will energize the phase B trip coil thru the carrier trip contacts RRP. This trips phase B breaker. At the same

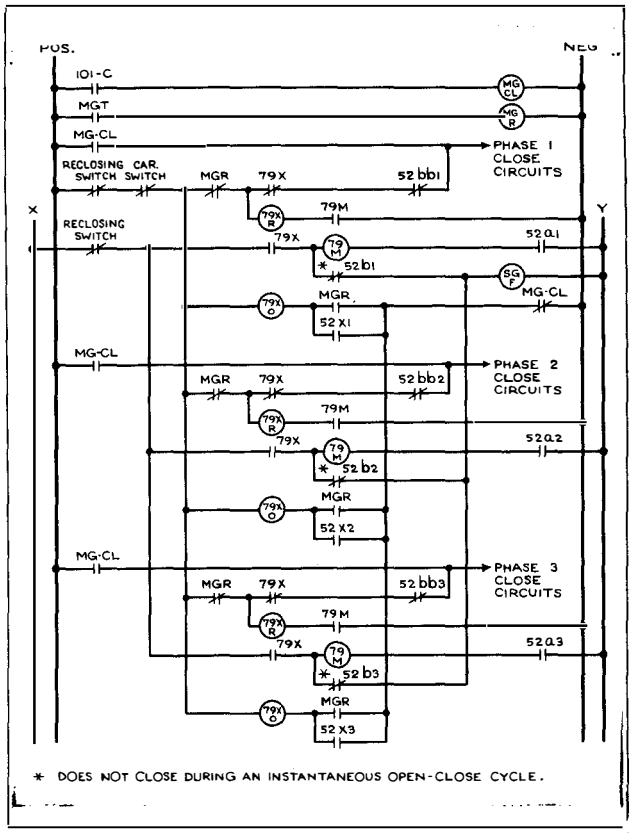

Fig. 4—Simplified Reclosing Circuit Schematic for the Selective Pole Carrier Relaying Scheme.

time, the phase selector contact, S_A, operates on a B-C to ground fault and thru D_o, I_o and RRG contacts energizes coil CSX. This coil has been unblocked by the operation of B1 contact on phase B type HZ or HZM-3 relay. The contacts on CSX connects phase C trip coil to the phase B trip circuit and thus B and C breakers are tripped.

For AB to ground faults, phase A type HZ or HZM relay operates and thru S_C of the type HQS relay energizes CSZ to connect phase B trip coil to phase A type HZ or HZM relay trip circuit. Thus phases A and B breakers are tripped. Similarly on CA to ground faults, phase C type HZ or HZM relay operates with S_B to energize CSY and connect trip coils A and C together.

Internal phase to phase faults pick up one of the type HZ or HZM relays to trip the corresponding phase breaker thru either Z1 or Z2 and the carrier RRP contacts. For example a phase AB fault trips phase A breaker, phase BC fault trips phase B breaker, and phase CA fault trips phase C breaker.

For three phase internal faults, all three poles of the breaker are tripped by the corresponding phase trip circuits.

The back-up relays either phase or ground trip all three poles of the breaker regardless of the type of fault in their range. The ground relay directly energizes the type MG relay (designated MGT) which trips the three phases. The phase back-up elements T2 and T3 of the type HZ relay energizes auxiliary type SG relays which in turn energize MGT coil. Only one type SG (designated SG) relay is required if T2 and T3 are connected thru the out-of-step blocking features, of the type RSN relay. If T3 is connected around the out-of-step blocking contacts, then a second type SG relay (designated SG2) is required.

The X3 break contact in each of the three ground trip circuits is used to prevent the other trip circuits from being energized on transients resulting from opening of only one or two phases of the three-phase line. This X3 element is a telephone type element with a fast pick-up and a slow drop-out, and its break contact opens the trip circuits of the untripped phases for a short interval when the other trip circuit is energized and sealed in.

The X3 relay as well as the JD and SGG relays are energized either by the carrier ground trip circuit thru the contactor switch in the HRK or HRP relay or when any one or two poles are open and the others or other closed. The SGG relay shorts out the coils of the ground back-up relay type CWC or CWP. This is necessary only if the relay is set sensitively with a short time and might operate before the opened phase is reclosed. The type JD timing relay limits the time which the line can be operated with one or two phases open and thus serves a back-up ground relay.

