ABB Automation, Inc.
Substation Automation & Protection Division
Coral Springs, FL
Allentown, PA

Instruction Leaflet
40-385.1B

Effective: May, 1992
Supersedes IL 40-385.1A
dated January, 1992

Numerical Distance Protection REL-300 (MDAR) Relaying System Version 2.02

ABB Network Partner

MDAR REVISION NOTICE

DATE	REV LEVEL	PAGES REMOVED	PAGES INSERTED
11/91	A	v, vi, 1-2, 1-5, 3-2, 3-4, 3-5, 3-7, 3-9, 3-10, 3-11, 3-14, 3-15, 4-3, 4-4, 4-11, 4-17, 5-1, 5-3, 5-5, 5-6, A-1, A-6, G-8, H-1, H-2, H-5, H-9	SAME
1/01/92	A	3-1, H-2, H-7	SAME
1/15/92	A	vi, 3-29, J-1, J-2, J-3, J-4, J-5, J-6	SAME
5/92	B	3-2, 3-19, 3-20, 3-21, 3-23, 3-26, 5-1, A-1, A-5 thru A-7, B4 thru B-6, C-1,C-4 thru C-6, D-1, D-4 thru D-6, E-1, E-7 thru E-12, F-4, F-5, G-1, G-4, thru G-8, H-2, H-6, H-8, H-9, H-14, H-17, H-21	3-2, 3-19, 3-20, 3-21, 3-23, 3-26, 5-1, A-1, C-1, D-1, E-1, G-1, H-2, H-6, H-8, H-9, H-14, H-17, H-21

CHANGE SUMMARY:

A CHANGE BAR (|) LOCATED IN THE MARGIN REPRESENTS A TECHNICAL CHANGE TO THE PRODUCT.

CAUTION

It is recommended that the user of MDAR equipment become acquainted with the information in this instruction leaflet before energizing the system. Failure to do so may result in injury to personnel or damage to the equipment, and may affect the equipment warranty. If the MDAR relay system is mounted in a cabinet, the cabinet must be bolted to the floor, or otherwise secured before MDAR installation, to prevent the system from tipping over.

All integrated circuits used on the modules are sensitive to and can be damaged by the discharge of static electricity. Electrostatic discharge precautions should be observed when handling modules or individual components.

ABB does not assume liability arising out of the application or use of any product or circuit described herein. ABB reserves the right to make changes to any products herein to improve reliability, function or design. Specifications and information herein are subject to change without notice. All possible contingencies which may arise during installation, operation, or maintenance, and all details and variations of this equipment do not purport to be covered by these instructions. If further information is desired by purchaser regarding a particular installation, operation or maintenance of equipment, the local ABB representative should be contacted.

PREFACE

Scope

This manual describes the functions and features of the MDAR Relay System. It is intended primarily for use by engineers and technicians involved in the installation, testing, operation and maintenance of the MDAR system.

Equipment Identification

The MDAR equipment is identified by the Catalog Number on the MDAR chassis nameplate. The Catalog Number can be decoded by using Catalog Number Table 3-1 (see Section 3).

Production Changes

When engineering and production changes are made to the MDAR equipment, a revision notation (SUB #) is reflected on the appropriate schematic diagram, and associated parts information. A summary of all Sub #s for the particular release is shown below.

Equipment Repair

Repair work is done most satisfactorily at the factory. When returning equipment, carefully pack modules and other units, etc. All equipment should be returned in the original packing containers if possible. Any damage due to improperly packed items will be charged to the customer.

Document Overview

The circuitry is divided into 6 standard modules and one option module. Section 1 provides the Product Description, which includes software functions. Appendices A through G include related module circuit descriptions. Section 2 presents the Specifications. Section 3 presents Non-Pilot applications (see Appendix H for the optional Pilot System) with related Catalog Numbers for ordering purposes. MDAR Installation, Operation and Maintenance are described in Section 4, with related Setting Calculations in Section 5. Acceptance Tests for both Non-Pilot and Pilot System are described in Appendix I. System Diagrams are included in Appendix J.

Contents of Relay System

The MDAR Relay System includes the style numbers, listed below, with appropriate sub numbers (representing revision levels) for each module. Addenda pages may be included (representing future revisions).

Module	Style and Sub Number	Addenda
• Backplane (Sub-Backplane Xfmr)	1609C23-4 1498B70-2	
• Interconnect	1611C30-2	
• Option	1608C39-4	
• Filter	1608C38-5	
• Microprocessor	1611C14-1	
• Display	1609C01-3	
• Power Supply	1608C35-10	

Software System

MDAR software version V2.01 is included in this I.L.

Setting Nomenclature Appliques

If this I.L. is included as part of the shipment of an MDAR Relay system, the I.L. will contain setting nomenclature appliques which can be placed in a convenient location, e.g., inside the two FT-14 covers. The appliques provide a convenient (and complete) set of MDAR “settings” (see Table 4-1 for setting nomenclature). There are two appliques which are printed protective sheets (contained in a plastic envelope); the back of the sheets can be removed thereby exposing a stick-on surface.

Features Included in Version V2.00

The following features are ***standard*** for the Non-Pilot MDAR V2.00:

- 3-Zone distance phase and ground relay, with reversible Zone 3 phase and ground; 4 impedance units per zone: 3 phase-to-ground; 1 phase-to-phase.
- Selectable Zone 1 extension
- • T1 timer (0 or 2 cycles)
- Independent timers for phase and ground (T2G, T2P, T3G/T3P)
- • Block selection for T2 and T3 timers
- Inverse time directional or non-directional (selectable) overcurrent ground backup logic
- Loss of potential supervision (LOP)
- Loss of current monitoring (LOI)
- Overcurrent supervision
- Instantaneous forward directional phase and ground highset overcurrent trip (ITP and ITG)
- Close Into Fault Trip (CIFT)
- • Stub Bus Protection (89b)
- Unequal-pole-closing load pickup logic
- • Selectable Loss-of-Load accelerated trip logic (LLT)...setting (YES/NO/FDOG)
- Current change fault detector (ΔI)
- Voltage change fault detector (ΔV)
- Last Fault LED now blinks once for a single fault and twice for more than one fault. When the RESET button is depressed, the flashing LED is reset, and the displayed data is returned to the green LED (i.e., Volts/Amps/Angle...metering mode). MDAR fault data cannot be cleared out of memory from the front panel. Fault data can be re-accessed by moving the LED down to the Last Fault or Previous Fault.
- Line voltage, current and phase angle monitor.
- • Selectable polarizing for directional O/C ground units (ZSEQ/NSEQ/DUAL)
- Programmable Reclose initiation and reclose block (RB) outputs; Reclose Initiate (RI2) can be enabled with the selection of:
  - 1PR for ϕG fault
  - 2PR for ϕG or $\phi\phi$ fault
  - 3PR for ϕG or $\phi\phi$ fault or 3ϕ fault
- Digital Processing
- Fault locator software
- Self-checking software shows error codes
- Breaker trip circuit test
- • Push-to-close test for output contacts
- Software switches for functional tests, e.g., TK (Carry Send Switch), RS1, RS2 and RS12 (Carry Receivers).
- • Trip contact sealed in by trip current; and selectable dropout delay timer, 0/50, (YES/NO)
- • 16 fault records (triggered by TRIP, Z2PU or Z2Z3)
- Real-time clock
- Low voltage pickup setting (LV) for weakfeed logic and CIF trip; selection can be made from 40 Vrms to 60 Vrms, in 1-volt steps.
- Setting of ZR, range from 0.1 to 7.0
- Setting of XPUD, range from 0.3 to 1.5 per mile or per km
- Setting of FDAT (trip, Z2 trip or Z2Z3 trip)
- Logic for load restrictions
- The reaches of Z1E are based on Zone 1 settings multiplied by a factor of 1.25 (e.g., 1.25 x Z1P and 1.25 x Z1G).

NOTE: The foregoing (and following) features preceded by two dots (• •) were not included in V1.65.

Features Included in Version V2.00

The following features are ***standard*** for the Pilot MDAR V2.00:

- All features listed as standard for the Non-Pilot MDAR V2.00 are included in the Pilot system
- Independent pilot phase and ground distance units
- Permissive Overreach Transfer Trip (POTT) / Simplified Unblocking
- Permissive Underreach Transfer Trip (PUTT)
- Directional Comparison Blocking Scheme (BLK)
- POTT or Simplified Unblocking Weakfeed
- • Instantaneous Forward Directional Overcurrent Function for High Resistance Ground Fault Supplement to Overreach Pilot, with adjustable timer (from 0 to 15) in 1 cycle steps or Block
- Instantaneous Reverse Directional Overcurrent Ground Function
  - Carrier Ground Start on Blocking Scheme
  - Weakfeed System Application
- • Reclose Block on Breaker Failure (BF) Squelch
- 3-Terminal Line Application
- Weakfeed Trip

Features Included in Version V2.00

The following features are ***optional*** for the Non-Pilot ***and*** the Pilot MDAR V2.00:

- Optional communications attachment

  RS232C/PONI
  INCOM/PONI

- • Optional
  16 sets of oscillographic data and intermediate target data. Each set includes 7 analog graphic inputs and 24 digital intermediate targets with 8 samples per cycle. Each analog input contains 1 prefault and 7 fault cycles. (Data collection can be started by TRIP, Z2PU, Z2Z3 or ΔV ΔI depending on the setting of OSC.)
- Optional FT-14 switches
- Optional Out-of-Step Block
- Optional Single-Pole-Trip (SPT) logic and outputs:
  - SPT/RI1 on first ϕGF and 3PT on other fault types.
  - 3PT/RB if reclosing on a permanent fault.
  - 3PT/RB if second phase(s) fault during single phasing.
  - 3PT on a time delay limit (o.35-5.0 sec in 0.05 sec steps) if the system fails to reclose (62T).
- Optional OSC Settings (trip or ΔV ΔI)
- Optional TRIP/RI mode selector for:

TTYP SET AT	TRIP	RI
OFF	3PT	NO
1PR	3PT	RI2 (ϕG)
2PR	3PT	RI2 (ϕG, ϕϕG)
3PR	3PT	RI2 (ϕG, Mϕ)
SPR	SPT (ϕG)	RI1
	3PT (Mϕ)	N0
SR3R	SPT (ϕG)	RI1
	3PT (Mϕ)	RI2

SPT	=	Single Pole Trip
3PT	=	3 Pole Trip
RI	=	Reclose Initiate
RB	=	Reclose Block
RI2	=	3 Pole Reclose Initiate
RI1	=	Single Pole Reclose Initiate
ϕG	=	Single Phase-to-Ground Faults
Mϕ	=	Multi-Phase Faults
ϕϕ	=	2-Phase Faults

Significant Changes to V2.00 (from V1.65)

(for customers who are familiar with Version 1.60 and beyond)

1. 16 fault records, triggered by TRIP or Z2PU or Z2Z3, depending on the FDAT settings (see Section 3.4.16, 4.8 and 5.2.2).
2. 16 sets of oscillographic data, triggered by TRIP or Z2PU or Z2Z3 or ΔV ΔI, depending on the OSC setting (see Sections 3.4.19, 4.9 and 5.2.1).
3. Dual (V or I) zero-sequence polarizing unit: see Systems External Connection Drawing, Figure 4-3; External Connection Diagram (Appendix J , 2419F59, Sheet 3 of 4); Section 3.4.11 (Selectable Ground Directional Unit (ZSEQ/NSEQ/DUAL); and Acceptance Test, Section 1.1.9, Step 25.
4. The front panel RESET button (now) cannot reset the fault data. It can only reset the flashing LED (see Section 4.4.3).
5. For the purpose of self-check, the display will now be blocked momentarily every minute (see Sections 1.3.6 and 4.4.2).
6. The push-to-close output contacts test simplifies the annual maintenance check (see Section 3.4.15 and Acceptance Test, Section 1.1.13, Step 35).
7. The $3I_0$ signal (now) is generated by software (I_a+I_b+I_c) and the fourth current transfer is for the DUAL polarizing direction application only. The test method and wiring for the 3ϕ tests are completely different from the previous version (refer to Acceptance Tests, Section 1.1.4, Step 12 (3ϕ test and Figure H-2); and Section 1.4 (OSB test).

