INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

K-DAR DIRECTIONAL COMPARISON BLOCKING SYSTEMS

INTRODUCTION

This leaflet describes the overall functioning of K-Dar relays when used in conjunction with a blocking channel (power line carrier, microwave or pilot wire). Detailed description of operation, as well as setting and maintenance recommendations for individual relays of the K-Dar directional comparison blocking system are covered in the individual relay instruction leaflets; the description here is intended to supplement these relay instructions.

APPLICATION

Directional comparison blocking is employed to eliminate delayed clearing of end-zone line faults; thus, high speed, simultaneous clearing of all line faults is accomplished. Protective relays energized with current and potential from the protected line are unable to trip both selectively and at high speed for line faults near the remote station. By transmitting a signal from the remote station when the fault is external to the protected line, the local relays are blocked from tripping. Without this additional means of intelligence, local relay tripping must be delayed for internal faults near the remote station, to insure against undesired tripping when the fault is on an adjacent circuit near the remote station.

This system can be utilized with minor differences with either on-off or frequency shift type of operation over pilot wire tones, microwave or power line carrier channels. Blocking of tripping is effected by either keying on or shifting the transmitter frequency.

* These instructions contemplate the use of separate primary and back-up relays, in line with local back-up philosophies. Fig. 4 shows the details of this arrangement. This contrasts to the previous 3-zone system where the zone 2 phase-distance units provided carrier tripping as well as back-up. Nevertheless, the underlying principles described here apply whether or not the back-up protection is independent or common with the primary protection. Of course, the relaying complement will vary.

EQUIPMENT COMPLEMENT

K-Dar is the designation for a group of relays, which are itemized below:

Directional Fault Detecting Relays

1 — Type KD Directional phase tripping unit, consisting of:

- 1 — Phase-to-phase unit (ZP-$\phi\phi$), which operates for all three combinations of phase-to-phase faults anywhere on the protected line.
- 1 — Three-phase unit (ZP-3ϕ), which operates for 3 phase faults anywhere on the protected line.
- 1 — Indicating contactor switch (ICS).

1 — Type KD-1 Directional Phase Start unit, consisting of:

- 1 — Phase-to-phase unit (ZS-$\phi\phi$), set to reach in the reversed direction to that of ZP-$\phi\phi$.
- 1 — Three phase unit (ZS-3ϕ), set to reach in the reversed direction to that of ZP-3ϕ.
- 1 — Indicating contactor switch (ICS).

1 — Type KRD (or KRC, or KRP, or KRQ) Directional ground tripping unit, consisting of:

- 1 — Directional unit, current polarized (D_{oc})
- 1 — Directional unit, voltage polarized (D_{op})
- 1 — Instantaneous overcurrent unit (I_o)
- 1 — Indicating contactor switch (ICS)

SUPERSEDES I.L. 41-911
*Denotes change from superseded issue.

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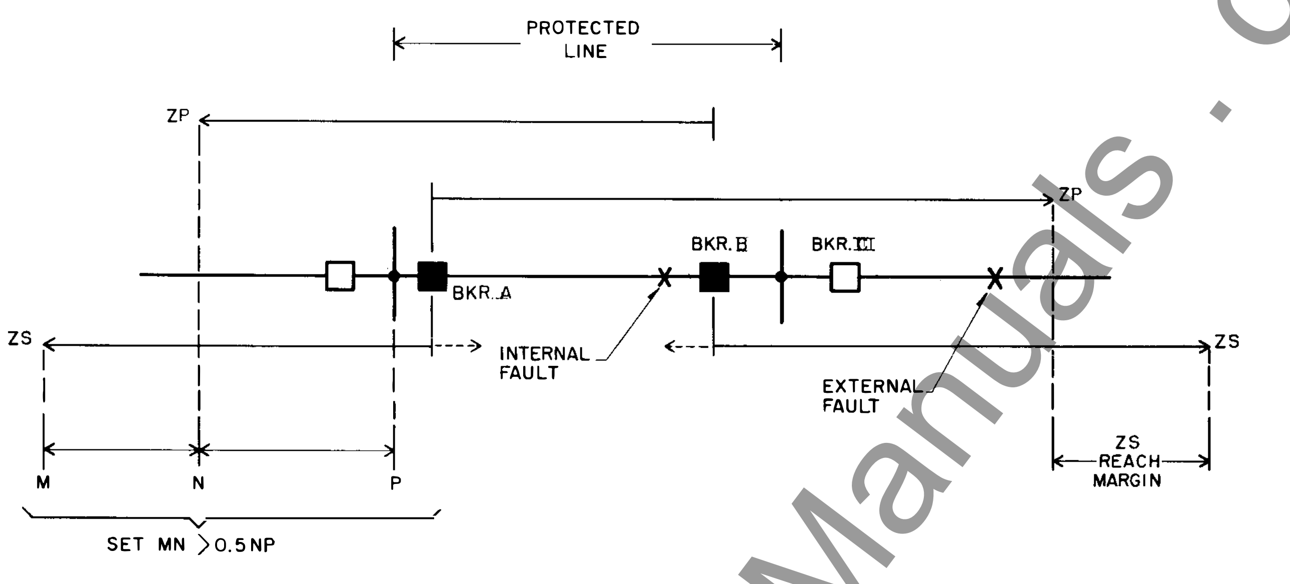
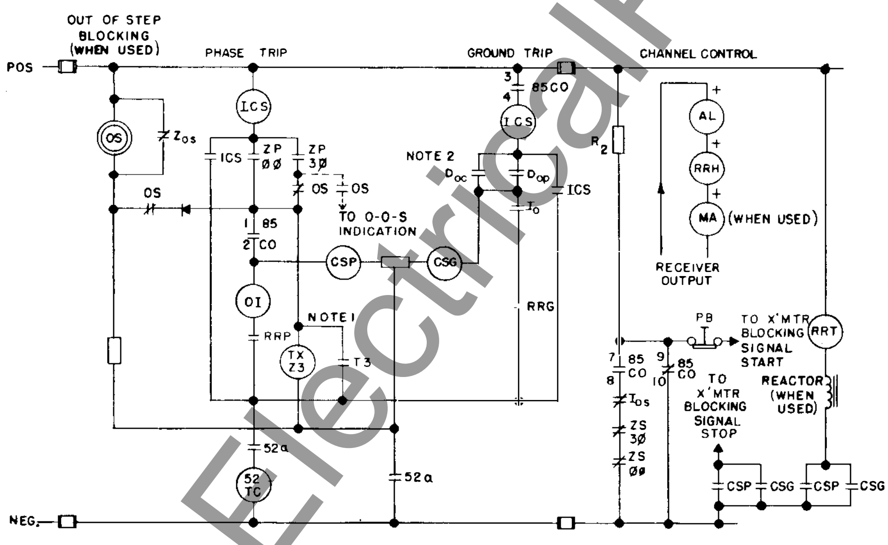