The operation of the carrier control circuits and the out of step blocking elements are the same as in the standard carrier scheme.

Automatic immediate reclosing is provided thru high speed breaker switches after either one or two poles of the breaker are opened, but if all three poles open immediate reclosure may or may not be permitted depending upon system conditions. The reclosing scheme is shown in figure 4, and operates as follows: For a phase A-to-ground fault which trip phase A pole, the high speed breaker switch 52 BB, will close to immediately reclose this pole. These breaker closing circuits are not shown for simplicity, but are any of the conventional schemes supplied with electrically or pneumatic operated modern circuit breakers. The breaker auxiliary closing relay closes its contact $52X_1$ to energize 79X-0 coil. This is the operating coil of the toggle element in the type SGR-12 Recloser. Contact 79X in the closing circuit is thus opened to prevent further reclosing of pole A. Another contact on the toggle element, 79X, is closed to energize the reset motor (79X) of the type SGR-12 relay when the breaker pole closes as indicated by the closing of 52_{A1}. If the breaker stays closed the motor contact 79M closes after a suitable delay to energize the toggle relay reset coil 79X-0. This coil resets the two 79X contacts which the turn de-energizes the timing motor and resets the closing circuit for a subsequent trip.

A similar sequence of operations will take place for the other breaker poles should any combination of them open by operation of the protected relays. It is to be noted that the manual control switch and the back-up relays all energize a master tripping relay MGT. One contact of MGT operates another auxiliary relay MGR. A back contact, on MGR opens up the reclosing circuit to prevent reclosure. Make contacts on MGR operate the toggle element 79X-0 of the type SGR-12 recloser to lock out reclosure until after the breaker poles are manually reclosed. In other words MGR break contacts temporarily open up the high speed reclosing circuit until the type SGR-12 recloser toggle elements are operated. Reclosure can also be blocked by a manual reclosing switch for the carrier cut-out switch as shown.

If instantaneous reclosing is to be prevented for three phase internal faults tripped by carrier, then the out of step blocking elements of the RSN relay used in the type HZ relay or a separate out of step relay should operate the type MGR relay as described above.

The manual closing switch, 101-C, operates a master closing relay designated MG-C1. The contacts of this relay energize the closing circuit of each of the three poles.

In the above discussion it was assumed that the breaker poles remained closed after the first reclosure indicating that the fault was not permanent. If the arc restrikes or the fault is solid, then the protective relays will operate to retrip the breaker poles again. This time one or more of the 79X reclosing contacts of the type SGR-12 recloser will be open from the first reclosure so that reclosure is locked out on these poles. When the poles are open, a breaker b switch $52b_1$, $52b_2$ or $52b_3$ is closed to energize relay SGF through the closed contact 79X. The contacts of SGF operate the MGT relay to trip all poles. Thus the second tripout results in tripping and locking out reclosure of all three breaker poles. This b switch which energizes the SGF relay must be set so that it never closes on a high-speed open-close cycle. In other words when the tripping and closing mechanisms of the breaker are energized approximately simultaneously, the breaker contacts are not fully opened but are parted sufficiently to extinguish the arc. Correspondingly, the breaker auxiliary switch is not completely operated.

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OPERATION

The selective-pole carrier relaying scheme operates in the same manner as the standard carrier scheme described in I.L. 41-600.5 or 41-600.6 except that additional elements have been added and modifications made to provide selective single-pole tripping. That is, for all internal phase A-to-ground faults, only the phase A pole of the circuit breakers of both ends of the protected line will be opened to isolate the fault. In a like manner, only phase B pole will operate for phase B-to-ground faults, and only phase C pole for phase C-to-ground faults. For all internal two phase-to-ground faults the correct phases are selected to open the circuit breaker poles of the faulted lines at both ends of the line. Thus, for example, on an internal B-to-C-to-ground fault only the phase B and phase C poles of the circuit breakers at both ends of the line will open. On an internal phase-to-phase fault one phase of the two faulted phases is selected to open the correct circuit breaker pole. On a phase A to phase B fault, only the phase A pole will be opened, and on a phase C to phase A fault only the phase C pole will be opened.