MDAR Version V2.01

1. Sensitivity of NSEQ – Change from I2=0.5 to 312=0.5.
2. LOPB – Add a NOT 52b to the input of AND1F gate to avoid the dropout of AL1 (alarm-1) for the condition of removing the ac voltages before the breaker opening.
3. For POTT system only
   a. Connect PLTP & PLTG to carrier keying directly (OR16A & OR18) and modify the signal continuation logic (TRSL, CIF, AND49A, etc.) to avoid the Send signal dropout time delay (o/150) for the remote forward fault.
   b. Remove RBSW setting. The reverse block timer logic should always be applied to the POTT system to increase security on transient due to the unequal pole trip of the adjacent or parallel line.
   c. Add a path between 16/0 (RDOG*Ios) and OR41A for weakfeed application to avoyid the false forward fault trip on the strong feed terminal if the fault is beyond the reach of Zone-3 setting of the weak-feed terminal.
   d. Add a path between 16/0 (RDOG*Ios) and OR9A to extend the reach of transient block.
   e. For open breaker, omit 52b keying and add echo keying (AND34B).
4. For BLOCKING system only
   a. Improve and speed up delta V & I keying.
   b. Extend the setting of BLKT timer from 0-32 to 0-98 ms.
   c. Remove open breaker (52b) timer (180/0) for Carrier Stop.

5. Use Z1rI (Yes/No) to control the pilot reclose (AND84).
6. Correct the clock setting to avoid the dropout of AL1.

NOTE: CONVERSION FROM MDAR FIRMWARE VERSION V2.00 TO V2.01 CAN BE ACCOMPLISHED AS FOLLOWS:

1. Standard precautions of the static voltage discharges should be observed such as using a grounded wrist strap in order to remove the I.C. from the socket.
2. Remove chips U103 and U104 from the Microprocessor module.
3. Replace chips U103 (605) and U104 (606) into the sockets.

MDAR VERSION 2.02

For BLOCKING system – Add a negated TBM (transient block) logic to the input of AND120 to prevent the pickup of Carrier Stop if the TBM is set. Without the new logic, the Keying signal may be interrupted momentarily by the Stop due to the logic inside the carrier equipment during the unequal pole clearing for the reverse external fault.

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FIGURES

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TABLES

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MDAR RELAY SYSTEM

(V2.02)

ABB Power T&D Company Inc.
Relay Divisions
Coral Springs, FL 33065

305 752-6700
800 523-2620

Printed in U.S.A.

I.L. 40-385.1B

(5/92)

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DATE	REV LEVEL	PAGES REMOVED	PAGES INSERTED
11/91	A	v, vi, 1-2, 1-5, 3-2, 3-4, 3-5, 3-7, 3-9, 3-10, 3-11, 3-14, 3-15, 4-3, 4-4, 4-11, 4-17, 5-1, 5-3, 5-5, 5-6, A-1, A-6, G-8, H-1, H-2, H-5, H-9	SAME
1/01/92	A	3-1, H-2, H-7	SAME
1/15/92	A	vi, 3-29, J-1, J-2, J-3, J-4, J-5, J-6	SAME
5/92	B	3-2, 3-19, 3-20, 3-21, 3-23, 3-26, 5-1, A-1, A-5 thru A-7, B4 thru B-6, C-1,C-4 thru C-6, D-1, D-4 thru D-6, E-1, E-7 thru E-12, F-4, F-5, G-1, G-4, thru G-8, H-2, H-6, H-8, H-9, H-14, H-17, H-21	3-2, 3-19, 3-20, 3-21, 3-23, 3-26, 5-1, A-1, C-1, D-1, E-1, G-1, H-2, H-6, H-8, H-9, H-14, H-17, H-21

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• Option	1608C39-4	
• Filter	1608C38-5	
• Microprocessor	1611C14-1	
• Display	1609C01-3	
• Power Supply	1608C35-10	

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MDAR software version V2.01 is included in this I.L.

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The following features are ***standard*** for the Non-Pilot MDAR V2.00:

- 3-Zone distance phase and ground relay, with reversible Zone 3 phase and ground; 4 impedance units per zone: 3 phase-to-ground; 1 phase-to-phase.
- Selectable Zone 1 extension
- • • T1 timer (0 or 2 cycles)
- Independent timers for phase and ground (T2G, T2P, T3G/T3P)
- • • Block selection for T2 and T3 timers
- Inverse time directional or non-directional (selectable) overcurrent ground backup logic
- Loss of potential supervision (LOP)
- Loss of current monitoring (LOI)
- Overcurrent supervision
- Instantaneous forward directional phase and ground highset overcurrent trip (ITP and ITG)
- Close Into Fault Trip (CIFT)
- • • Stub Bus Protection (89b)
- Unequal-pole-closing load pickup logic
- • • Selectable Loss-of-Load accelerated trip logic (LLT)...setting (YES/NO/FDOG)
- Current change fault detector (ΔI)
- Voltage change fault detector (ΔV)
- Last Fault LED now blinks once for a single fault and twice for more than one fault. When the RESET button is depressed, the flashing LED is reset, and the displayed data is returned to the green LED (i.e., Volts/Amps/Angle...metering mode). MDAR fault data cannot be cleared out of memory from the front panel. Fault data can be re-accessed by moving the LED down to the Last Fault or Previous Fault.
- Line voltage, current and phase angle monitor.
- • • Selectable polarizing for directional O/C ground units (ZSEQ/NSEQ/DUAL)
- Programmable Reclose initiation and reclose block (RB) outputs; Reclose Initiate (RI2) can be enabled with the selection of:
  – 1PR for ϕG fault
  – 2PR for ϕG or $\phi\phi$ fault
  – 3PR for ϕG or $\phi\phi$ fault or 3ϕ fault
- Digital Processing
- Fault locator software
- Self-checking software shows error codes
- Breaker trip circuit test
- • • Push-to-close test for output contacts
- Software switches for functional tests, e.g., TK (Carry Send Switch), RS1, RS2 and RS12 (Carry Receivers).
- • • Trip contact sealed in by trip current; and selectable dropout delay timer, 0/50, (YES/NO)
- • • 16 fault records (triggered by TRIP, Z2PU or Z2Z3)
- Real-time clock
- Low voltage pickup setting (LV) for weakfeed logic and CIF trip; selection can be made from 40 Vrms to 60 Vrms, in 1-volt steps.
- Setting of ZR, range from 0.1 to 7.0
- Setting of XPUD, range from 0.3 to 1.5 per mile or per km
- Setting of FDAT (trip, Z2 trip or Z2Z3 trip)
- Logic for load restrictions
- The reaches of Z1E are based on Zone 1 settings multiplied by a factor of 1.25 (e.g., 1.25 x Z1P and 1.25 x Z1G).

NOTE: The foregoing (and following) features preceded by two dots (• •) were not included in V1.65.

Features Included in Version V2.00

The following features are ***standard*** for the Pilot MDAR V2.00:

- All features listed as standard for the Non-Pilot MDAR V2.00 are included in the Pilot system
- Independent pilot phase and ground distance units
- Permissive Overreach Transfer Trip (POTT) / Simplified Unblocking
- Permissive Underreach Transfer Trip (PUTT)
- Directional Comparison Blocking Scheme (BLK)
- POTT or Simplified Unblocking Weakfeed
- • Instantaneous Forward Directional Overcurrent Function for High Resistance Ground Fault Supplement to Overreach Pilot, with adjustable timer (from 0 to 15) in 1 cycle steps or Block
- Instantaneous Reverse Directional Overcurrent Ground Function
  - Carrier Ground Start on Blocking Scheme
  - Weakfeed System Application
- • Reclose Block on Breaker Failure (BF) Squelch
- 3-Terminal Line Application
- Weakfeed Trip

Features Included in Version V2.00

The following features are ***optional*** for the Non-Pilot ***and*** the Pilot MDAR V2.00:

- Optional communications attachment

  RS232C/PONI
  INCOM/PONI

- • Optional
  16 sets of oscillographic data and intermediate target data. Each set includes 7 analog graphic inputs and 24 digital intermediate targets with 8 samples per cycle. Each analog input contains 1 prefault and 7 fault cycles. (Data collection can be started by TRIP, Z2PU, Z2Z3 or ΔV ΔI depending on the setting of OSC.)
- Optional FT-14 switches
- Optional Out-of-Step Block
- Optional Single-Pole-Trip (SPT) logic and outputs:
  - SPT/RI1 on first ϕGF and 3PT on other fault types.
  - 3PT/RB if reclosing on a permanent fault.
  - 3PT/RB if second phase(s) fault during single phasing.
  - 3PT on a time delay limit (o.35-5.0 sec in 0.05 sec steps) if the system fails to reclose (62T).
- Optional OSC Settings (trip or ΔV ΔI)
- Optional TRIP/RI mode selector for:

TTYP SET AT	TRIP	RI
OFF	3PT	NO
1PR	3PT	RI2 (ϕG)
2PR	3PT	RI2 (ϕG, ϕϕG)
3PR	3PT	RI2 (ϕG, Mϕ)
SPR	SPT (ϕG)	RI1
	3PT (Mϕ)	N0
SR3R	SPT (ϕG)	RI1
	3PT (Mϕ)	RI2

SPT	=	Single Pole Trip
3PT	=	3 Pole Trip
RI	=	Reclose Initiate
RB	=	Reclose Block
RI2	=	3 Pole Reclose Initiate
RI1	=	Single Pole Reclose Initiate
ϕG	=	Single Phase-to-Ground Faults
Mϕ	=	Multi-Phase Faults
ϕϕ	=	2-Phase Faults

Significant Changes to V2.00 (from V1.65)

(for customers who are familiar with Version 1.60 and beyond)

1. 16 fault records, triggered by TRIP or Z2PU or Z2Z3, depending on the FDAT settings (see Section 3.4.16, 4.8 and 5.2.2).
2. 16 sets of oscillographic data, triggered by TRIP or Z2PU or Z2Z3 or ΔV ΔI, depending on the OSC setting (see Sections 3.4.19, 4.9 and 5.2.1).
3. Dual (V or I) zero-sequence polarizing unit: see Systems External Connection Drawing, Figure 4-3; External Connection Diagram (Appendix J , 2419F59, Sheet 3 of 4); Section 3.4.11 (Selectable Ground Directional Unit (ZSEQ/NSEQ/DUAL); and Acceptance Test, Section 1.1.9, Step 25.
4. The front panel RESET button (now) cannot reset the fault data. It can only reset the flashing LED (see Section 4.4.3).
5. For the purpose of self-check, the display will now be blocked momentarily every minute (see Sections 1.3.6 and 4.4.2).
6. The push-to-close output contacts test simplifies the annual maintenance check (see Section 3.4.15 and Acceptance Test, Section 1.1.13, Step 35).
7. The $3I_0$ signal (now) is generated by software (I_a+I_b+I_c) and the fourth current transfer is for the DUAL polarizing direction application only. The test method and wiring for the 3ϕ tests are completely different from the previous version (refer to Acceptance Tests, Section 1.1.4, Step 12 (3ϕ test and Figure H-2); and Section 1.4 (OSB test).

MDAR Version V2.01

1. Sensitivity of NSEQ – Change from I2=0.5 to 312=0.5.
2. LOPB – Add a NOT 52b to the input of AND1F gate to avoid the dropout of AL1 (alarm-1) for the condition of removing the ac voltages before the breaker opening.
3. For POTT system only
   a. Connect PLTP & PLTG to carrier keying directly (OR16A & OR18) and modify the signal continuation logic (TRSL, CIF, AND49A, etc.) to avoid the Send signal dropout time delay (o/150) for the remote forward fault.
   b. Remove RBSW setting. The reverse block timer logic should always be applied to the POTT system to increase security on transient due to the unequal pole trip of the adjacent or parallel line.
   c. Add a path between 16/0 (RDOG*Ios) and OR41A for weakfeed application to avoyid the false forward fault trip on the strong feed terminal if the fault is beyond the reach of Zone-3 setting of the weak-feed terminal.
   d. Add a path between 16/0 (RDOG*Ios) and OR9A to extend the reach of transient block.
   e. For open breaker, omit 52b keying and add echo keying (AND34B).
4. For BLOCKING system only
   a. Improve and speed up delta V & I keying.
   b. Extend the setting of BLKT timer from 0-32 to 0-98 ms.
   c. Remove open breaker (52b) timer (180/0) for Carrier Stop.

