INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

K-DAR/KQS SINGLE POLE TRIP SYSTEM

The following is a description of the relaying system whose trip circuits are shown in Fig. 1. The system differs from the standard directional comparison blocking type described in I.L. 41-911 in that means are provided to trip only the faulted phase-breaker pole for single-line-to-ground faults. The specific directional-comparison system shown in the drawing is a 4-zone type.

The 4-zone scheme provides two separate trip circuits and, if desired, two separate current transformer circuits so that for a fault anywhere in the protected line section any one relay failure can be tolerated while still achieving fast tripping. In the case of phase faults in the immediate line section, trip circuit No. 1 in Fig. 1 provides instantaneous zone 1 protection over the first 90 percent of the line and a zone 2 delayed trip for the remainder. Trip circuit No. 2 for the same conditions provides instantaneous clearing over the entire line section by distance relay 21P working in conjunction with the carrier auxiliary relay (85) whose supervising contact RRP closes in the absence of a blocking signal to allow 21P to trip. Likewise, on ground faults trip circuit No. 1 provides instantaneous tripping for faults near the breaker and for a portion of the line extending from the breaker, and delayed tripping for the remainder. Circuit No. 2-67N relay trips instantaneously for all immediate line section ground faults. To provide selecttivity it is supervised by the RRG contact of the 85 relay. This contact, like the RRP contact, remains open for external faults in the presence of a carrier blocking signal. The above operation is somewhat modified for single-pole tripping as described later.

With carrier in service, the carrier ground relay is permitted to trip only the faulted-phase pole if the fault is a single line to ground fault. For all other types of faults the relays are permitted to trip all three poles. An alternative arrangement would provide tripping of two poles for faults involving two phases. For example, if the fault were to involve phases A and B, only those poles would be tripped. This "selective-pole" arrangement has been provided in a few instances with previous schemes. However, experience has shown that the improvement to stability occasioned by leaving one pole in service is not of sufficient benefit to justify the increased order of complexity in the relaying circuits necessary to provide this feature.

In addition to the relays described in the aforementioned literature for three pole tripping, the scheme in Fig. 1 shows the following additional relays: KQS(83G), SRD(83P, 83S) and SC(50N), AR(94-), AR(62X, Y, Z), TT-18 (94X), TT-19 (21X) and TD-5 (62). These relays working in conjunction with the HD-4 phase distance relays and the directional overcurrent ground relays provide the single pole tripping protection. Of the various phase and ground relays, the 67N relay, the instantaneous unit I of 67NT and the phase-to-phase unit of relay 21P remain in service during the single-phasing period (one pole open) to provide sound-phase protection. These relays provide fast protecttion should a phase-to-phase or ground fault occur on one or two phases not originally faulted. The functioning of each of the additional relays required for single pole tripping will now be described.

KQS (83G)

This relay working in conjunction with an external negative-sequence current filter detects which of the three phases is grounded for a single line to ground fault. Three high-speed induction cylinder units compare the phase angle of the negative sequence current and the zero sequence current. The phase A unit (SA) receives phase A negative sequence current while the other two phase selectors receive their respective negative sequence currents. For example, for a phase A to ground fault the phase A negative sequence current is almost in phase with the zero sequence current thus causing operation of the SA unit. At the same time the sound-phase negative sequence currents are 120° out of phase with the zero sequence current, producing contact opening torque

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*Denotes change from superseded issue.

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on SB and SC. Thus, the KQS phase selectors tell the 67N directional overcurrent carrier ground relay which breaker pole to trip. Their sensitivity is 0.33 amperes negative and zero-sequence current. This is compatible with the normal $3I_0$ pickup of 1.0 amp. on the I_0 unit of 67N. On a two phase to ground fault the phase selector on the sound phase is operated due to the nature of the fault. This means that the carrier ground relay trips the sound-phase pole. At the same time the 21P phase distance relay is operating to trip all three poles, so that KQS operation is irrelevant for double line to ground faults.

For a single line to ground fault with one pole opening on each breaker the 52a-52b disagreement circuit in Fig. 1 energizes auxiliary unit X3 of the KQS relay. Note that auxiliary switches are shown for two breakers as would be the case, for example, for a ring bus. Unit X3 blocks the sound-phase selector trip circuits to avoid the possibility of these phases being tripped at the time that the faulted phase pole is opening.