Fig. 1. Phase Relay Settings



AL	ALARM UNIT OF KA RELAY
CSG	GROUND AUXILIARY UNIT OF KA RELAY
CSP	PHASE AUXILIARY UNIT OF KA RELAY
D_{oc}	CURRENT POLARIZED DIRECTIONAL UNIT OF KRD RELAY
D_{op}	VOLTAGE POLARIZED DIRECTIONAL UNIT OF KRD RELAY
ICS	INDICATING CONTACTOR SWITCH OF KD & KRD RELAYS
I_o	GROUND OVERCURRENT TRIP UNIT OF KRD RELAY
I_{os}	GROUND START OVERCURRENT UNIT OF KA RELAY
MA	MILLIAMMETER
OI	OPERATION INDICATOR OF KA RELAY
OS	AUXILIARY UNIT OF KS RELAY
RRG, RRP	RECEIVER RELAY UNIT CONTACTS OF KA RELAY
RRH	HOLDING COIL OF RECEIVER RELAY UNIT OF KA RELAY
RRT	TRIPPING COIL OF RECEIVER RELAY UNIT OF KA RELAY
TXZ3	TIMER START AUXILIARY UNIT OF TD-2 RELAY
ZOS	DISTANCE UNIT OF KS RELAY
ZP-ØØ	PHASE-TO-PHASE UNIT OF KD RELAY
ZP-3Ø	3 PHASE UNIT OF KD RELAY
ZS-ØØ	PHASE-TO-PHASE UNIT OF KD-1 RELAY
ZS-3Ø	3 PHASE UNIT OF KD-1 RELAY
52a	CIRCUIT BREAKER AUXILIARY SWITCH CONTACT-CLOSED WHEN BREAKER IS CLOSED
52TC	CIRCUIT BREAKER TRIP COIL
85CO	CUTOUT SWITCH-IN "ON" POSITION WHEN CHANNEL IS OPERATIVE

85CO ON-OFF SWITCH

CONTACT	POSITION ON	POSITION OFF
1-2	X	
3-4	X	
5-6	X	
7-8	X	
9-10		X
11-12		X

X-DENOTES CONTACT CLOSED

NOTES:

1. OPTIONAL CONNECTION, WHERE T3 CONTACT OF TD-2 IS AVAILABLE IN BACKUP CIRCUITS
2. OMIT D_{oc} IF KRP RELAY; OMIT D_{op} IF KRC RELAY; SUBSTITUTE D2 FOR D_{oc} & D_{op} IF KRQ RELAY

290B153

Fig. 2. Directional Comparison Blacking – Trip & Control Circuits.

Auxiliary Relay & Accessories

1 – Type KA Carrier auxiliary relay, consisting of:

- 1 – Receiver relay unit (RR), with a holding coil, RRH, a tripping coil, RRT, and two contacts, RRG & RRP
- 1 – Phase auxiliary unit (CSP)
- 1 – Ground auxiliary unit (CSG)
- 1 – Instantaneous ground overcurrent start unit (I_{OS})
- 1 – Operation indicator (OI)
- 1 – Alarm unit (AL)

1 – Type W On-off Switch (85CO)

1 – Test pushbutton (PB)

1 – Milliammeter (MA)

Out-of-Step Blocking (Optional)

1 – KS Out-of-Step blocking relay (Z_{OS}), used to block phase tripping or to block breaker reclosing, with auxiliary unit (OS)

Backup

2 – KD Phase distance relays (Zones 1 & 2)

1 – TD-2 Timing relay consisting of:

- 1 – Timing unit (T), with contacts, T2 & T3
- 1 – Auxiliary unit (TX), with two operating coils, TXZ2 & TXZ3
- 1 – Indicating contactor switch (ICS)

* 1 – TD-4 Timing Relay (alternative to TD-2)

OPERATION

When an external fault occurs, as shown in fig. 1, the transmitter at breaker B is keyed by the "start" relays to block tripping at breaker A. Breaker B is not tripped because the fault power flow is not in the proper direction to close the D_O, ZP-$\phi\phi$ or ZP-3ϕ contacts.

When an internal fault occurs, a blocking signal is transmitted from neither A nor B in fig. 1; in the absence of blocking the tripping units at each station (ZP-$\phi\phi$ or ZP-3ϕ for phase faults, D_O & I_O for ground faults) are permitted to trip. Succeeding paragraphs will explain how this is performed.

Phase Fault Tripping

Distance units, ZP (ZP-$\phi\phi$ & ZP-3ϕ), operate only when fault power flows into the protected line, as shown in fig. 1. They are set to reach beyond the end of the line (overreaching setting), so that faults anywhere on the protected line will be detected & cleared at high speed. These units such as at breaker A, fig. 1 also operate for faults on the adjacent system; therefore, the ZP contacts must be supervised by a contact which does not close during external faults. This supervising contact is RRP in fig. 2. For internal faults the RRP contact closes to permit one of the ZP contacts to energize the breaker trip coil, 52 TC. The trip path is from positive, through ICS coil, ZP-$\phi\phi$ or ZP-3ϕ & OS contacts, 85-CO contact 1-2, OI coil, RRP contact, 52a contact, to the trip coil.

Fig. 2 also shows an optional time delay backup path, through T3 contact which bypasses the RRP contact circuit. T3 contact & TX-Z3 coil are from the TD-2 timing relay, which is associated with an independent 2-zone-distance backup circuit (not shown). Operation of ZP energizes TX-Z3 coil, which starts the timer. If the fault, either internal or external, is not cleared by other means, the breaker will be tripped after time delay, T3, if the fault is within the reach of ZP.

Ground Fault Tripping

Ground directional unit, D_O (D_{OC} & D_{OP} when KRD dual polarized relay is used), closes only for ground faults in one direction, as is the case for the phase tripping units, ZP. The instantaneous unit, I_O, is set to pickup for a zero sequence current well below the solid ground fault level, to insure high speed tripping even with substantial fault resistance. As with ZP, this overreaching setting results in relay operation for external faults in the "trip direction." To prevent breaker tripping for external faults, the ground trip path must likewise be supervised. RRG is the ground fault supervising contact, which remains open during external faults, but closes during internal faults to permit the ground tripping relay, KRC, KRD, or KRP, to clear the fault.

Tripping from positive is through 85-CO contact 3-4, ICS coil, contacts D_O, I_O, RRG, 52a, to the trip coil. A backup ground relay is not shown in fig. 2. It is recommended that this relay trip circuit be on a

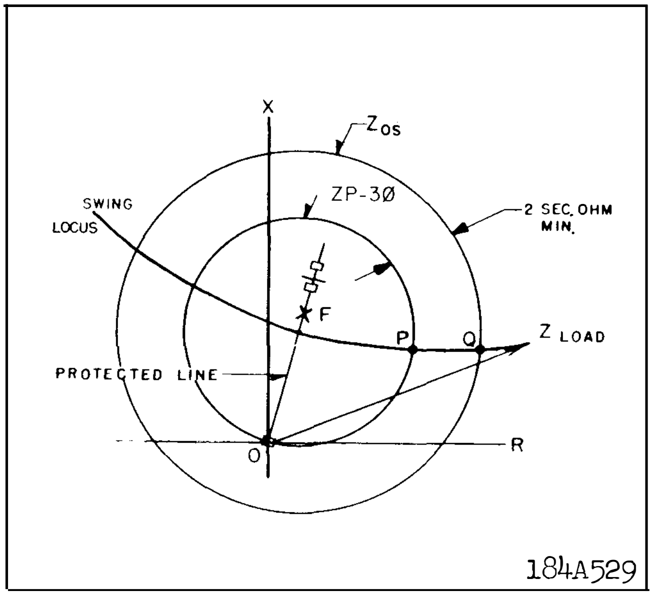


Fig. 3. Out-of-Step Blocking Operations.

separately fused supply, along with the phase back-up relays.