5. Use Z1rI (Yes/No) to control the pilot reclose (AND84).
6. Correct the clock setting to avoid the dropout of AL1.

NOTE: CONVERSION FROM MDAR FIRMWARE VERSION V2.00 TO V2.01 CAN BE ACCOMPLISHED AS FOLLOWS:

1. Standard precautions of the static voltage discharges should be observed such as using a grounded wrist strap in order to remove the I.C. from the socket.
2. Remove chips U103 and U104 from the Microprocessor module.
3. Replace chips U103 (605) and U104 (606) into the sockets.

MDAR VERSION 2.02

For BLOCKING system – Add a negated TBM (transient block) logic to the input of AND120 to prevent the pickup of Carrier Stop if the TBM is set. Without the new logic, the Keying signal may be interrupted momentarily by the Stop due to the logic inside the carrier equipment during the unequal pole clearing for the reverse external fault.

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TABLES

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Section 1. PRODUCT DESCRIPTION

1.1 INTRODUCTION

The MDAR relay assembly (Figure 1-1) is a digital transmission line protection system, with three zones of distance protection. All measurements and logic are performed by digital means, using a microprocessor. Self-checking and line monitoring techniques are included. MDAR is primarily recommended for application on non-series compensated lines.

The non-pilot MDAR relay assembly is standard (see Section 3); an optional pilot MDAR relay assembly is also available (in Section 3).

1.2 MDAR CONSTRUCTION

The standard nomenclature for **ABB r**elay protection equipment is as follows:

- Cabinet - contains fixed-racks, swing-racks, or open racks
- Rack - contains one or more chassis (e.g., the MDAR)
- Chassis - contains several modules (e.g., Microprocessor or Power Supply)
- Module - contains a number of functional circuits (on printed circuit board)
- Circuit - a complete function on a printed circuit board (e.g., analog-to-digital conversion)
- The MDAR relay assembly consists of an outer-chassis and an inner-chassis which slides into the outer-chassis. The MDAR conforms to the following dimensions and weight (see also Section 2):
  - Height 7" (requires 4 rack units; 1.75" each)
  - Width 19"
  - Depth 13.6"
  - Weight 35 Lbs

All of the relay circuitry, with the exception of the input isolation transformers and first-line surge protection, are mounted on the inner chassis, to which the front panel is attached. The outer chassis has a Backplate, which is a receptacle for all external connections, including a communication adaptor (see Figure 4-1). Two FT-14 switches may be included, as options, in the two peripheral areas of the outer chassis. The FT-14 switches permit convenient and safe disconnection of trip, ac and dc input circuits, and provide for injection of test signals.

1.3 MDAR MODULES

The inner and outer chassis, together, contain 6 standard modules, plus the option module for single pole trip applications (see Figure 1-2). The Backplate is connected to the Backplane module (outer chassis). The remaining modules are attached to the inner chassis:

- Interconnect module
- Option module
- Filter module
- Microprocessor module
- Display module
- Power Supply module

Circuit descriptions for each module, may be found in Appendices A thru G, in accordance with the list in the Preface to this document (see "Contents of Relay System").

1.3.1 Backplane Module

The Backplane Assembly includes three voltage transformers, four current transformers, two filter chokes and several surge protection capacitors.

The Backplane Module (see Appendix A) receives all external connections (with or without the FT-14 switch option), and connects directly to the Interconnect module, thru plug-in connectors (J11, J12, J13) which provide the connection between outer and inner chassis.

The female parts of the connectors are mounted on the Backplane module, which is part of the outer chassis. The male parts of the connectors are mounted on the Interconnect module, which is part of the inner chassis.

The INCOM® or RS232 PONI[1] (see Figure 1-3) is mounted on the Backplate of the outer chassis and is connected to the Backplane module.

1. "INCOM® "stands for INtegrated COMmunications. The "PONI" acronym stands for Product Operated Network Interface.

1.3.2 Interconnect Module

The Interconnect module (see Appendix B) becomes the floor of the MDAR inner chassis; it provides electrical connections from and to all other modules: from the Backplane (at the rear), to the Filter and Power Supply modules (at left and right, respectively), and to the Microprocessor and Display modules at the front of the inner chassis.

The Interconnect module receives inputs V_{AN}, V_{BN}, V_{CN}, I_A, I_B, I_C, I_P from the Backplane module and feeds them to the Filter module. The I_P input is used for zero-sequence dual-polarizing ground current measurement; the input is from the power transformer neutral ct. Also, seven opto-couplers, on the Interconnect module, send the following signals to the Microprocessor module:

- External Reset - resets the front target display.
- 52b - used for close-into-fault (CIF) detection, load loss trip (LLT) and carrier-start and stop control in a pilot system.
- 52a (for single-pole trip option; i.e., for pole disagreement).
- Pilot Enable - should be “ON” for the pilot system option.
- Receiver #1 (for Pilot option) - carrier receiver for two terminal application.
- Receiver #2 (for Pilot option) - second carrier receiver for three-terminal application.
- SBP (89b) for stub bus protection.

1.3.3 Option Module

For 3-pole tripping application, an optional Contact module can be plugged into the connector and provide 8 additional programmable output contacts.

1.3.4 Filter Module

The Filter module (see Appendix D) band-limits the seven inputs from the Interconnect module: V_{AN}, V_{BN}, V_{CN}, I_A, I_B, I_C, I_P. These inputs are fed to the Microprocessor module (analog signal multiplexer).

1.3.5 Microprocessor Module

The Microprocessor module (see Appendix E) includes the following subsystems:

- **Microprocessor** - Intel 80C196, a 16-bit microcontroller operating with a 10 MHz clock.
- **EPROM** - Program memory in separate, easily-replaced EPROM chips.
- **PROM** - Programmable read-only memory.
- **RAM** - Volatile read-write memory, for working storage.
- **NOVRAM** (EEPROM) - Non-volatile memory for storing settings and fault-data targets when the MDAR relay is deenergized.
- **A/D Converter** - The seven inputs from the filter module are analog-multiplexed to a single sample/hold circuit. The output of the sample/hold is fed to the Analog-to-Digital Converter through an auto-ranging circuit which shifts gain by a factor of eight.
- **Digital I/O Circuitry** - Status inputs from breaker auxiliary contacts (52a and 52b), and External Reset signal are interfaced to the microprocessor via optical isolators (Figure 4-2). The microprocessor executes control outputs using dry contacts. Output relays (Figure 4-2) are used for breaker tripping, breaker failure initiation (BFI), reclose initiation (RI), and reclose blocking (RB). General start contact (GS) is provided for starting the external sequence of events or fault recorders. Trip and relay-failure alarm contacts are included. Reed relays in the trip circuits sense trip coil current flow and feedback target information to the microprocessor.

1.3.6 Display Module

The Display module has two (four-digit) alphanumeric displays for settings, metering fault designation and information. The metering display shows three-phase voltage, current and angle. Fault data, stored in the Microprocessor module, is accessible through the front panel display. Fault data includes: pre-fault phase A voltage, current and angle. It also shows the type of fault, fault voltages, currents, angles and fault location. The Display module is attached to the front panel (see Figure 1-1); it can be used to access and store data, and contains 7 LEDs, as follows:

- Relay in Service (ready to use)
- Settings (can read or change settings)
- Volts/Amps/Angles (can read measuring inputs)
- Last Fault (when flashing, indicates new fault information available)
- Previous Fault (when last fault LED flashes twice/minute, indicates information for the fault preceding the last fault)
- Value Accepted (when the Settings LED is also “ON”, a new setting value is accepted; when the Test LED is also “ON”, the output contacts can be tested)

- Test (can verify self-check and perform functional test)

The display will be blocked momentarily, every minute, for the purpose of self-check; this will not affect the relay protection function.

1.3.7 Power Supply Module

The Power Supply module (see Appendix G) is available in three ranges:

- 38 - 70 Vdc
- 88 - 145 Vdc
- 176 - 290 Vdc

Provides isolation from station battery; includes overcurrent and overvoltage protection. Status monitoring and loss-of-power indication are accomplished via a failure-alarm relay (on the Interconnect module). Relay is normally picked up, but the processor deenergizes it when a problem is found. Total power loss also drops-out the relay. Front-panel test points provide access to power-supply output voltages for test purposes:

- +12 Vdc
- -12Vdc
- -24 Vdc
- + 5 Vdc

1.3.8 Contact Outputs

- 4 make contacts (2 trip, 2 BFI); 8 additional optional contacts when single pole trip option is used.
- Single pole reclose initiate (2 Form A)
- Three pole reclose initiate (2 Form A)
- Reclose block (2 Form A)
- General Start (1 Form A)
- System failure alarm (1 Form C)
- Trip alarm (1Form C; 1 Form A is available if SBP is not used).

1.4 TEST ACCESSORIES

The MDAR may be tested with two devices:

- Inner Chassis Test Fixture.

This device is similar to the outer chassis, and includes a Backplane and Transformer assembly.

- Extender Board

This device includes two small pc boards with two ribbon cables. The inner chassis can be tested outside of the outer case by means of the Extender Board.

1.5 FAULT DETECTION SOFTWARE

MDAR fault-detection software operates in two modes:

- Background mode
- Fault mode

The MDAR relay normally operates in the “Background mode” where it looks for phase current or phase voltage disturbances. Once a phase disturbance is detected, the relay enters the “Fault mode”. During non-fault operation (in the Background mode), the MDAR Microprocessor (U100) used its spare time to check its hardware, service the operator panel, and check for a disturbance in voltage or current which indicates a possible fault. If a disturbance is seen, the programs switch to the Fault mode, for several power cycles or longer, to perform phase and ground unit checks for each zone and function.

1.5.1 Background Mode

During the background mode, the seven inputs (currents and voltages shown in Figure 1-4) are sampled to test for line faults. These currents and voltages are sampled and converted into digital quantities and input to the Microprocessor where all signal processing takes place. (MDAR detects faults by digital computation; not by analog.) The system continuously takes 8 samples per cycle. The components of the signals which are power system frequency are extracted.

The MDAR software which does the sampling has 8 states; these states correspond to the sampling rate (8 samples per cycle). Movement from state to state is controlled by a timer. The timer is loaded with a state time at the beginning of the state. The code executed within a state should be completed before the timer expires. The software then waits for the timer to time out.

The MDAR relay program functions are included in a flow chart loop (shown in Figure 1-5), which the Microprocessor repeats 8 times per power cycle. Most functions are performed all of the time, in the background mode, as shown. An important detail (not shown in Figure 1-5) is that many of the checks are broken into small parcels, so that the whole complement of tasks is performed over a one-cycle period (eight passes through the loop). Some of the checks are performed more than once per cycle.

The 60 Hz components are extracted from the samples (from each cycle) and converted to voltage and current phasor values using a Fourier notch-filter algorithm. An additional dc-offset correction algorithm reduces overreach errors from decaying exponential transients. During the process, the sum of squares of the inputs are accumulated to provide rms values of current and voltage. The Fourier coefficients and sums are calculated for computing the phase angles. The sum of squares and the sums of the Fourier coefficients are updated for each sample, using information from the previous seven samples, to provide a full cycle of data.

1.5.2 Fault Mode and Restricted Fault Tests

Upon entry into the fault mode, the sums of the Fourier coefficients and sum of squares from the background mode are stored. New sums are obtained, using fault data, to which offset compensation has been applied.

To speed up tripping for severe faults, restricted fault testing is implemented. The last half cycle of background mode input samples and the first half cycle of fault mode input samples are used to compute the current and voltage vectors and rms values. No dc offset compensation is performed. High-set instantaneous overcurrent and Zone 1 distance unit tests are executed (see Section 3.2, MDAR Line Measurement). This will speed up tripping by as much as one cycle for high current faults.

Instantaneous overcurrent, inverse time overcurrent protection, and out-of-step blocking are also conducted during the fault mode and background mode.

For Zone 2 and Zone 3 faults (see Section 3), impedance computation and checking will continue throughout the specified time delay. The impedance calculation will be performed once every cycle, in the fault mode and background mode.

1.5.3 Unique Qualities of MDAR

A unique characteristic of the MDAR system is its phase selection principle. It determines the sum of positive and negative sequence currents for each phase by a novel method which excludes the influence of pre-fault load current. From this information, the fault type can be clearly identified and the actual distance to the fault can be estimated.