SRD (83P, 83S) and SC (50N)

The SRD relay operates for faults involving two phases but will not operate for a three-phase or a single-phase-to-ground fault. It compares the magnitude of the three voltages (phase-to-ground). When one of three voltages is larger than the other two the relay contacts close to permit the KD-4 zone 1 and KD-4 carrier trip relay 21P to clear the fault. One of three phase-to-ground voltages will be larger than the other two for phase-to-phase and two phase-to-ground faults. For a single phase-to-ground fault one of the three phase voltages will be smaller than the other two and the SRD relay will not operate. The SRD operates on a minimum of 10 volts difference between the largest voltage and the larger of the remaining two voltages. Rated potential is 70V.

SRD contacts are inserted in series with the KD-4 zone 1 and 21P carrier phase trip paths, to prevent a 3-pole trip for a single-line-ground fault. Since the SRD (83P) will not operate for 3-phase faults an SC (50N) break contact bypasses the SRD contact. The 50N relay is energized with residual current to sense ground faults. Thus, the parallel combination of 83P and 50N contacts provides a trip path except for single-phase-to-ground faults.

Another SRD contact bypasses the X contact interlock in series with the 85 CSG coil, to provide sound-phase protection as will be described later.

AR (94) Relays 94-1, 2, 3, 4, & 5 provide a 2 ms auxiliary trip function. Each relay has four make contacts. Relays 94-1 and 94-2 trip all three poles, while 94-3, 94-4, & 94-5 each trip their associated breaker pole. Spare contacts of 94-3, 4, & 5 may be used to initiate breaker closing. If two sets of breakers must be tripped (e.g., ring bus) 6 contacts may be needed, so the 94-1 and 94-2 functions may require two AR relays each.

TT-18 (94X)

Telephone type relays X, X2, X4, and X5 are packaged in the TT-18 relay. X and X2 relays perform transient blocking functions to eliminate the possibility of undesired trips during various periods enumerated in Table II "Trip Schedule". Relay X2 also sets up 21P, 67N and the instantaneous unit (I) of 67NT relay for the purpose of providing sound-phase protection during single phasing. In addition, the X3 unit sets up relay 78N for a three pole trip should the single breaker pole reclose into a permanent fault. This is accomplished by connecting the 67N trip circuit to the auxiliary trip relay 94-2.

Unit X4 introduces a coordinating delay in the tripping of the instantaneous unit of 67NT in trip circuit No. 1 This delay insures that the initial fault will be cleared by opening only the affected phase for single line to ground faults. Otherwise faults within the range of this instantaneous unit will be three-pole tripped. Unit X5 introduces a coordinating delay in the 21P trip circuit during the single-phasing period. In particular, this delay functions at the time of a single-pole reclose to insure that possible operation of 21P due to transients will not incorrectly cause tripping. The delay of X5 is inserted only during the single-phasing period and is not present during normal operation.

TT-19 (21X)

This relay grounds the open-phase potential terminals of certain relays during the single-phasing period. With line-side potential applications the 21P, 21S, 68 and 83P relay terminals are grounded. With bus-side potential applications only 83P needs to be grounded.

With potential taken from the line side the open phase voltage during single phasing is determined by the interphase capacitance between the faulted phase and the two sound phases. The exact potential is a function of the line configuration. The rotation of the three voltages could actually be negative sequence or a very small positive sequence triangle, providing insufficient restraint for the distance relays. For this reason the distance relays may have their contacts closed during the single phasing period if line side potential is utilized. This condition is tolerable if the trip circuits of these relays are disabled by relay X of the TT-18 relay. However, the 21P relay phase-to-phase unit provides sound phase protection, so the TT-19 disconnects the 21P, 21S, and 68 relays from the potential source on the phase with the open breaker pole and grounds that terminal. For example as shown in Fig. 1 if phase A pole opens, terminal 7 is grounded.

Regardless of the potential source location, the TT-19 relay switches the SRD, so that the SRD can operate for a ground fault on one of the "sound" phases during the single-phasing period. With one SRD potential pole grounded and normal voltage to ground on the other two phases, the SRD is reset; however, should one of the latter phases become grounded, the SRD would see a 1 large 2 small voltage condition.

TD-5 (62)

This relay limits the duration of single-phasing to prevent excessive heating of rotating equipment due to unbalanced current flow and to prevent undesired tripping of overcurrent ground relays in the vicinity of the protected line due to the zero sequence current flow throughout the system as a result of the single phasing operation.

AR (62X, 62Y, 62Z)

These are 0.2 sec. drop-out relays used primarily to initiate breaker-failure timing. The latter must be used in conjunction with a breaker-failure timer set for 0.17 sec. or less and with 3 independent phase current detectors as shown in Fig. 2. Time delay on dropout of 62X/Y is needed since RRG, RRP and X unit contacts can otherwise deenergize 62X/Y prematurely during a breaker failure.