Transmitter Control

Break contacts, ZS (ZS-$\phi\phi$ & ZS-3ϕ) & I_{OS}, 85 CO contact 7-8, and the test pushbutton break contact, PB, in fig. 2, connect the transmitter "start" lead to minus. When any one of these contacts opens, the "start" lead is connected to positive through resistor, R2. This positive potential will key the transmitter on (or shift the frequency, when a frequency shift channel is utilized), to block remote breaker tripping, provided that the "stop" lead is not tied to minus, through contact CSP or CSG. CSP & CSG coils are energized by ZP & D_O contacts, respectively, so that any time a fault is detected in the trip direction the "stop" lead is tied to minus to prevent transmission of a blocking signal. Thus, the stop lead has precedence over the start lead. If, for example, the channel is being used for voice communication at the instant of an internal fault, the stop circuit will interrupt transmission to permit tripping, provided that either ZP or D_O operates.

A blocking signal is required from breaker B, fig. 1, during an external fault because the phase or ground tripping units would otherwise trip at breaker A. At breaker B either the I_{OS} or the ZS contact opens to put positive voltage on the start lead; since neither the CSP nor the CSG contacts close at B the stop lead is not energized, and, therefore, a blocking signal is transmitted.

Receiver Relay Comparison Circuits

Receiver relay, RR, has an RRH holding coil and an RRT tripping coil as shown in Fig. 2. RRH is energized by the receiver output when a blocking signal is transmitted; RRT coil is energized whenever the local tripping relay contacts close in an attempt to trip the breaker. RRH coil current holds the RRP and RRG contacts open; RRT coil current closes the RRP and RRG contacts in the absence of RRH coil current. This is the key point, which produces the comparison function — the force produced by RRH current is stronger than the opposing force produced by RRT current, so that the RRP and RRG contacts will be closed by RRT current only when no blocking signal is received.

In Fig. 1, ZP or $D_O + I_O$ contacts close at breaker A whether the fault is internal, or external to the right of breaker B; in either case, CSP or CSG is energized and RRT, in turn, is energized. For the external fault only, the transmitter at B sends a blocking signal, which produces a receiver output at A, which energizes the RRH coil to prevent RRP and RRG contacts from closing; thus, tripping is prevented. Conversely, for an internal fault, tripping units operate at both stations to energize CSP or CSG contacts to prevent transmission of a blocking signal; another set of CSP/CSG contacts energize the RRT coil. Since neither station receives a blocking signal, both RRH coils are deenergized; both RR relays operate to close their RRP and RRG contacts to permit either ZP or $D_O + I_O$ contacts to energize the trip coil.

A reactor is shown in series with the RRT coil in fig. 2. This reactor is used only with audio tone or frequency shift carrier channels, where the channel delay time is abnormally large. This reactor delays RRT coil current buildup long enough to compensate for the RRH coil current buildup time occasioned by the channel delay. Otherwise undesired tripping might occur before a blocking signal can be received.

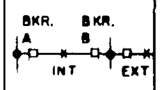
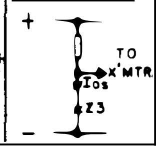
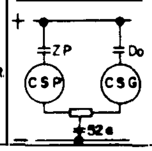
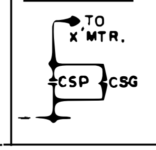
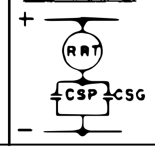
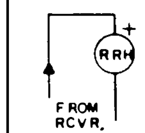
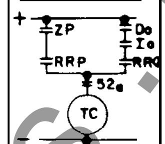
Operation will now be summarized.

External Phase Fault Operation

Refer to Table I, which tabulates external phase fault functioning at the top. The external fault is to the right of breaker B as shown in the upper left of Table I.

At breaker B, ZS contact opens and the ZP contact remains open, so that CSP is not energized; the start lead is at positive and the stop lead is open,

Table I. Summary of Operation.

	X'MTR. START	CSP & CSG COILS	X'MTR. STOP	RRT COIL	RRH COIL	TRIP CIRCUIT
						
	EXTERNAL		PHASE		FAULT	
BKR. A	Z_3 STAYS CLOSED	Z_p ENERGIZES CSP	CSP CLOSES	CSP CLOSES	RRH ENERGIZED	RRP & RRG HELD OPEN BY RRH CURRENT
BKR. B	Z_3 OPENS	Z_p STAYS OPEN	CSP & CSG STAY OPEN	CSP & CSG STAY OPEN	RRH DE-ENERGIZED (NOTE 1)	RRP & RRG HELD OPEN BY MAGNETIC BIAS (NOTE 1)
	INTERNAL		PHASE		FAULT	
BKR. A	Z_3 STAYS CLOSED	Z_p ENERGIZES CSP	CSP CLOSES	CSP CLOSES	RRH DE-ENERGIZED	TRIP THROUGH ZP & RRP
BKR. B	Z_3 STAYS CLOSED	Z_p ENERGIZES CSP	CSP CLOSES	CSP CLOSES	RRH DE-ENERGIZED	TRIP THROUGH ZP & RRP
	EXTERNAL		GROUND		FAULT	
BKR. A	I_{os} OPENS	D_o ENERGIZES CSP	CSG CLOSES	CSG CLOSES	RRH ENERGIZED	RRP & RRG HELD OPEN BY RRH CURRENT
BKR. B	I_{os} OPENS	D_o STAYS OPEN	CSP & CSG STAY OPEN	CSP & CSG STAY OPEN	RRH DENERGIZED	RRP & RRG HELD OPEN BY MAGNETIC BIAS
	INTERNAL		GROUND		FAULT	
BKR. A	I_{os} OPENS (NOTE 2)	D_o ENERGIZES CSG	CSG CLOSES	CSG CLOSES	RRH DE-ENERGIZED	TRIP THROUGH D_o, I_o, & RRG
BKR. B	I_{os} OPENS (NOTE 2)	D_o ENERGIZES CSG	CSG CLOSES	CSG CLOSES	RRH DE-ENERGIZED	TRIP THROUGH D_o, I_o, & RRG

NOTE 1 RRH COIL IS ENERGIZED BY ITS OWN TRANSMITTER WHEN CHANNEL USES SINGLE FREQUENCY OPERATION. THIS FEATURE IS NOT ESSENTIAL TO PROPER OPERATION

NOTE 2 I_{os} OPERATION IS INEFFECTIVE SINCE CSG CONTACT CLOSES TO STOP BLOCKING SIGNAL.