High-resistance ground-fault detection is available in MDAR. Sensitive directional pilot tripping is achieved through an FDOG timer (FDGT), which is selectable from 0 to 15 cycles or block, on the Microprocessor module. The pilot distance unit is always active and has the priority for tripping.

Load-loss tripping entails high-speed, essentially simultaneous clearing at both terminals of a transmission line for all fault types except three-phase, without the need of a pilot channel.

Any fault location on the protected circuit will be within the reach of the zone 1 relays at one or both terminals. This causes direct tripping of the local breaker without the need for any information from the remote terminal. The remote terminal recognizes the loss of load-current in the unfaulted phase(s) as evidence of tripping of the remote breaker. This, coupled with Zone 2 distance or directional overcurrent ground fault recognition at that terminal, allows immediate tripping to take place at that terminal.

1.6 SELF-CHECKING SOFTWARE

MDAR continually monitors its ac input subsystems using multiple A/D converter calibration-check inputs, plus loss-of-potential and loss-of-current monitoring described. Failures of the converter, or any problem in a single ac channel which unbalances nonfault inputs, trigger alarms. Self-checking software includes the following functions:

a. Digital Front-end A/D Converter Check

b. Program Memory Check Sum

Immediately upon power-up, the relay does a complete ROM (EPROM) checksum of program memory. Afterwards, the MDAR relay continually computes the program memory checksum.

c. Power Up RAM Check

Immediately upon power-up, the relay does a complete ROM test of the RAM data memory.

d. Nonvolatile RAM Check

All front-panel-entered constants (settings) are stored in nonvolatile RAM in three identical arrays. These arrays are continuously checked by the program. If all three array entrees disagree, a nonvolatile RAM failure is detected.

For failures which do not disable the processor, the cause of the problem can be read on the display.

The failure modes, represented by their corresponding bits (zero thru 5), are shown in the value field if the “Test” mode is selected by the “Display Select” pushbutton.

- Bit 0 External RAM Failure
- Bit 1 EEPROM Warning
- Bit 2 ROM (EPROM) Failure
- Bit 3 EEPROM Failure (Non-Volatile memory)
- Bit 4 Analog Input Circuit Failure
- Bit 5 Microprocessor Failure

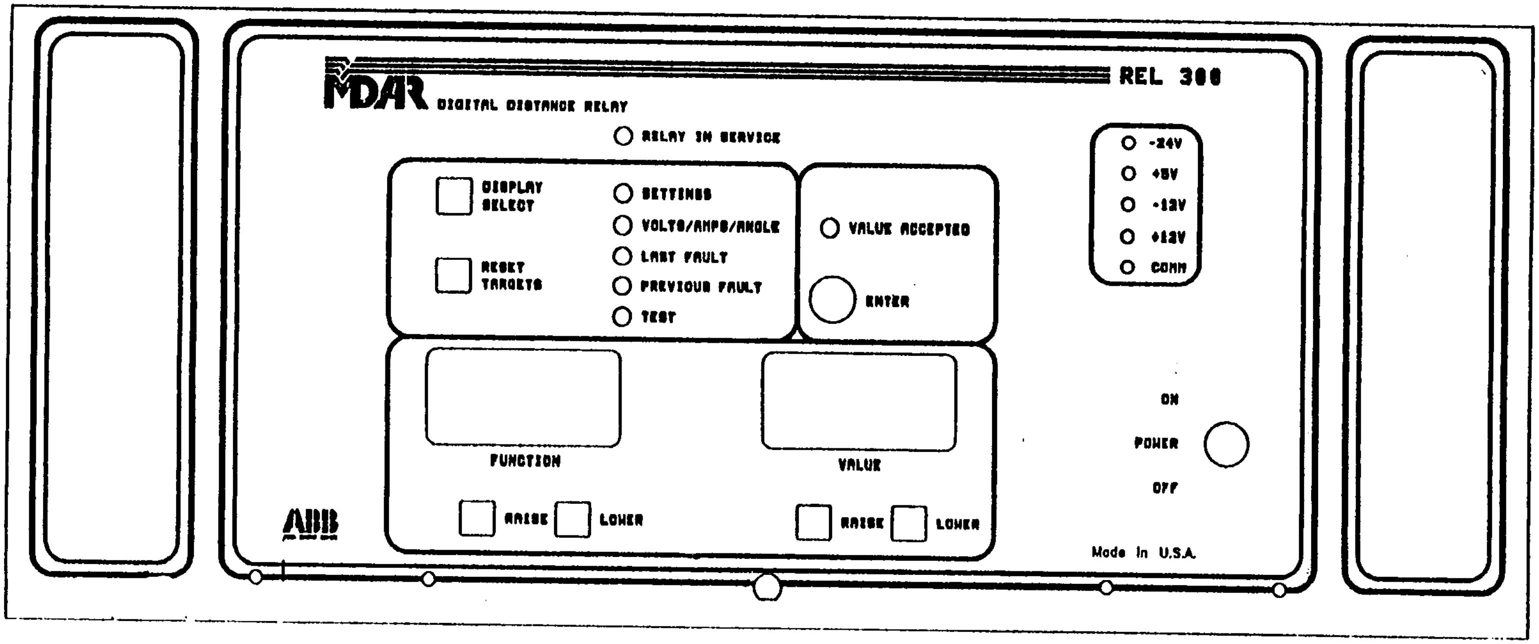
All bits are expressed in a HEX byte form. For example, if the display shows “Test 1B”, whose binary representation is 00011011, this means that the relay failed the self-test in the area of External RAM (bit 0), EEPROM (one-out-of-three failure, bit 1), EEPROM (two-out-of-three failure, bit 3) and Analog Input Circuit (bit 4). Normally, the test mode should show “Test 0", meaning that the relay passed the self-test routines.

1.7 UNIQUE REMOTE COMMUNICATION (WRELCOM) PROGRAM

Two optional types of remote interface can be ordered.

- RS232C-for single point computer communication.
- INCOM-for local network communication.

A special software (WRELCOM) program is provided for obtaining or sending the setting information to the MDAR. The MDAR front panel shows two fault events (last and previous), but thru the remote communication, 16 fault events and 16 records of intermediate target data can be obtained and stored. Each record of the intermediate target data contains 8-cycle information (1-prefault and 7 post-fault), with 7 analog inputs and 24 digital data (at the sampling rate of 8 per cycle). Refer to WRELCOM manual for detailed information.



* Sub 9
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Figure 1-1. MDAR Relay Assembly Showing FT-14 Switch Covers