Spare contacts from these relays may be used for such things as reclose block (in the case of 62X and Y) and carrier squelch in the case of 62Y. The latter performs the same function as the SQ unit of relay 85 in preventing a carrier blocking signal from being transmitted during and immediately after local breaker tripping.

These relays have delayed drop-out in order to maintain energization of 62BF in Fig. 2. Even though a breaker failure occurs the 62X, Y, Z relays will be deenergized in Fig. 1 by X or by the opening of RRG and RRG contacts before 62BF has timed out.

The KC-4 relay consists of three current detector units I_1, I_2, and I_3 energized by the phase A, B, and C breaker currents, respectively. Following a single-pole trip the sound phase current detectors may be operated by load current; therefore, the TRB-1 blocking diodes in Fig. 2 prevent undesired 62BF energization. For example, if phase C is tripped open successfully 62BF could be energized by I_2 or I_1 plus 62Z-C unless the TRB-1 diodes are used.

Summary of operation

For a phase to ground fault in the protected line with carrier in service, the faulted phase pole will be tripped by the 67N carrier ground relay through the 85-CO contact A-5 B-5 and the RRG carrier supervising contact or the KA-4 relay and through the phase selector unit SA, SB, or SC of the KQS relay. Simultaneously the 67N relay energizes relay units X, X3 and 62. Relay X and X3 operate immediately to block other trip paths which otherwise could produce a three pole trip. When the breaker poles on the faulted phase open, their 52b contacts close to keep the X, X3 and 62 relays energized. At this point X2 is also energized by the 52a-52b disagreement circuit. Shortly thereafter (See Table I "Auxiliary Unit Times"), relay X2 inserts relay X5 delay in the 21P trip path and at the same time bypasses the 50N contact in the same path. Another X2 contact bypasses the X4 delay of the directional ground relay instantaneous unit in trip circuit No. 1. Another X2 contact connects the 67N trip circuit to auxiliary tripping relay 94-2 so that a sound phase ground fault can be cleared by 67N and so that 67N can initiate a 3-pole trip if the open breaker pole closes into a fault.

Returning now to the instant when tripping was initiated, the faulted-phase selector unit of the KQS relay energizes unit AX, BX or CX of the TT-19 relay, grounding a potential terminal of the SRD and of distance relays 21P and 68 (line-side potential only). This grounding allows the trip circuit of 21P to be reestablished to provide sound-phase protection during the remainder of the single phasing interval.

Should a ground occur on one of the energized phases during the single phasing period relay 67NT instantaneous unit I can immediately trip if the fault produces enough current to pick it up. If not, 67N can initiate 3 pole tripping. If the ground occurs soon after the single-pole trip, unit X2 will not have had time to pick up; in this case 67N tripping will be delayed. After X2 operates, 67N can energize CSG through the 83P contact (which closes at inception of the sound-phase fault). When the remote carrier transmitter turns off, RRG closes, energizing 94-2. Note that carrier is transmitted continuously during the single-phasing period (unless CSP or CSG is operated) due to the unbalanced load-current operation of I_{OS} of relay 85. So either 67N plus 83P or I of 67NT must operate at both ends to turn off both transmitters in order to effect a 67N carrier trip. The phase-to-phase unit of 21P may also operate for a sound phase ground; however, this is not too likely.

The directional unit of 67N (type KRD-4 or KRQ) in some cases, may have a contact opening torque during a sound-phase fault while single phasing due to the phase angle shift of the polarizing voltage (V_0 in KRD-4 or V_2 in KRQ) if line side potential is used. The angle shift causes the potential polarizing effect to produce a contact opening torque which may overcome the contact closing torque produced by current polarizing in KRD-4 application. There are two alternatives recommended as follows:

1. Reverting KRD-4 to current polarizing only during single phasing. See note 12 on figure 1 for detailed connections. This alternative is not recommended unless a current polarizing source is utilized.
2. Bypass D-contact of KRD-4 (or KRQ) during single phasing. See note 13 on Fig. 1 for detailed connections. This alternative may cause tripping for an external fault on a phase other than the open phase during single phasing, but this would be a double contingency assumption.

Should a phase fault occur involving the two sound phases, relay 21P will trip all three poles through contacts RRP, X2 (make) or SRD or 50N, X5 or X2 (break). Before X2 operates, 50N will provide a trip path unless ground is involved in the fault. After X2 operates tripping will be delayed by X5.