On any three phase fault, grounded or ungrounded, all three circuit breaker poles will be opened. However, for any faults external to the line section being protected by the power line carrier the back up protection incorporated in this relaying scheme will in the event of an external fault initiate the tripping of the poles of all three phases of the circuit breaker regardless of the type of external fault.

When using the Selective Pole Carrier Relaying and Reclosing Scheme, the voltage rating of the circuit breakers should be carefully considered in line with NEMA rule SG-6-83.

The scheme utilizes three type HZ or HZM relays, one type HRK or HRP relay, one type HQS relay, one type RS or RSN relay, one type TS relay, one or two type SG relays as required, and one type MG relay. Where the type HZM relay is used a type HZM-3 relay is required.

The connection of these relays and their operation in the scheme is as follows with reference to figures 1 to 3. The directional and impedance elements of the type HZ or HZM relay are energized with star current instead of the usual delta current. Thus for a phase A to ground fault, only the phase A relay will receive fault current which would not be the case with delta current. This assures that phase B and C relays will not operate to cause incorrect tripping. However this connection requires that Z1 be set for less than the usual 80 or 90% of the protected line section, to prevent it from over-reaching on external double line-to-ground faults. The setting will vary for different systems, since it is determined by the relative magnitude of the negative and zero sequence impedances.

Delta voltage on the impedance element provides the operation of only one relay on inter-phase faults. On a phase AB fault, the phase A relay receiving AB voltage operates because of the low voltage and high phase A current. Phase B relay, while it receives a high phase B current, does not operate except under extreme conditions because it receives BC voltage which is essentially uncollapsed. Similarly, phase B relay operates on a phase BC fault, and phase C relay on a phase CA fault.