* ᴰanotes Change

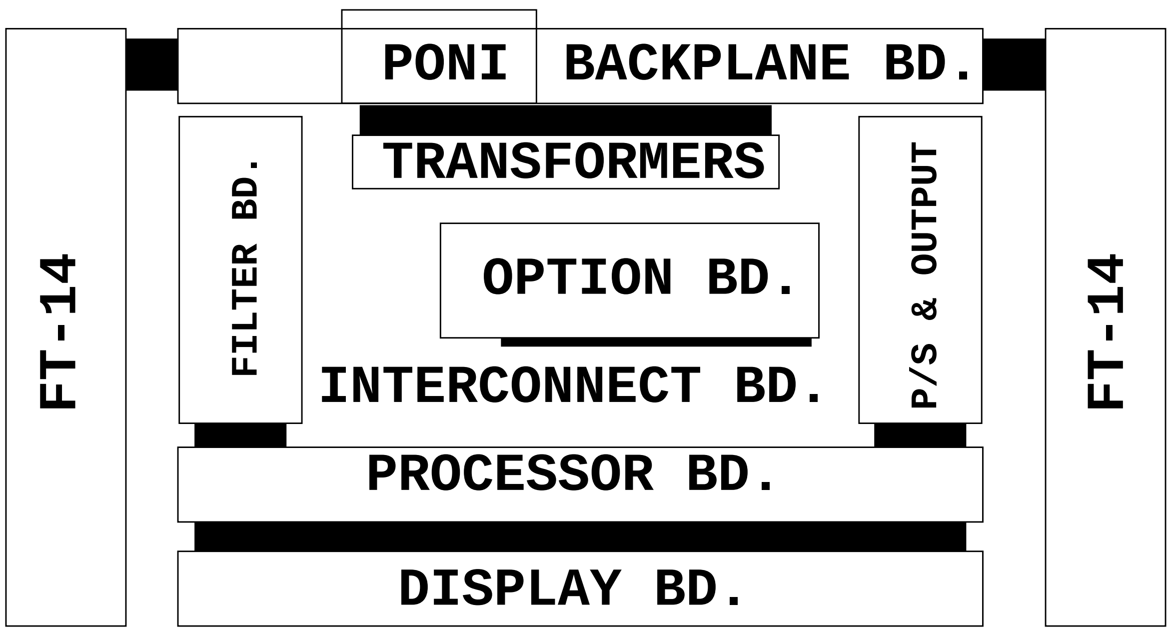


Figure 1-2. Layout of MDAR Modules Within Inner and Outer Chassis

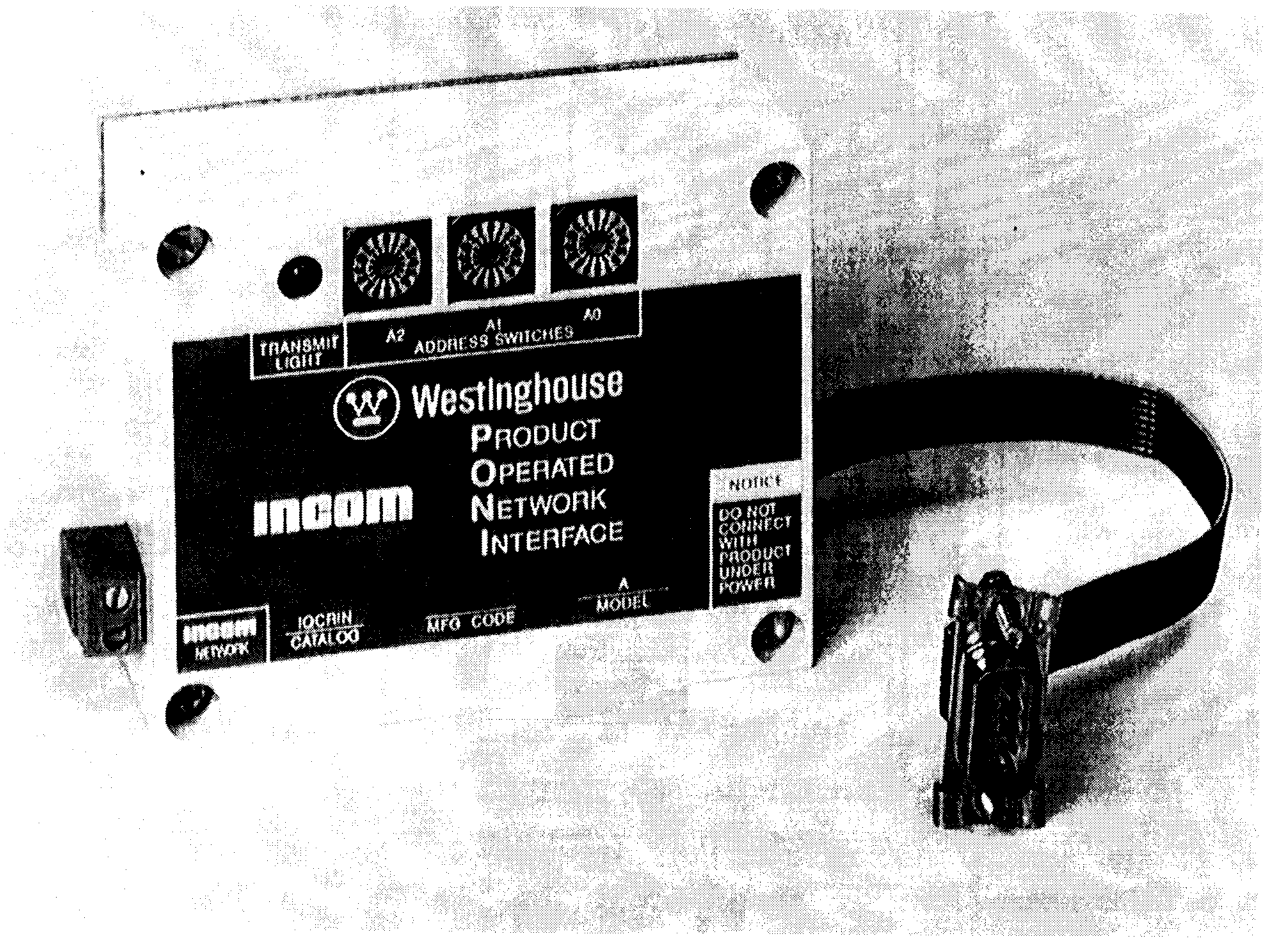


Figure 1-3. INCOM/PONI Communication Interface Device

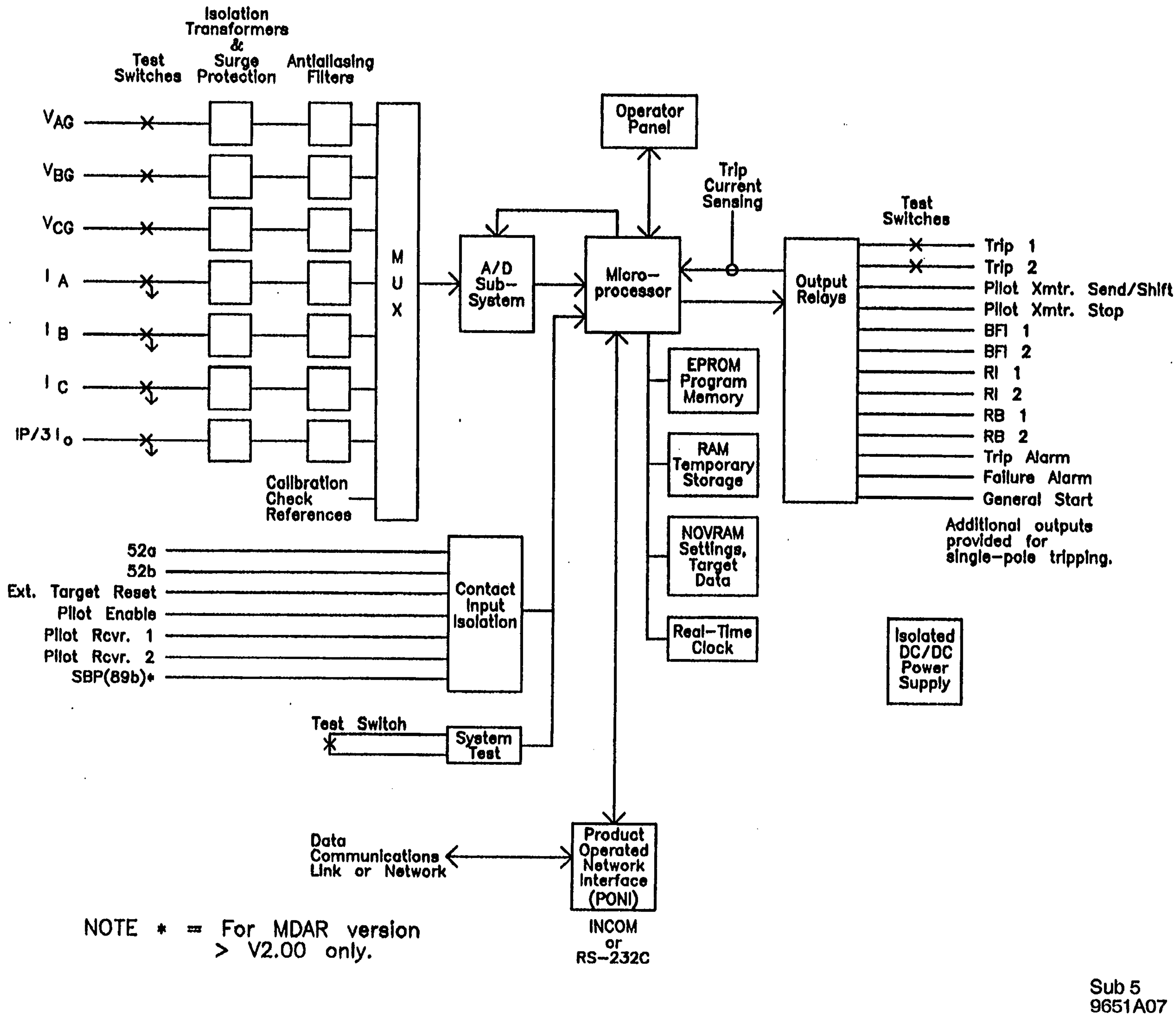


Figure 1-4. Simplified Block Diagram of MDAR Relay

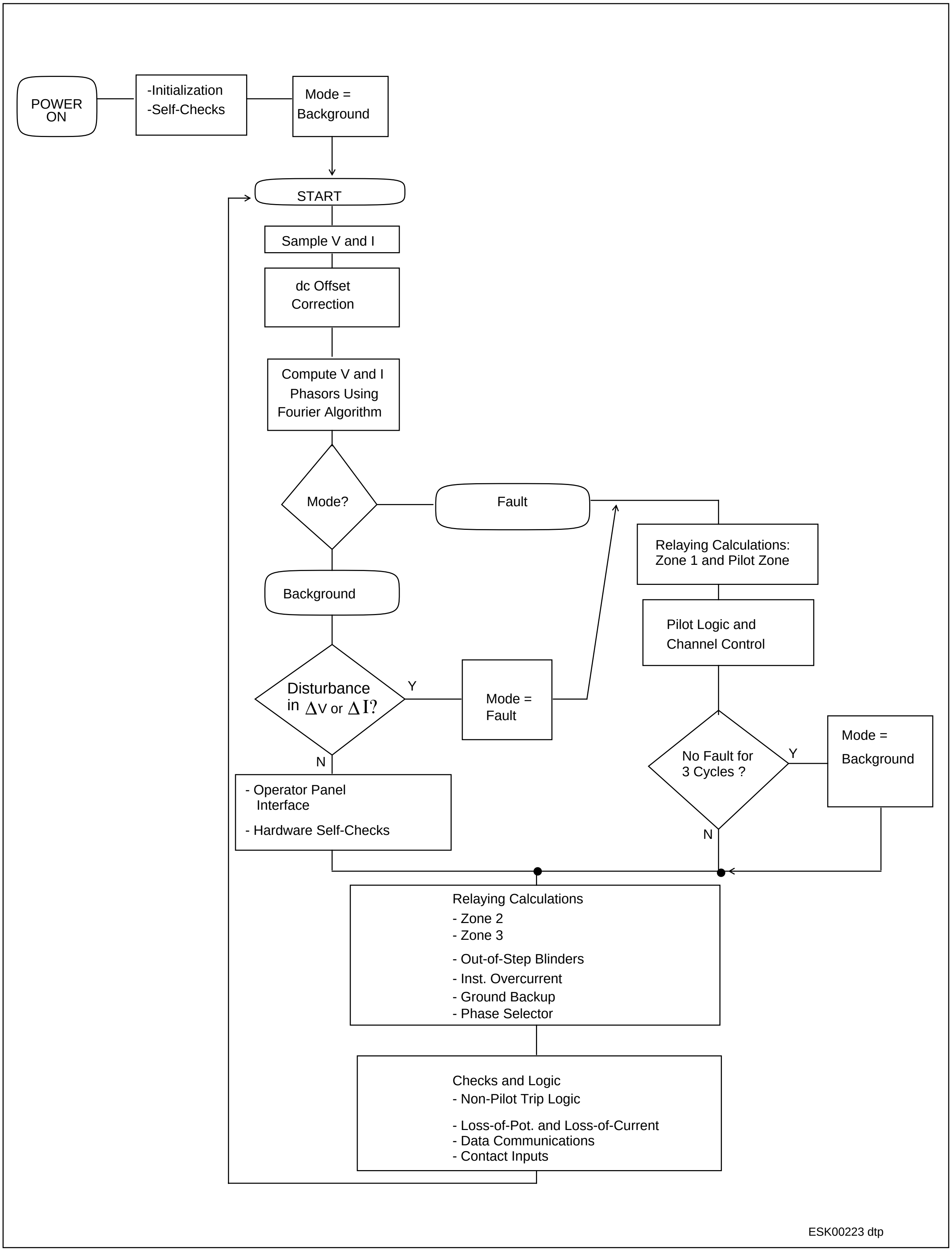


Figure 1-5. MDAR Relay Program Functions

Section 2. SPECIFICATIONS

2.1 TECHNICAL

Operating Speed (from fault detection to trip contact close -60 Hz)	 12-14 ms (minimum) 22 ms (typical)
ac Voltage (VLN) at 60 Hz (VLN) at 50 Hz	70 Vrms 63.5 Vrms
ac Current (In)	1 or 5 A
Rated Frequency	50 or 60 Hz
Maximum Permissible ac Voltage	
• Continuous	1.5 x nominal voltage
• 10 Second	2.5 x nominal voltage
Maximum Permissible ac Current	
• Continuous	3 x Nominal Current
• 1 Second	100 x Nominal Current
Typical Operating Current	0.5 A
dc Battery Voltages	
Nominal	Operating Range
48/60 Vdc	38 - 70 Vdc
110/125 Vdc	88- 145 Vdc
220/250 Vdc	176 - 290 Vdc
dc Burdens: Battery	7 W normal 30 W tripping
ac Burdens:	
Volts per Phase	0.02VA at 70 Vac
Current per Phase	0.15VA at 5 A

2.2 EXTERNAL CONNECTIONS

Terminal blocks located on the rear of the chassis suitable for #14 square tongue lugs

Wiring to FT-14 switches suitable for #12 wire lugs

2.3 CONTACT DATA

Trip Contacts - make & carry 30 A for 1 second, 10 A continuous capability, break 50 watts resistive or 25 watts with L/R =.045 seconds

- Non-Trip Contacts
  1A Continuous
  0.1A Resistive Interrupt Capability

Supports 1000 Vac across open contacts

Contacts also meet IEC - 255-6A, IEC - 255-12, IEC -255-16, BS142-1982.

2.4 MEASUREMENTS

Number of zones: 3 zones are standard (optional pilot adds additional zone).

Operating Characteristics: variable mho characteristics for all fault types.

2.5 MEASUREMENT UNITS

Three variable mho phase-to-earth units and one variable mho phase-to-phase impedance unit per zone.

One ground directional (ITG) and one phase directional (ITP) high-set overcurrent unit.

Three-phase non-directional overcurrent units (IL) for load loss trip and CIFT.

One non-directional ground overcurrent unit medium set (IOM) for ground supervision.

One ground overcurrent unit for LOI monitoring.

One inverse time overcurrent ground unit with CO characteristics (see Figures 2-1 thru 2-7); selectable non-directional or directional capability.

One forward set instantaneous directional overcurrent ground unit. (Pilot-high resistance ground faults.)

Three under-voltage units (LV) for weakfeed and LOP supervision.

Four current change fault detectors, and three voltage change fault detectors.

One instantaneous overcurrent unit low set (IOS)

One reverse set instantaneous directional overcurrent ground unit (Pilot Carrier Start, Weakfeed, Transient Blocking)

2.6 SETTING RANGES

Phase and Ground Distance (Zone 1, 2, 3):

- 0.01-50 ohms in 0.01 ohm steps for 5 A (ct)
- 0.05-250 ohms in 0.05 ohm steps for 1 A (ct)

Zone Timers - Separate timers for phase and ground:

- Zone 1 (No/Yes; 2 cycle delay if Yes is selected)
- Zone 2 (0.10 to 2.99 seconds in 0.01 second steps, Block)
- Zone 3 (0.10 to 9.99 seconds in 0.01 second steps, Block)

Forward Directional Ground Timer (FDGT)

- 0 to 15 cycles in 1 cycle steps, Block

Ohms per Unit Distance

- 0.300-1.500 in 0.001/DTYP (Km or Mi)

Inverse Time Overcurrent Ground Relay:

- Pickup (0.1-0.8) in 0.1 A increments for 1 A (ct).
- Pickup (0.5-4.0) in 0.5 A increments for 5A (ct). Choice of 7 time-curve families (CO-2, 5, 6, 7, 8, 9, 11 Characteristics), 63 time curves per family. (See Figures 2-1 thru 2-7.)
- Set for directional or non-directional operation.

High set instantaneous directional overcurrent trip units - phase and ground (I_{AH}, I_{BH}, I_{CH}, I_{OH}).