For a two phase to ground fault with all poles closed the 67N relay trips the sound phase pole while the phase distance relays trip all three poles. Phase relay operation is as described in I.L. 41-911 except for the fact that the SRD ratio discriminator senses one large and two small voltages to permit KD-4 distance relay tripping.

For a phase-to-phase fault with all poles closed the phase distance relays and the SRD relay operate, tripping all three poles. Should a three-phase fault develop in the protected line the KD-4 three-phase units function in a conventional fashion. In the case of 21P or 21-1 the three-phase unit trips through the break contact of 50N (SC relay).

Unbalanced load flow during the single phasing period operates the I_{OS} carrier-start unit of relay 85. This action is beneficial during the interval at the end of the single-phasing period. When the first pole closes the disagreement circuit at that end of the line deenergizes the X unit of 94X. If X resets before the remote breaker pole recloses, 67N will still be operated by the unbalanced load current; however, the carrier signal prevents RRG closure, avoiding misoperation.

If the single-pole reclose is unsuccessful all three poles will be tripped. If the fault is beyond the 67NT I-unit range, tripping by 67N will be delayed until X resets. Unless the remote 67NT I-unit operates to squelch carrier, local 67N trip might have to await X unit reset at both stations; this is true since I_{OS} will not begin to reset until the laggard breaker pole closes. On the other hand, Although not likely, the $\phi\phi$ unit of 21P might see the ground fault and immediately stop carrier. Thus, a fault not cleared by the 67NT I-units at both stations might not be cleared until after about 100 ms or more upon reclose.

Remote Backup Protection

Faults on adjacent lines will be detected and cleared on backup operation by the 67NT time delay unit and by either 21-2 or relay 21P after the T3 delay provided by TD-4 timer (device 2). The trip path for the phase-fault remote-backup protection is 21P relay energizing auxiliary unit TX-Z3 which eventually closes contact TR to trip 94-2. The fact that 67NT is connected in trip circuit No. 1 and 21P in trip circuit No. 2 should be only incidental on the basis that we can assume that both trip circuits will be available when remote backup protection is required. This assumption is valid on the basis that the first contingency is a failure of the protection system on the adjacent line and any other failure at the location in question would result in a double-contingency failure. Stating the above in a different manner, if we assume a failure of the d.c. supply to trip circuit No 1 or to trip circuit No. 2 it is not legitimate to also assume a failure of the protection system at the remote station on the adjacent line; this would be a double-contingency assumption.

Operation with Carrier Out of Service

If the carrier set is being maintained or otherwise unserviceable, the carrier on-off switch (85-CO) should be turned to the OFF position. This will disable the 21P and 67N carrier trip circuits. In addition, contact A6-B6 and C6-D6 bypass interlocks in trip circuit No. 1 which are not required when single-pole tripping is removed. Contact A1-B1 of this switch is available for reclosing circuit use to block high-speed reclosing when carrier is out of service if this feature is required.

TABLE I

AUXILIARY UNIT TIMES – MILLISECONDS			
RELAY	UNIT	PICKUP	DROPOUT
TT-18	X	10- 20	70-100
TT-18	X2	65-200	150-250
KQS	X3	20- 30	30- 70
TT-18	X4	45- 80	10- 40
TT-18	X5	45- 80	10- 40
TT-19	AX,BX,CX	5- 15	10- 30

TABLE II

TRIP SCHEDULE

RELAY	PREFAULT PERIOD		DURING SINGLE POLE TRIP	(NOTE 6) DURING SINGLE PHASING	DURING SINGLE POLE CLOSE	PERMANENT FAULT ON RECLOSE
	CARRIER IN SERVICE	CARRIER OUT				
21-1	3PT $\phi\phi$ UNIT SUPERVISED BY SRD	SRD BYPASSED BY 85 CO	BLOCKED BY X	BLOCKED BY X	BLOCKED BY X	3PT DELAYED BY X DROP OUT
21P CARRIER TRIP	3PT 3ϕ & $\phi\phi$ UNITS SUPERVISED BY SRD + 50N	BLOCKED BY 85 CO		3PT DELAYED BY X5-SRD BYPASSED BY X2	DELAYED BY X5	3PT DELAYED BY X5
21P ZONE 3	3PT	3PT	3PT	3PT	3PT	3PT
67N	SPT KQS SUPERVISION	BLOCKED BY 85 CO	SOUND PHASES BLOCKED BY X3	3PT THRU SRD AND X2	BLOCKED BY X3 OF KQS	3PT THRU X2 DELAYED BY X D.O.
67NT INST.	3PT IF 67N FAILS TO SPT-DELAYED BY X4	IMMEDIATE 3PT THRU 85 CO	BLOCKED BY X	3PT THRU X2	3PT THRU X2	3PT THRU X2
67NT TIMED TRIP	3PT 3PT	3PT	BLOCKED BY X	BLOCKED BY X	BLOCKED BY X	3PT DELAYED BY X DROP OUT