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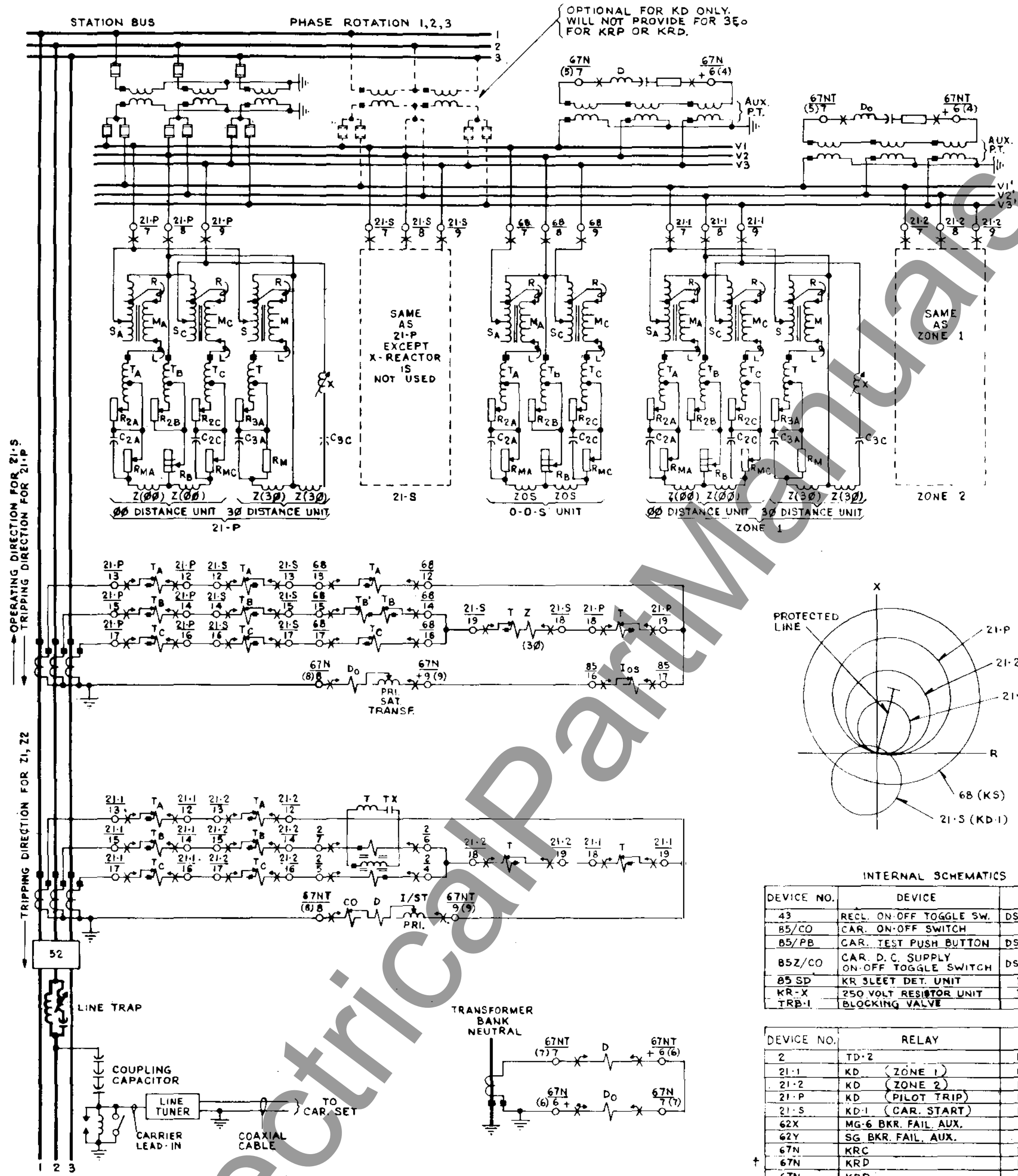

RESISTOR VALUES IN OHMS

	48 V. D.C.	125 V. D.C.	250 V. D.C.
R1	100	300	6000
R2	2000	3750	19000
R3	1320	5000	11200
RS	500	2000	4500
RT	0	750	2000

85/CO

TYPE W CARRIER ON-OFF SWITCH

CONTACT	POSITION	
	ON	OFF
1-2	X	
3-4	X	
5-6	X	
7-8	X	
9-10		X
11-12		X

X DENOTES CONTACT CLOSED

INTERNAL SCHEMATICS

DEVICE NO.	DEVICE	DWG. NO.
43	RECL. ON-OFF TOGGLE SW.	DS 41-600-F 9
85/CO	CAR. ON-OFF SWITCH	
85/PB	CAR. TEST PUSH BUTTON	DS 41-600-F 14
85Z/CO	CAR. D.C. SUPPLY ON-OFF TOGGLE SWITCH	DS 41-600-F 9
85 SD	KR SLEET DET. UNIT	329 C 703
KR-X	250 VOLT RESISTOR UNIT	330 C 191
TRB-1	BLOCKING VALVE	184 A 415

DEVICE NO.	RELAY	DWG. NO.
2	TD-2	184 A 273
21-1	KD (ZONE 1)	183 A 507
21-2	KD (ZONE 2)	183 A 507
21-P	KD (PILOT TRIP)	183 A 507
21-S	KD-1 (CAR. START)	183 A 527
62X	MG-6 BKR. FAIL. AUX.	
62Y	SG BKR. FAIL. AUX.	
67N	KRC	183 A 022
† 67N	KRD	183 A 412
67N	KRP	183 A 025
67NT	IRC	184 A 034
† 67NT	IRD	184 A 020
67NT	IRP	184 A 033
68	KS	183 A 583
79	SGR-12	184 A 246
79Z	SG	183 A 457
85	KA	184 A 558
86B	BUS DIFF. LOCKOUT	
86LN	MG-6 LOCKOUT	
94	TR-1 AUX. TRIP	
50X	KC-3 CURRENT DETECTOR	