- 2.0-150 in 0.5 A steps for 5 A (ct)
- 0.4-30 in 0.1 A steps for 1 A (ct)

2.7 GROUND, OVERCURRENT AND UNDER-VOLTAGE UNITS

- (I_{os}, I_{om}, I_L and LV)

Undervoltage level units (LVA, LVB, LVC and CIF) for weakfeed and close-into-fault, from 40 to 60 Vrms in 1-volt steps.

Current Units (IAL, IBL, ICL)

- 0.5-10 in 0.5 A steps for 5 A (ct)
- 0.1-2 in 0.1 A steps for 1 A (ct)

Current Change Fault Detectors (ΔI_A,ΔI_B,ΔI_C, and ΔI_0), no setting required.

Voltage change fault detectors (ΔV_A, ΔV_B and ΔV_C) no setting required

Ground Overvoltage Unit $3V_0$ (no setting required).

2.8 OPTIONAL SINGLE-POLE-TRIP LOGIC AND OUTPUTS

- SPT/RI1 on first ϕGF fault and 3PT on other types of faults
- 3PT/RB if reclosing on a permanent fault
- 3PT/RB if second phase(s) fault during single phasing
- 3PT on a selectable time delay limit if the system fails to reclose (62T)
- TRIP/RI mode selections (TTYP):

SELECT	TRIP	RI
OFF	3PT	NO
1PR	3PT	RI2(ϕG)
2PR	3PT	RI2(ϕG,ϕϕ)
3PR	3PT	RI2(ϕG,ϕϕ,Mϕ)
SPR	SPT (ϕG)	RI1
	3PT (Mϕ)	NO
SPR/3PR	SPT (ϕG)	RI1
	3PT (Mϕ)	RI2

Legend:

SPT - Single Pole Trip
3PT - 3 Pole Trip
RI - Reclose Initiation
RB - Reclose Block
RI2 - 3 Pole Reclose Initiate
RI1 - Single Pole Reclose Initiate
ϕG - Single Phase to Ground Faults
Mϕ - Multi-Phase Faults
ϕϕ - 2-Phase Faults

2.9 OPTIONAL OUT-OF-STEP BLOCK

- OSB Override Timer

  400-4000 ms in 16 ms steps

- OSB Inner Blinder (RT)

  1.0-15.0 ohms in 0.1 ohm steps

NOTE: The RT is a standard setting; it can be used as a load restriction.

- OSB Outer Blinder (RU)

  3.0-15.0 ohms in 0.1 ohm steps

2.10 OPTIONAL COMMUNICATION INTERFACE

- RS-232C PONI - for single point computer communications
- INCOM/PONI - for local network communications

2.11 CHASSIS DIMENSIONS AND WEIGHT

Height 7" (177.8mm), 4 Rack Units (See Figure 2-8)

Width 19" (482.6mm)

Depth 14" (356mm) including terminal blocks

Weight 35 lb. (16Kg net)

2.12 ENVIRONMENTAL DATA

Ambient Temperature Range

- For Operation -20°C to +60°C
- For Storage -40°C to +80°C

Dielectric Test Voltage 2.8 kV, dc, 1 minute (ANSI C37.90.0, IEC 255-5)

Impulse Withstand Level 5 kV peak, 1.2/50 µsec, 0.5 joule (IEC 255-5)

Fast Transient Surge Withstand Capability 4 kV, 5/50 nsec (IEC 801-4); 5kV 10/150 nsec (ANSI C37.90.1)

Oscillatory Surge Withstand Capability 2.5 kV, 1 MHz (ANSI C37.90.1, IEC 255-6)

EMI Volts/Meter Withstand 25 MHz-1GHz, 10V/m Withstand (Proposed ANSI C37.90.2).