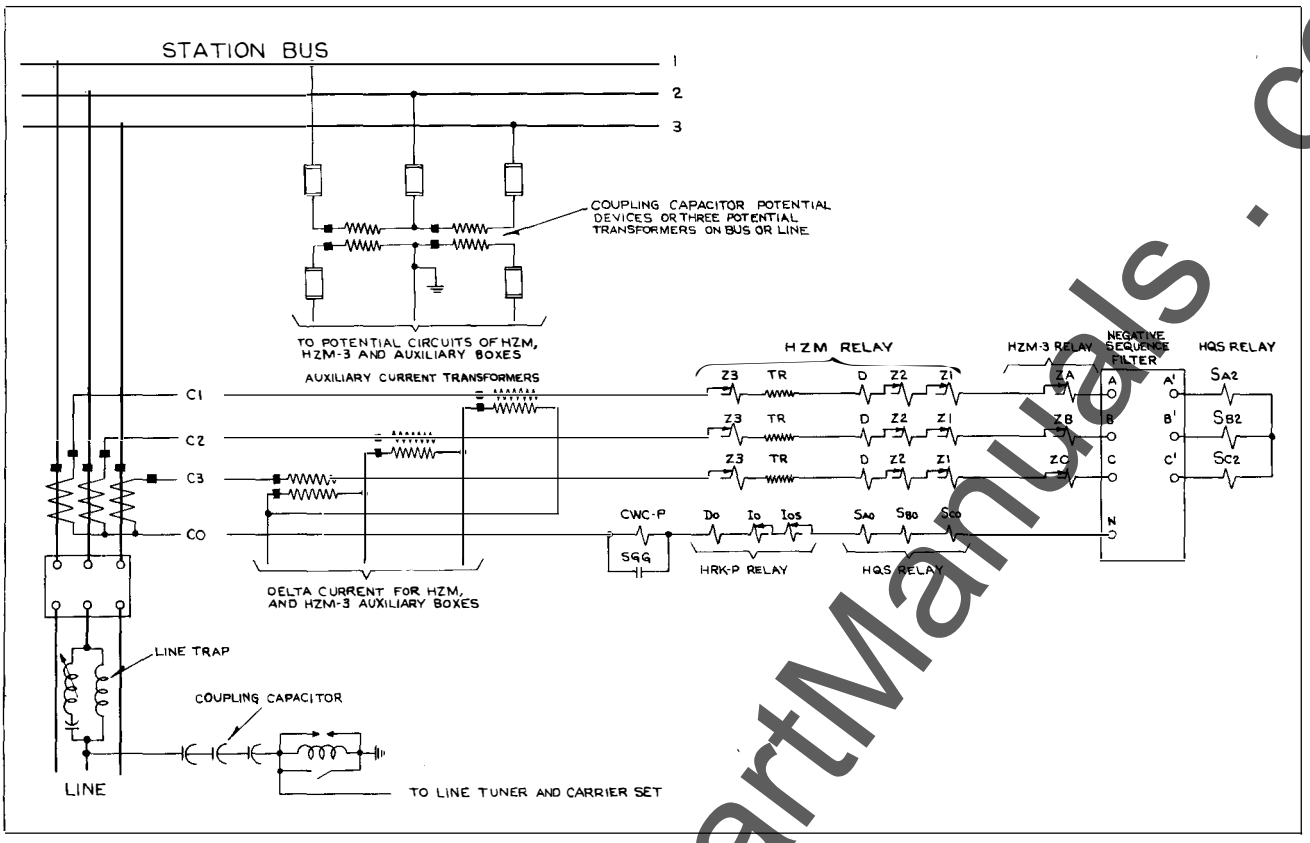

Fig. 1—Simplified A-C Schematic of the Selective Pole Carrier Relaying Scheme.

By using delta current on the HZM auxiliary box, there is no shift for various type faults in the angular position and displacement of the impedance circle. The star current in the impedance element does cause a change in the impedance circle diameter for various types of faults.

The type HQS phase selector relay is connected to receive negative sequence current from a three-phase negative sequence filter energized by the current transformers and the residual current from the neutral circuit of the current transformers. On all single line-to-ground faults, the zero sequence components of all three phases are essentially in phase with the negative sequence component of the faulted phase. This means on a phase-A-to-ground fault, for example, the phase A phase selector element, which has directional characteristics, will have contact-closing torque while the phase B and C elements will have contact-opening torque, since the B and C components of negative sequence current are essentially 120° out of phase with the negative sequence component of the unfaulted phase. For example, consider a phase B-C to-ground fault. In this case the phase A phase selector element will receive operating torque while the phase B and C elements will not, because the negative sequence components of these two phases are essentially 120° out-of phase with the respective zero sequence phase B and C components.

For phase faults not involving ground, the type HQS relay does not operate as the zero sequence currents are zero.

The three poles of the breaker are tripped as follows with reference to figures 2 and 3. On a single line-to-ground faults, the respective phase selector contacts, S_A, S_B, or S_C, of the type HQS relay closes its make contact and opens its associated back contact. The make contact thereby selects the proper