† IRD, KRD - TERMINAL NUMBERS ARE INDICATED IN PARENTHESIS

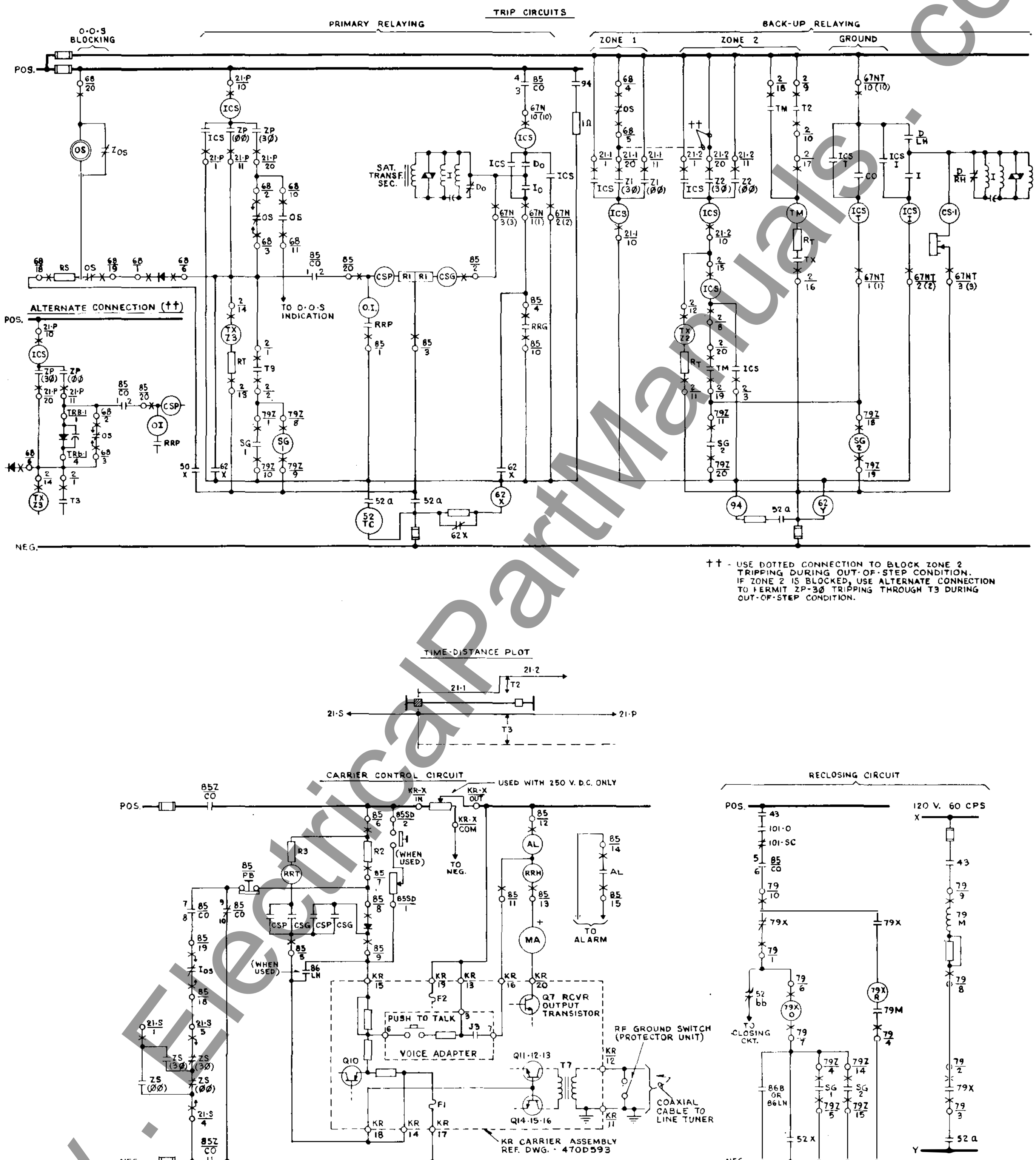

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Fig. 4 Detailed schematic of the K-Dar 4 zone directional-comparison blocking system.

so the transmitter sends a blocking signal. Tripping does not occur because ZP is open.

At breaker A, ZP contact closes, energizing CSP. CSP contact energizes RRT; however, RRP contact is held open by RRH current.

Internal Phase Fault Operation

Operation is the same at both stations. Refer to Table I. Z3 does not operate, since it is set to look into the external system. ZP contact closes, energizing CSP. CSP contact closes to apply negative to the stop lead, preventing blocking signal transmission. Another CSP contact energizes RRT; since there is no signal to produce RRH coil current, RRT coil

External Ground Fault Operation

Refer to Table I. Since the ground overcurrent units I_{OS}, are not directional, they operate at both A&B to open their contacts. At breaker A, I_{OS} operation is ineffective, since the stop lead is energized by CSG. However, at breaker B, CSG and the stop lead are not energized, so that the opening of the I_{OS} contact results in transmission of a blocking signal from B. Tripping at breaker B does not occur because D_O re-remains open.

At breaker A RRT coil is energized when D_O closes to operate CSG; however, tripping is prevented by RRH coil current, which holds RRG open.

Internal Ground Fault Operation

Refer to Table I. Operation is the same at both stations. D_O closes, energizing CSG. CSG contacts stop blocking signal transmission and energize the RRT coil. Since no blocking signal is received. RRH is not energized; therefore, RRG closes, and the breaker trip coil is energized through 85 CO contact 3-4, D_O, I_O, RRG and 52a contacts.

Out-of-Step Operation

KS relay distance unit, Z_{OS}, is set to include the ZP-3ϕ unit R-X diagram circle as shown in Figure 3. A minimum separation of two secondary ohms is recommended between the Z_{OS} and ZP-3ϕ unit circles. This separation provides the means for distinguishing between 3-phase faults and out-of-step conditions. When a fault occurs on the protected line, the impedance seen by the relays changes suddenly from the prefault value, Z_{Load}, to the fault value, represented by the line O-F in Fig. 3. When a swing or out-of-step condition occurs the impedance seen by Z_{OS} & ZP changes gradually, as the voltage decreases and the current increases. In Fig. 3 the swing describes an arc which intersects the Z_{OS} circle at point Q and ZP-3ϕ circle, at point P.

During an out-of-step condition the Z_{OS} contact in figure 2 opens before ZP-3ϕ contact closes. OS unit is energized, and after 4 cycles, an OS contact opens the ZP-3ϕ trip-circuit. All this occurs before the swing reaches point, P, in Fig. 3.

During a fault, the ZP-3ϕ contact closes almost at the same instant that the Z_{OS} contact opens in Fig. 2. ZP-3ϕ contact short-circuits the OS coil to prevent OS from operating. Thus a fault condition results in a nearly simultaneous operation of Z_{OS} and ZP-3ϕ; while an out-of-step condition produces a discrete difference in the operating time of these two distance units.

In some cases it is preferable to block breaker reclosing rather than blocking tripping, when an out-of-step condition occurs. A make contact of OS shown in Figure 2, is available for this purpose. Otherwise, this OS contact may be used for alarm purposes, as shown by the dotted connection in Figure 2.

RELAY SETTINGS

It is essential that the local start units, which initiate blocking signal transmission, operate for any external fault for which the remote tripping units also operate; otherwise undesired tripping of the remote breaker will occur.

Phase

In Fig. 1, breaker A-ZS is set to reach further than the breaker B-ZP units by the distance, M-N. It is recommended that this distance be at least half of N-P, as shown in Fig. 1. Unless ZS is used for tripping as well as for starting a blocking signal, and unless an undesirably large tripping area would otherwise result, it is recommended that the ZS setting be made at least as large as the remote ZP setting.

Ground

Set the remote I_O unit for a pickup at least 25% higher than the local I_{OS} pickup to insure operation of the I_{OS} for any fault which will also result in I_O operation.