SPT = SINGLE POLE TRIP

3PT = 3 POLE TRIP

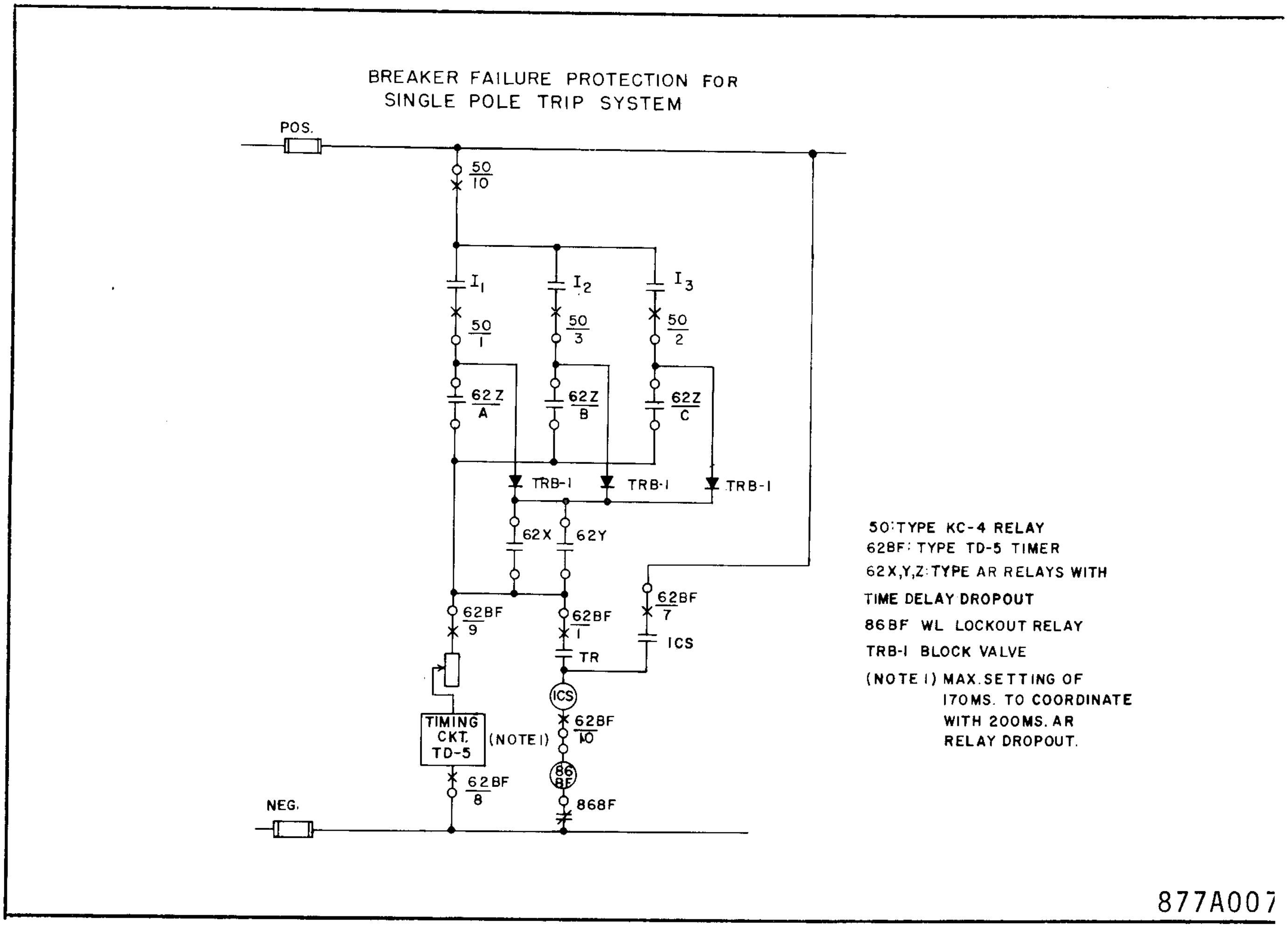

Fig. 2. Breaker-Failure Protection for Single-Pole Trip System (For each breaker).