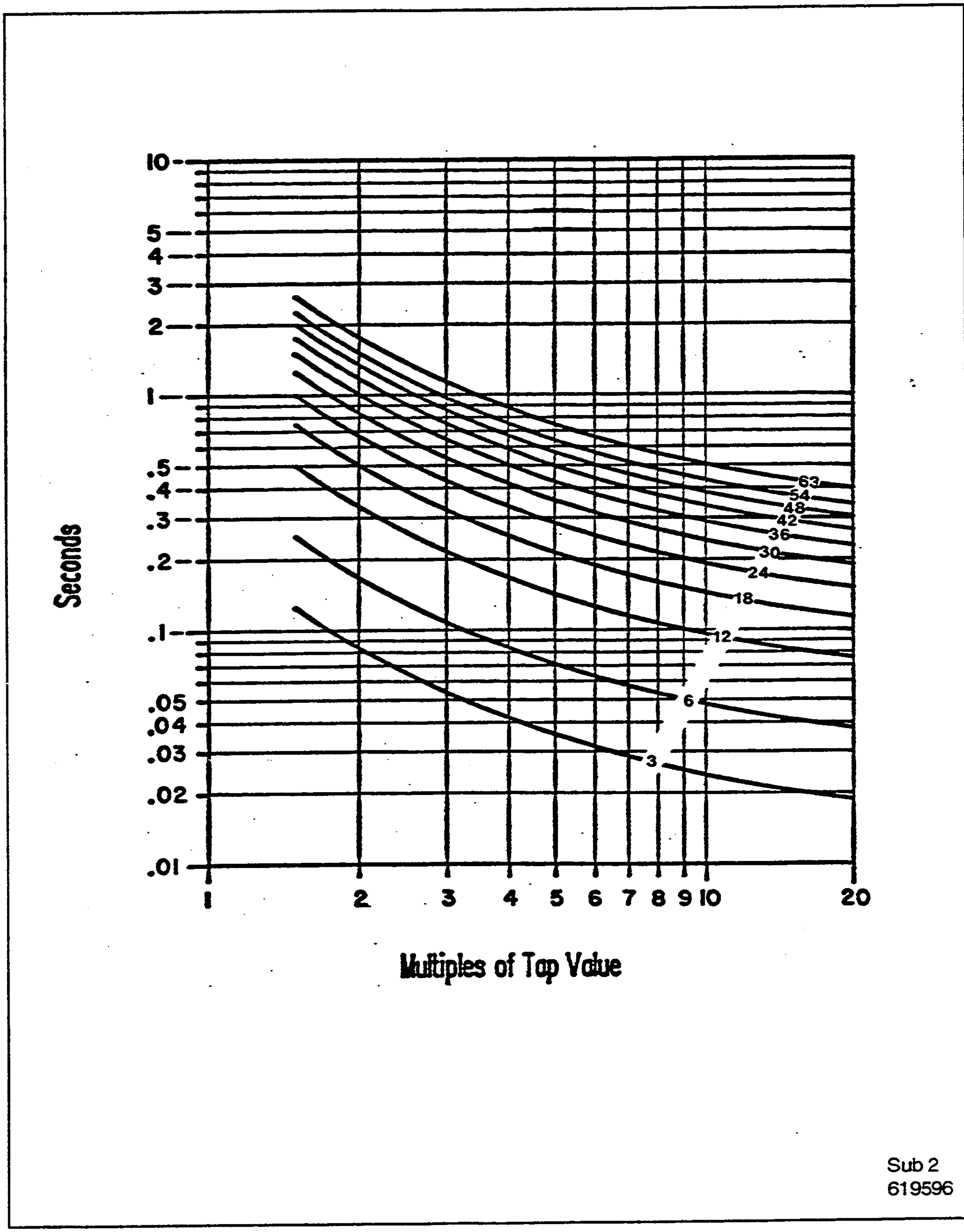


Figure 2-1. CO-2 Curve Characteristics

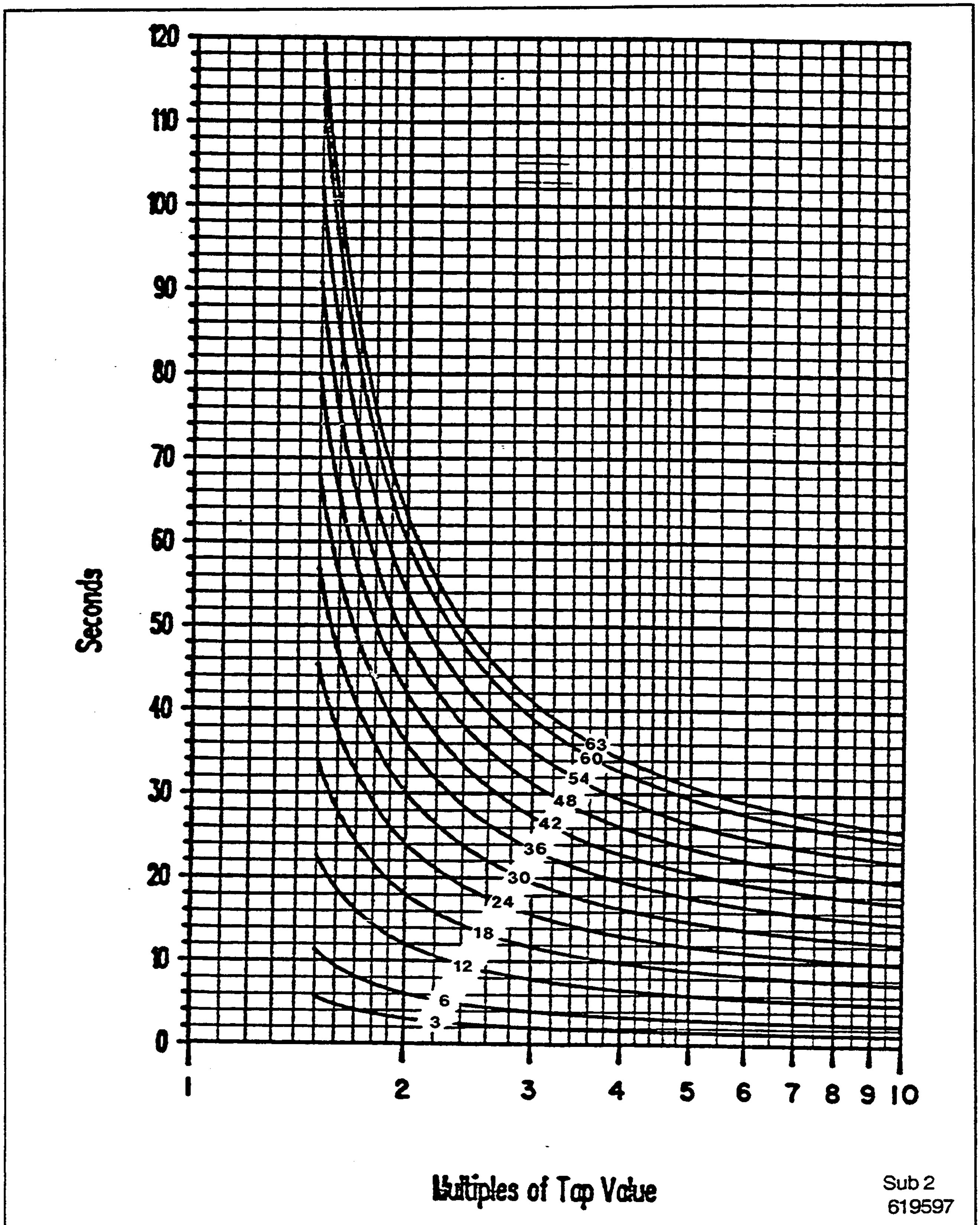


Figure 2-2. CO-5 Curve Characteristics

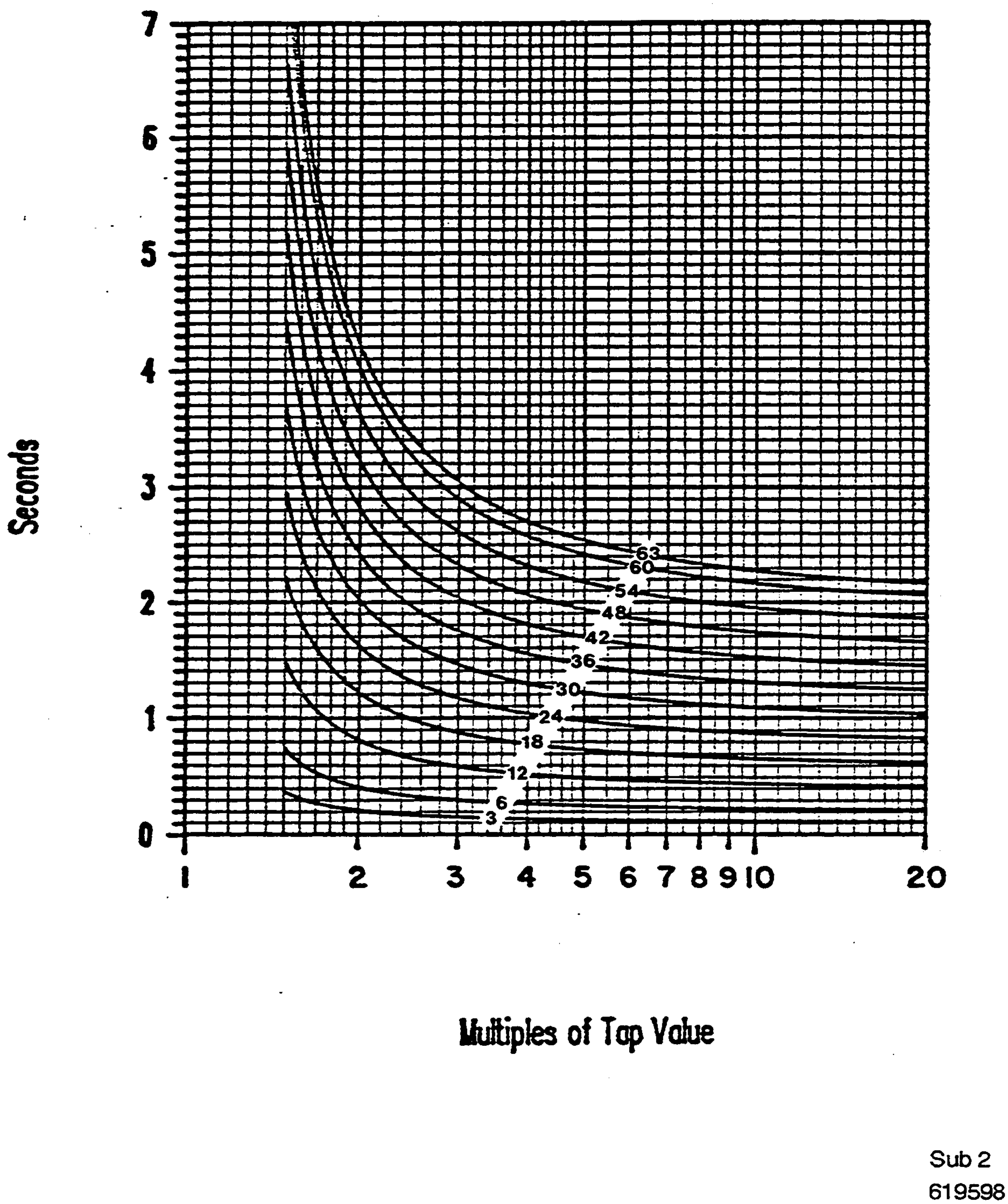


Figure 2-3. CO-6 Curve Characteristics

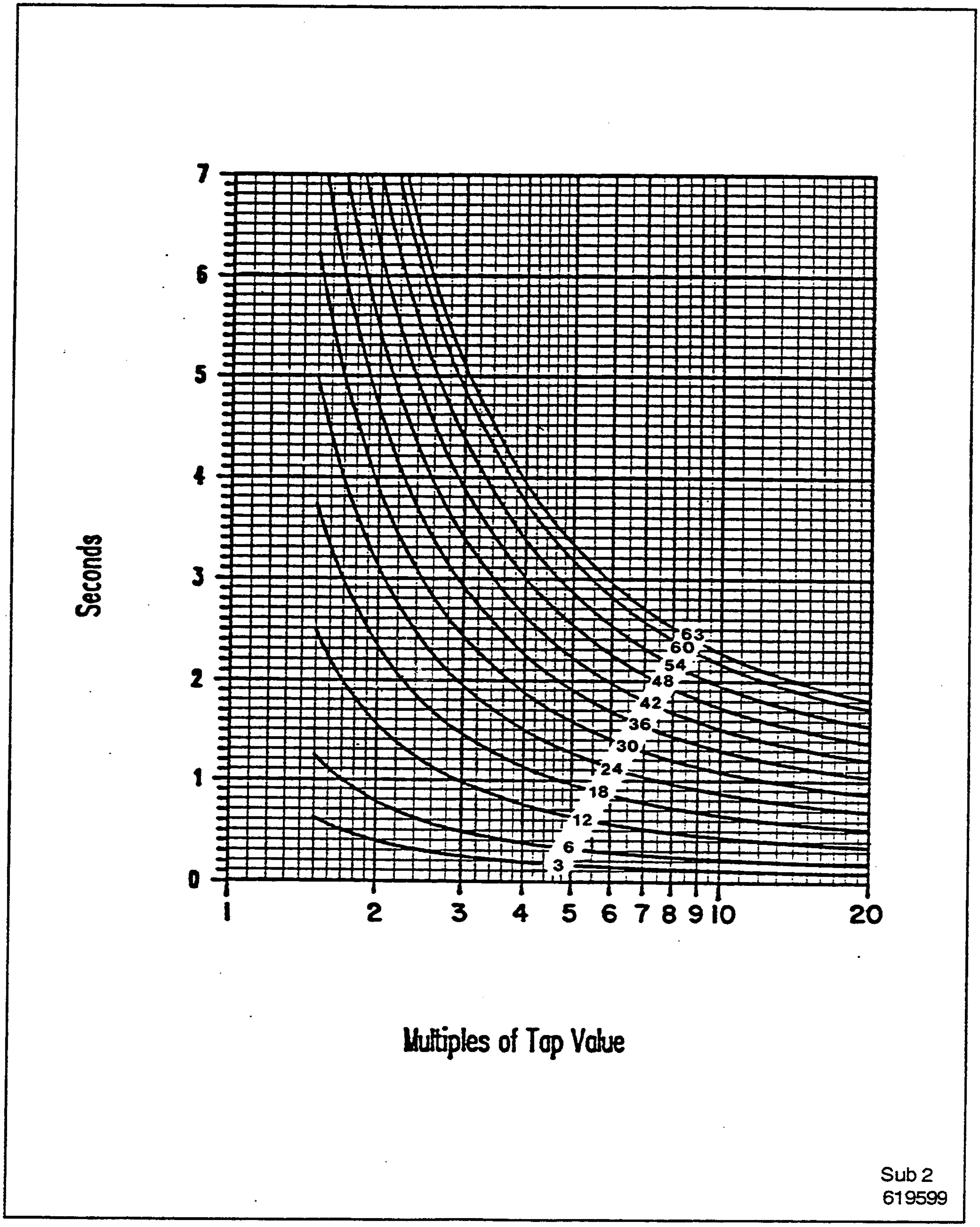


Figure 2-4. CO-7 Curve Characteristics

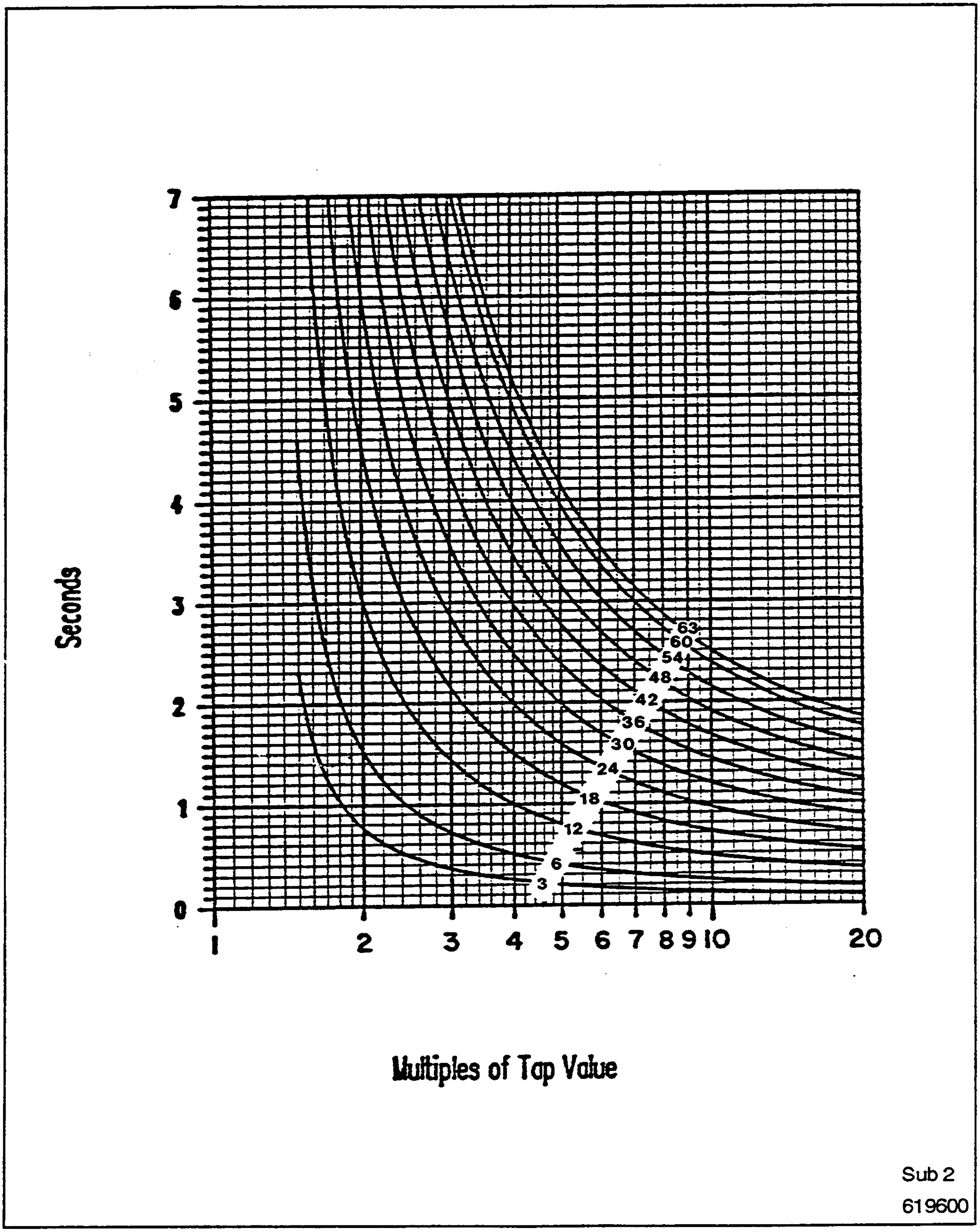


Figure 2-5. CO-8 Curve Characteristics

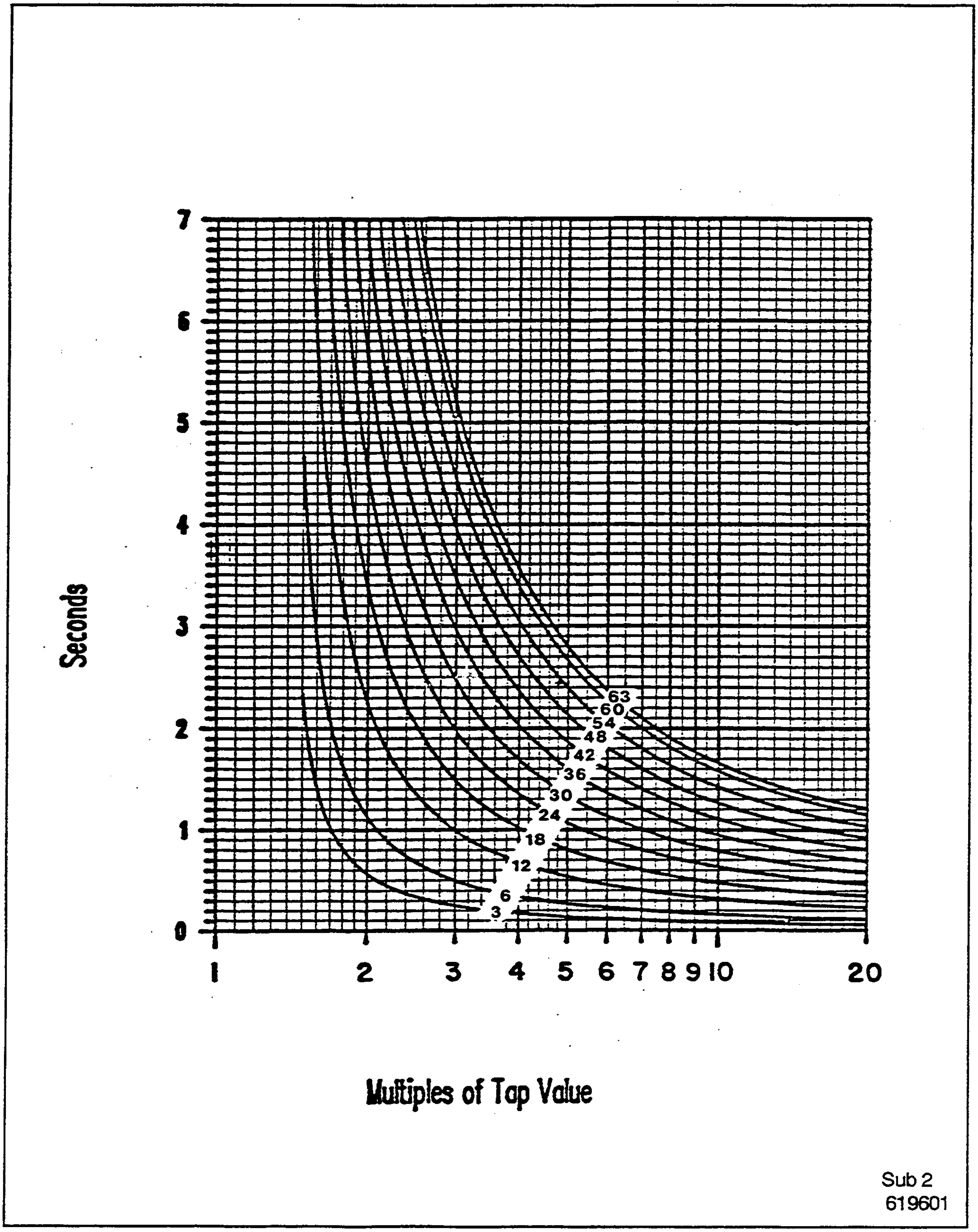


Figure 2-6. CO-9 Curve Characteristics

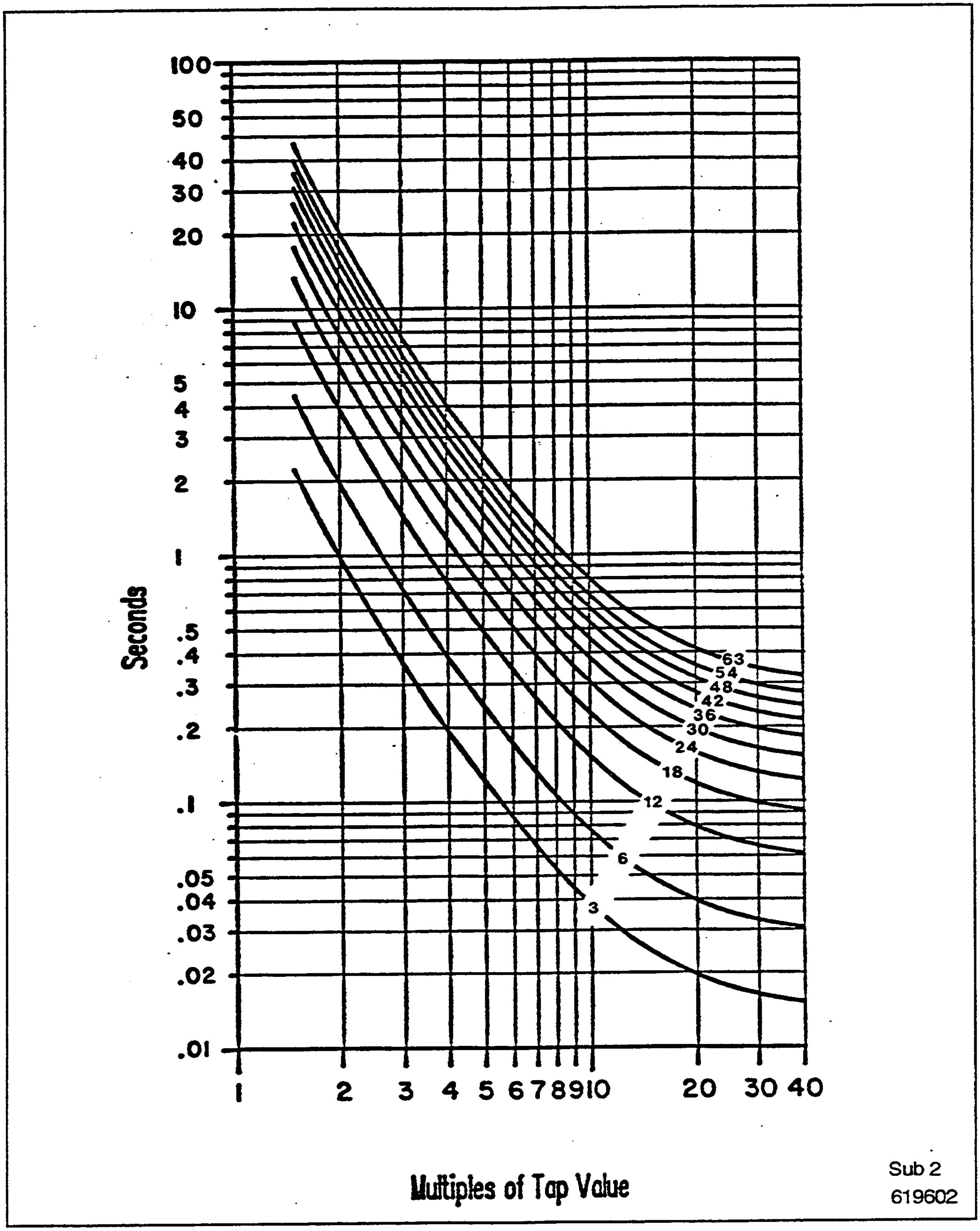
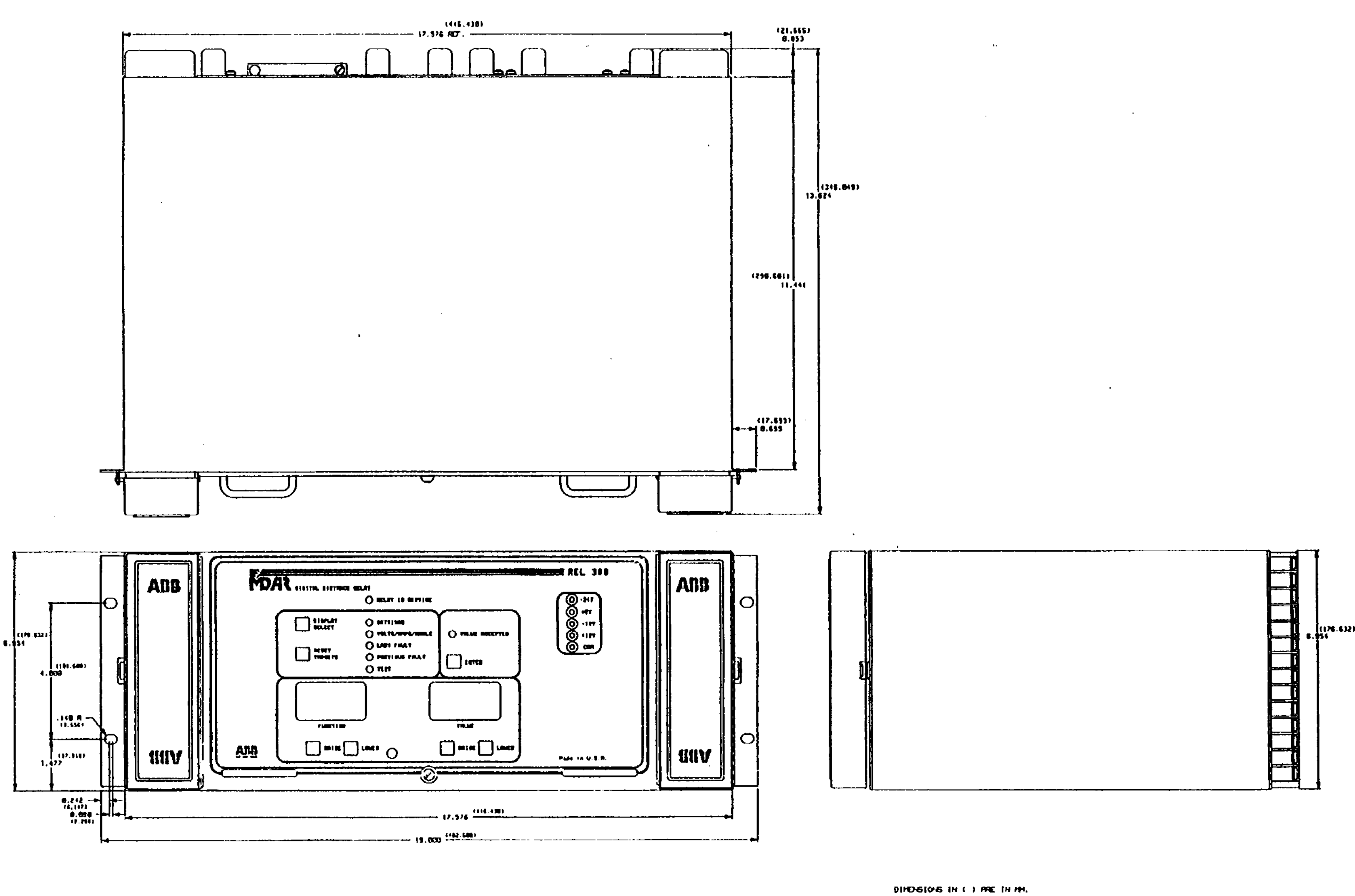


Figure 2-7. CO-11 Curve Characteristics



Sub 2
2403F38

Figure 2-8. MDAR Outline Drawing

Section 3. APPLICATIONS AND ORDERING INFORMATION

3. 1. NON-PILOT SYSTEM

The MDAR non-pilot relay system detects faults in three zones of distance, phase and ground. Zones 1 and 2 are forward set; Zone 3 can be set to forward or reverse. There is also a separate optional pilot zone (see Section 3.5). The fault locator can be set to indicate fault distance in miles or kilometers.

The R-X Diagram, shown in Figure 3-1, describes the characteristics available with MDAR. Zone 1 phase and ground settings are chosen to provide substantial coverage of the protected line without overreaching the next bus. A setting of 80% of the line impedance is typical. Faults occurring within the reach of the Zone 1 measurement cause direct tripping without regard to any action occurring at the remote terminal. Zone 2 settings are chosen to assure that faults occurring on the next bus are recognized. Settings are chosen (independent of the Zone 1 settings), generally to be 120 to 150% of the line