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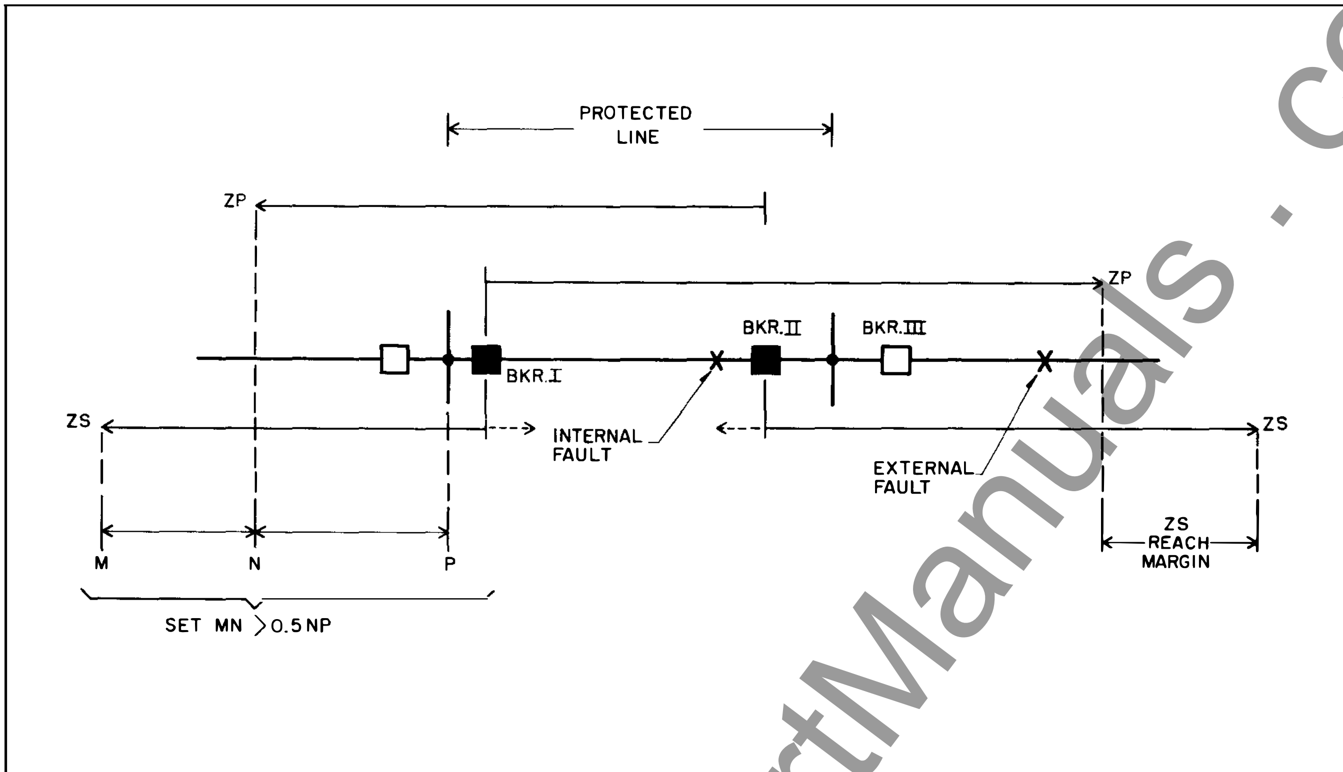
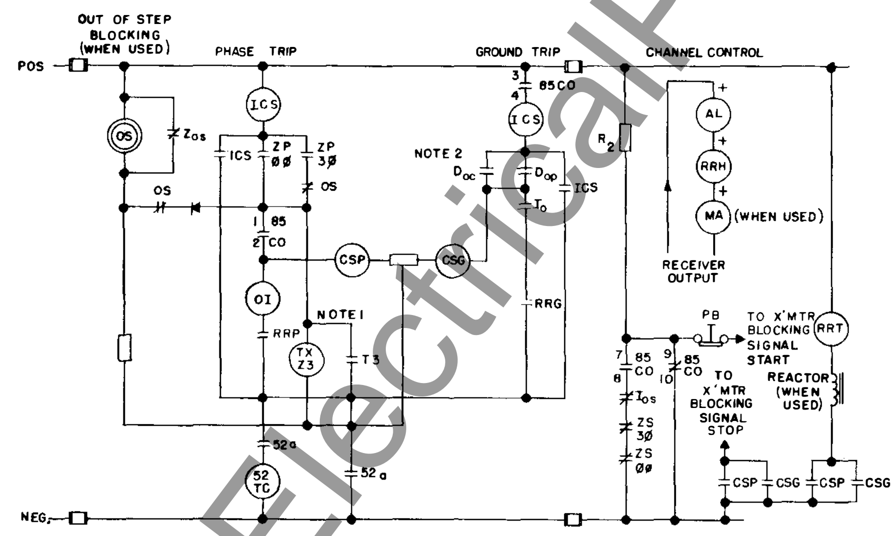


Fig. 1. Phase Relay Settings



AL	ALARM UNIT OF KA RELAY
CSG	GROUND AUXILIARY UNIT OF KA RELAY
CSP	PHASE AUXILIARY UNIT OF KA RELAY
D_{oc}	CURRENT POLARIZED DIRECTIONAL UNIT OF KRD RELAY
D_{op}	VOLTAGE POLARIZED DIRECTIONAL UNIT OF KRD RELAY
ICS	INDICATING CONTACTOR SWITCH OF KD & KRD RELAYS
I_o	GROUND OVERCURRENT TRIP UNIT OF KRD RELAY
I_{os}	GROUND START OVERCURRENT UNIT OF KA RELAY
MA	MILLIAMMETER
OI	OPERATION INDICATOR OF KA RELAY
OS	AUXILIARY UNIT OF KS RELAY
RRG,RRP	RECEIVER RELAY UNIT CONTACTS OF KA RELAY
RRH	HOLDING COIL OF RECEIVER RELAY UNIT OF KA RELAY
RRT	TRIPPING COIL OF RECEIVER RELAY UNIT OF KA RELAY
TXZ3	TIMER START AUXILIARY UNIT OF TD-2 RELAY
ZOS	DISTANCE UNIT OF KS RELAY
ZP-ØØ	PHASE-TO-PHASE UNIT OF KD RELAY
ZP-3Ø	3 PHASE UNIT OF KD RELAY
ZS-ØØ	PHASE-TO-PHASE UNIT OF KD-1 RELAY
ZS-3Ø	3 PHASE UNIT OF KD-1 RELAY
52a	CIRCUIT BREAKER AUXILIARY SWITCH CONTACT-CLOSED WHEN BREAKER IS CLOSED
52TC	CIRCUIT BREAKER TRIP COIL
85CO	CUTOUT SWITCH-IN "ON" POSITION WHEN CHANNEL IS OPERATIVE

85CO ON-OFF SWITCH

CONTACT	POSITION	
	ON	OFF
1-2	X	
3-4	X	
5-6	X	
7-8	X	
9-10		X
11-12		X

X-DENOTES CONTACT CLOSED

NOTES:

1. OPTIONAL CONNECTION, WHERE T3 CONTACT OF TD-2 IS AVAILABLE IN BACKUP CIRCUITS
2. OMIT D_{oc} IF KRP RELAY; OMIT D_{op} IF KRC RELAY; SUBSTITUTE D2 FOR D_{oc} & D_{op} IF KRQ RELAY

Fig. 2. Directional Comparison Blocking — Trip & Control Circuits.

1 – Instantaneous ground overcurrent start unit (I_{OS})

1 – Operation indicator (OI)

1 – Alarm unit (AL)

1 – Type W On-off Switch (85CO)

1 – Test pushbutton (PB)

1 – Milliammeter (MA)

Out-of-Step Blocking (Optional)

1 – KS Out-of-Step blocking relay (Z_{OS}), used to block phase tripping or to block breaker reclosing, with auxiliary unit (OS)

Backup

2 – KD Phase distance relays (Zones 1 & 2)

1 – TD-2 Timing relay consisting of:

1 – Timing unit (T), with contacts, T2 & T3

1 – Auxiliary unit (TX), with two operating coils, TXZ2 & TXZ3

1 – Indicating contactor switch (ICS)

OPERATION

When an external fault occurs, as shown in fig. 1, the transmitter at breaker B is keyed by the "start" relays to block tripping at breaker A. Breaker B is not tripped because the fault power flow is not in the proper direction to close the D_O, ZP-$\phi\phi$ or ZP-3ϕ contacts.