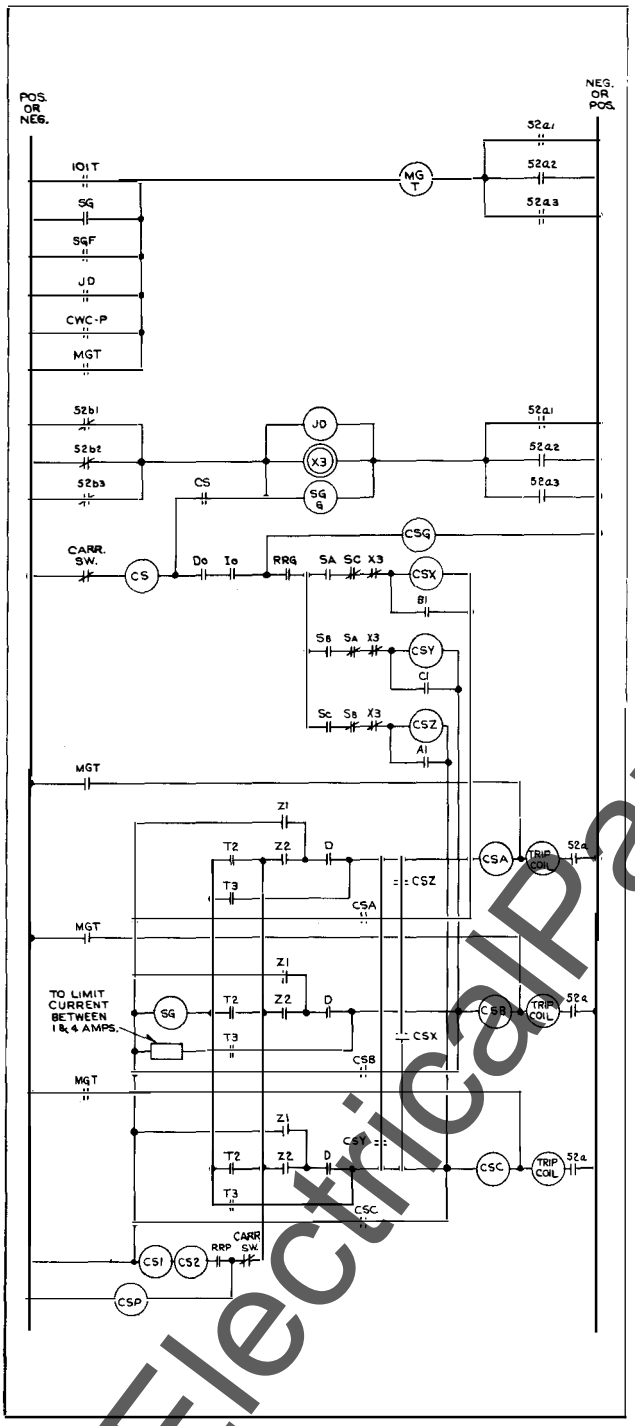

Fig. 2—Simplified D-C Trip Circuit Schematic of the Selective Pole Carrier Relaying Scheme.

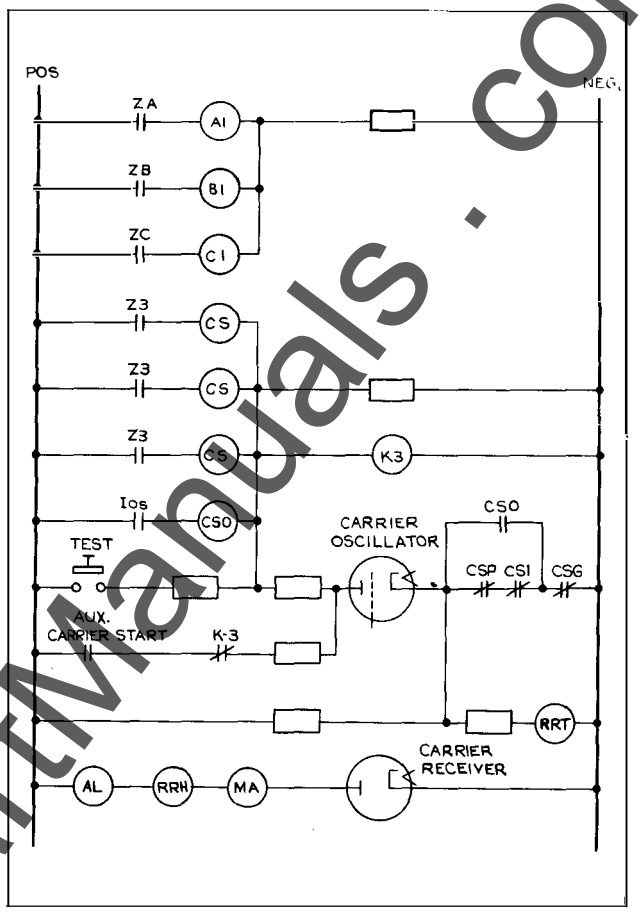

Fig. 3—Simplified Carrier Control Circuit Schematic for the Selective Pole Carrier Relaying Scheme.