When an internal fault occurs, a blocking signal is transmitted from neither A nor B in fig. 1; in the absence of blocking the tripping units at each station (ZP-$\phi\phi$ or ZP-3ϕ for phase faults, D_O & I_O for ground faults) are permitted to trip. Succeeding paragraphs will explain how this is performed.

Phase Fault Tripping

Distance units, ZP (ZP-$\phi\phi$ & ZP-3ϕ), operate only when fault power flows into the protected line, as shown in fig. 1. They are set to reach beyond the end of the line (overreaching setting), so that faults anywhere on the protected line will be detected & cleared at high speed. These units such as at breaker A, fig. 1 also operate for faults on the adjacent system; therefore, the ZP contacts must be supervised by a contact which does not close during external faults. This supervising contact is RRP in fig. 2. For internal faults the RRP contact closes to permit one of the ZP contacts to energize the breaker trip coil, 52 TC. The trip path is from positive, through ICS coil, ZP-$\phi\phi$ or ZP-3ϕ & OS contacts, 85-CO contact 1-2, OI coil, RRP contact, 52a contact, to the trip coil.

Fig. 2 also shows an optional time delay backup path, through T3 contact which bypasses the RRP contact circuit. T3 contact & TX-Z3 coil are from the TD-2 timing relay, which is associated with an independent 2-zone-distance backup circuit (not shown). Operation of ZP energizes TX-Z3 coil, which starts the timer. If the fault, either internal or external, is not cleared by other means, the breaker will be tripped after time delay, T3, if the fault is within the reach of ZP.

Ground Fault Tripping

Ground directional unit, D_O (D_{OC} & D_{OP} when KRD dual polarized relay is used), closes only for ground faults in one direction, as is the case for the phase tripping units, ZP. The instantaneous unit, I_O, is set to pickup for a zero sequence current well below the solid ground fault level, to insure high speed tripping even with substantial fault resistance. As with ZP, this overreaching setting results in relay operation for external faults in the "trip direction." To prevent breaker tripping for external faults, the ground trip path must likewise be supervised. RRG is the ground fault supervising contact, which remains open during external faults, but closes during internal faults to permit the ground tripping relay, KRC, KRD, or KRP, to clear the fault.

Tripping from positive is through 85-CO contact 3-4, ICS coil, contacts D_O, I_O, RRG, 52a, to the trip coil. A backup ground relay is not shown in fig. 2. It is recommended that this relay trip circuit be on a separately fused supply, along with the phase backup relays.

Transmitter Control

Break contacts, ZS (ZS-$\phi\phi$ & ZS-3ϕ) & I_{OS}, 85 CO contact 7-8, and the test pushbutton break contact, PB, in fig. 2, connect the transmitter "start" lead to minus. When any one of these contacts opens, the "start" lead is connected to positive through resistor, R2. This positive potential will key the transmitter on (or shift the frequency, when a frequency shift channel is utilized), to block remote breaker tripping, provided that the "stop" lead is not tied to minus, through contact CSP or CSG. CSP & CSG coils are energized by ZP & D_O contacts, re-

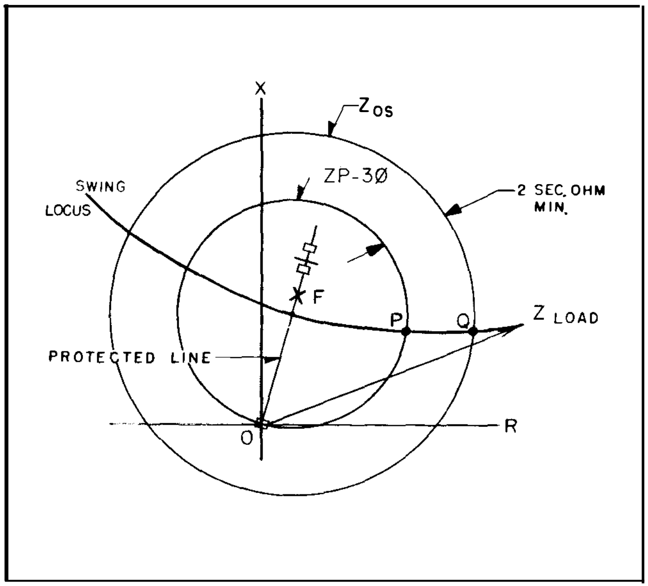


Fig. 3. Out-of-Step Blocking Operations.

spectively, so that any time a fault is detected in the trip direction the "stop" lead is tied to minus to prevent transmission of a blocking signal. Thus, the stop lead has precedence over the start lead. If, for example, the channel is being used for voice communication at the instant of an internal fault, the stop circuit will interrupt transmission to permit tripping, provided that either ZP or D_O operates.

A blocking signal is required from breaker B, fig. 1, during an external fault because the phase or ground tripping units would otherwise trip at breaker A. At breaker B either the I_{OS} or the ZS contact opens to put positive voltage on the start lead; since neither the CSP nor the CSG contacts close at B the stop lead is not energized, and, therefore, a blocking signal is transmitted.

Receiver Relay Comparison Circuits

Receiver relay, RR, has an RRH holding coil and an RRT tripping coil as shown in Fig. 2. RRH is energized by the receiver output when a blocking signal is transmitted; RRT coil is energized whenever the local tripping relay contacts close in an attempt to trip the breaker. RRH coil current holds the RRP and RRG contacts open; RRT coil current closes the RRP and RRG contacts in the absence of RRH coil current. This is the key point, which produces the comparison function — the force produced by RRH current is stronger than the opposing force produced by RRT current, so that the RRP and RRG contacts will be closed by RRT current only when no blocking signal is received.

In Fig. 1, ZP or $D_O + I_O$ contacts close at breaker A whether the fault is internal, or external to the right of breaker B; in either case, CSP or CSG is energized and RRT, in turn, is energized. For the external fault only, the transmitter at B sends a blocking signal, which produces a receiver output at A, which energizes the RRH coil to prevent RRP and RRG contacts from closing; thus, tripping is prevented. Conversely, for an internal fault, tripping units operate at both stations to energize CSP or CSG contacts to prevent transmission of a blocking signal; another set of CSP/CSG contacts energize the RRT coil. Since neither station receives a blocking signal, both RRH coils are deenergized; both RR relays operate to close their RRP and RRG contacts to permit either ZP or $D_O + I_O$ contacts to energize the trip coil.

A reactor is shown in series with the RRT coil in fig. 2. This reactor is used only with audio tone or frequency shift carrier channels, where the channel delay time is abnormally large. This reactor delays RRT coil current buildup long enough to compensate for the RRH coil current buildup time occasioned by the channel delay. Otherwise undesired tripping might occur before a blocking signal can be received.

Operation will now be summarized.

External Phase Fault Operation

Refer to Table I, which tabulates external phase fault functioning at the top. The external fault is to the right of breaker B as shown in the upper left of Table I.