phase to be tripped by the D_o and the I_o contacts of the type HRK or HRP ground relay and the carrier ground trip contacts, RRG, of the type RS relay. For example, on a phase A to ground internal fault, the following operations take place to select the correct pole of the circuit breaker. In the trip circuit the contacts D_o and I_o of the type HRP or type HRK relay, the contact S_A of the type HQS relay all close to trip phase A breaker. Make contacts S_B and S_C of the type HQS relay remain open and the trip coils of phase B and phase C poles of the circuit breaker are not energized. Relay type HZ or HZM phase A contact Z1 may trip under the conditions of a phase A-to-ground fault thereby tripping simultaneous through the ground relays and the phase relays phase A pole of the circuit breaker. Thus in a single phase to ground fault only the phase involved with the fault is cleared from the system.

On double line to ground internal faults, for example, a B-to-C ground fault, the phase B type HZ or HZM relay will energize the phase B trip coil thru the carrier trip contacts RRP. This trips phase B breaker. At the same

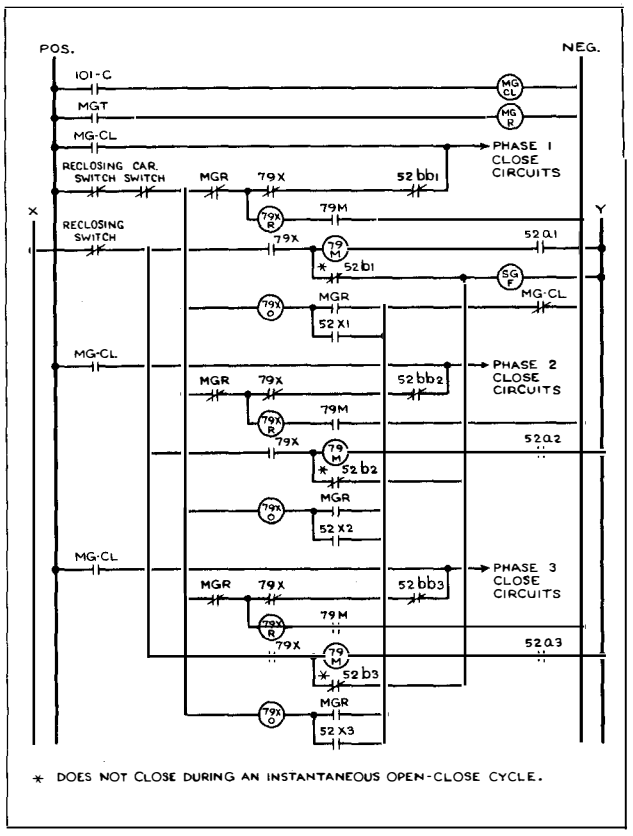

Fig. 4—Simplified Reclosing Circuit Schematic for the Selective Pole Carrier Relaying Scheme.

time, the phase selector contact, S_A, operates on a B-C to ground fault and thru D_o, I_o and RRG contacts energizes coil CSX. This coil has been unblocked by the operation of B1 contact on phase B type HZ or HZM-3 relay. The contacts on CSX connects phase C trip coil to the phase B trip circuit and thus B and C breakers are tripped.

For AB to ground faults, phase A type HZ or HZM relay operates and thru S_C of the type HQS relay energizes CSZ to connect phase B trip coil to phase A type HZ or HZM relay trip circuit. Thus phases A and B breakers are tripped. Similarly on CA to ground faults, phase C type HZ or HZM relay operates with S_B to energize CSY and connect trip coils A and C together.

Internal phase to phase faults pick up one of the type HZ or HZM relays to trip the corresponding phase breaker thru either Z1 or Z2 and the carrier RRP contacts. For example a phase AB fault trips phase A breaker, phase BC fault trips phase B breaker, and phase CA fault trips phase C breaker.

For three phase internal faults, all three poles of the breaker are tripped by the corresponding phase trip circuits.

The back-up relays either phase or ground trip all three poles of the breaker regardless of the type of fault in their range. The ground relay directly energizes the type MG relay (designated MGT) which trips the three phases. The phase back-up elements T2 and T3 of the type HZ relay energizes auxiliary type SG relays which in turn energize MGT coil. Only one type SG (designated SG) relay is required if T2 and T3 are connected thru the out-of-step blocking features, of the type RSN relay. If T3 is connected around the out-of-step blocking contacts, then a second type SG relay (designated SG2) is required.

The X3 break contact in each of the three ground trip circuits is used to prevent the other trip circuits from being energized on transients resulting from opening of only one or two phases of the three-phase line. This X3 element is a telephone type element with a fast pick-up and a slow drop-out, and its break contact opens the trip circuits of the untripped phases for a short interval when the other trip circuit is energized and sealed in.

The X3 relay as well as the JD and SGG relays are energized either by the carrier ground trip circuit thru the contactor switch in the HRK or HRP relay or when any one or two poles are open and the others or other closed. The SGG relay shorts out the coils of the ground back-up relay type CWC or CWP. This is necessary only if the relay is set sensitivity with a short time and might operate before the opened phase is reclosed. The type JD timing relay limits the time which the line can be operated with one or two phases open and thus serves a back-up ground relay.

The operation of the carrier control circuits and the out of step blocking elements are the same as in the standard carrier scheme.

Automatic immediate reclosing is provided thru high speed breaker switches after either one or two poles of the breaker are opened, but if all three poles open immediate recloser may or may not be permitted depending upon system conditions. The reclosing scheme is shown in figure 4, and operates as follows: For a phase A-to-ground fault which trip phase A pole, the high speed breaker switch 52 BB, will close to immediately reclose this pole. These breaker closing circuits are not shown for simplicity, but are any of the conventional schemes supplied with electrically or pneumatic operated modern circuit breakers. The breaker auxiliary closing relay closes its contact $52X_1$ to energize 79X-0 coil. This is the operating coil of the toggle element in the type SGR-12 Recloser. Contact 79X in the closing circuit is thus opened to prevent further reclosing of pole A. Another contact on the toggle element, 79X, is closed to energize the reset motor (79X) of the type SGR-12 relay when the breaker pole closes as indicated by the closing of 52_{A1}. If the breaker stays closed the motor contact 79M closes after a suitable delay to energize the toggle relay reset coil 79X-0. This coil resets the two 79X contacts which the turn de-energizes the timing motor and resets the closing circuit for a subsequent trip.

A similar sequence of operations will take place for the other breaker poles should any combination of them open by operation of the protected relays. It is to be noted that the manual control switch and the back-up relays all energize a master tripping relay MGT. One contact of MGT operates another auxiliary relay MGR. A back contact, on MGR opens up the reclosing circuit to prevent reclosure. Make contacts on MGR operate the toggle element 79X-0 of the type SGR-12 recloser to lock out reclosure until after the breaker poles are manually reclosed. In other words MGR break contacts temporarily open up the high speed reclosing circuit until the type SGR-12 recloser toggle elements are operated. Recloser can also be blocked by a manual reclosing switch or the carrier cut-out switch as shown.

If instantaneous reclosing is to be prevented for three phase internal faults tripped by carrier, then the out of step blocking elements of the RSN relay used in the type HZ relay or a separate out of step relay should operate the type MGR relay as described above.

The manual closing switch, 101-C, operates a master closing relay designated MG-C1. The contacts of this relay energize the closing circuit of each of the three poles.

In the above discussion it was assumed that the breaker poles remained closed after the first reclosure indicating that the fault was not permanent. If the arc restrikes or the fault is solid, then the protective relays will operate to retrip the breaker poles again. This time one or more of the 79X reclosing contacts of the type SGR-12 recloser will be open from the first reclosure so that reclosure is locked out on these poles. When the poles are open, a breaker b switch $52b_1$, $52b_2$ or $52b_3$ is closed to energize relay SGF through the closed contact 79X. The contacts of SGF operate the MGT relay to trip all poles. Thus the second tripout results in tripping and locking out reclosure of all three breaker poles. This b switch which energizes the SGF relay must be set so that it never closes on a high-speed open-close cycle. In other words when the tripping and closing mechanisms of the breaker are energized approximately simultaneously, the breaker contacts are not fully opened but are parted sufficiently to extinguish the arc. Correspondingly, the breaker auxiliary switch is not completely operated.

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