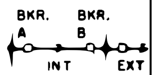
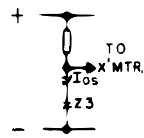
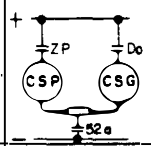
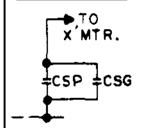
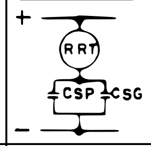
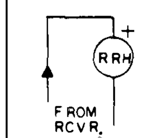
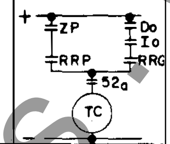
At breaker B, ZS contact opens and the ZP contact remains open,.so that CSP is not energized; the start lead is at positive and the stop lead is open, so the transmitter sends a blocking signal. Tripping does not occur because ZP is open.

At breaker A, ZP contact closes, energizing CSP. CSP contact energizes RRT; however, RRP contact is held open by RRH current.

Internal Phase Fault Operation

Operation is the same at both stations. Refer to Table I. ZS does not operate, since it is set to look into the external system. ZP contact closes, energizing CSP. CSP contact closes to apply negative to the stop lead, preventing blocking signal transmission. Another CSP contact energizes RRT; since there is no signal to produce RRH coil current, RRT coil current closes RRP, permitting ZP to trip the breaker.

Table I. Summary of Operation.

	X'MTR. START 	CSP & CSG COILS 	X'MTR. STOP 	RRT COIL 	RRH COIL 	TRIP CIRCUIT 
	EXTERNAL		PHASE		FAULT	
BKR. A	Z_3 STAYS CLOSED	Z_p ENERGIZES CSP	CSP CLOSES	CSP CLOSES	RRH ENERGIZED	RRP & RRG HELD OPEN BY RRH CURRENT
BKR. B	Z_3 OPENS	Z_p STAYS OPEN	CSP & CSG STAY OPEN	CSP & CSG STAY OPEN	RRH DE-ENERGIZED (NOTE 1)	RRP & RRG HELD OPEN BY MAGNETIC BIAS (NOTE 1)
	INTERNAL		PHASE		FAULT	
BKR. A	Z_3 STAYS CLOSED	Z_p ENERGIZES CSP	CSP CLOSES	CSP CLOSES	RRH DE-ENERGIZED	TRIP THROUGH ZP & RRP
BKR. B	Z_3 STAYS CLOSED	Z_p ENERGIZES CSP	CSP CLOSES	CSP CLOSES	RRH DE-ENERGIZED	TRIP THROUGH ZP & RRP
	EXTERNAL		GROUND		FAULT	
BKR. A	I_{os} OPENS	D_o ENERGIZES CSP	CSG CLOSES	CSG CLOSES	RRH ENERGIZED	RRP & RRG HELD OPEN BY RRH CURRENT
BKR. B	I_{os} OPENS	D_o STAYS OPEN	CSP & CSG STAY OPEN	CSP & CSG STAY OPEN	RRH DENERGIZED	RRP & RRG HELD OPEN BY MAGNETIC BIAS
	INTERNAL		GROUND		FAULT	
BKR. A	I_{os} OPENS (NOTE 2)	D_o ENERGIZES CSG	CSG CLOSES	CSG CLOSES	RRH DE-ENERGIZED	TRIP THROUGH D_o, I_o, & RRG
BKR. B	I_{os} OPENS (NOTE 2)	D_o ENERGIZES CSG	CSG CLOSES	CSG CLOSES	RRH DE-ENERGIZED	TRIP THROUGH D_o, I_o, & RRG

NOTE 1 RRH COIL IS ENERGIZED BY ITS OWN TRANSMITTER WHEN CHANNEL USES SINGLE FREQUENCY OPERATION. THIS FEATURE IS NOT ESSENTIAL TO PROPER OPERATION

NOTE 2 I_{os} OPERATION IS INEFFECTIVE SINCE CSG CONTACT CLOSES TO STOP BLOCKING SIGNAL.

External Ground Fault Operation

Refer to Table I. Since the ground overcurrent units I_{OS}, are not directional, they operate at both A&B to open their contacts. At breaker A, I_{OS} operation is ineffective, since the stop lead is energized by CSG. However, at breaker B, CSG and the stop lead are not energized, so that the opening of the I_{OS} contact results in transmission of a blocking signal from B. Tripping at breaker B does not occur because D_O re-remains open.

At breaker A RRT coil is energized when D_O closes to operate CSG; however, tripping is prevented by RRH coil current, which holds RRG open.

Internal Ground Fault Operation

Refer to Table I. Operation is the same at both stations. D_O closes, energizing CSG. CSG contacts stop blocking signal transmission and energize the RRT coil. Since no blocking signal is received. RRG is not energized; therefore, RRG closes, and the breaker trip coil is energized through 85 CO contact 3-4, D_O, I_O, RRG and 52a contacts.

Out-of-Step Operation

KS relay distance unit, Z_{OS}, is set to include the ZP-3ϕ unit R-X diagram circle as shown in Figure 3. A minimum separation of two secondary ohms is recommended between the Z_{OS} and ZP-3ϕ unit circles. This separation provides the means for distinguishing between 3-phase faults and out-of-step conditions. When a fault occurs on the protected line, the impedance seen by the relays changes suddenly from the prefault value, Z_{Load}, to the fault value, represented by the line O-F in Fig. 3. When a swing or out-of-step condition occurs the impedance seen by Z_{OS} & ZP changes gradually, as the voltage decreases and the current increases. In Fig. 3 the swing describes an arc which intersects the Z_{OS} circle at point Q and ZP-3ϕ circle, at point P.

During an out-of-step condition the Z_{OS} contact in figure 2 opens before ZP-3ϕ contact closes. OS unit is energized, and after 4 cycles, an OS contact opens the ZP-3ϕ trip-circuit. All this occurs before the swing reaches point, P, in Fig. 3.

During a fault, the ZP-3ϕ contact closes almost at the same instant that the Z_{OS} contact opens in Fig. 2. ZP-3ϕ contact short-circuits the OS coil to prevent OS from operating. Thus a fault condition results in a nearly simultaneous operation of Z_{OS} and ZP-3ϕ; while an out-of-step condition produces a discrete difference in the operating time of these two distance units.

In some cases it is preferable to block breaker reclosing rather than blocking tripping, when an out-of-step condition occurs. A make contact of OS shown in Figure 2, is available for this purpose. Otherwise, this OS contact may be used for alarm purposes, as shown by the dotted connection in Figure 2.

RELAY SETTINGS

It is essential that the local start units, which initiate blocking signal transmission, operate for any external fault for which the remote tripping units also operate; otherwise undesired tripping of the remote breaker will occur.

Phase

In Fig. 1, breaker A-ZS is set to reach further than the breaker B-ZP units by the distance, M-N. It is recommended that this distance be at least half of N-P, as shown in Fig. 1. Unless ZS is used for tripping as well as for starting a blocking signal, and unless an undesirably large tripping area would otherwise result, it is recommended that the ZS setting be made at least as large as the remote ZP setting.

Ground

Set the remote I_O unit for a pickup at least 25% higher than the local I_{OS} pickup to insure operation of the I_{OS} for any fault which will also result in I_O operation.

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