impedance. Any fault occurring on the protected line will be recognized by this Zone 2 measurement (within the fault resistance and current limitations of the relaying system). Zone 2 tripping occurs with time delay (T2) or, where equipped with pilot provisions, at high speed, subject to the constraints imposed by the pilot channel for the particular pilot system selected. The Zone 3 measurement is directional, and may be chosen to respond to forward or reverse faults. The reverse sensing option is chosen for the blocking system where the reverse fault carrier start function is required. It is also used in conjunction with the T3 trip function, chosen to coordinate with adjacent terminal Zone 2 timing. The forward sensing option produces time delayed backup to other devices sensing forward faults. Blinder measurements (B1, B2, B3, B4) are available as an option for out-of-step sensing. The inner blinder (as a standard function) also restricts the trip zone of each of the 3-phase fault measuring units.

3. 2. LINE MEASUREMENT TECHNIQUES

Line measurement techniques applied to each zone include:

- Single-Phase-To-Ground fault detection
- 3-Phase fault detection
- Phase-to-Phase fault detection
- Phase-to-Phase-to-Ground fault detection

3.2.1 Single-Phase-to-Ground

Single-phase-to-ground fault detection (see Figure 3-2) is accomplished by 3 quadrature polarized phase units (ϕA, ϕB, ϕC). Equations 1 and 2 (below) are for operating and reference quantity, respectively. The unit will produce output when the operating quantity leads the reference quantity.

$$V_{XG} - \left[I_X + \left(\frac{Z_{0L} - Z_{1L}}{Z_{1L}} \right) I_0 \right] Z_{CG} \qquad (1)$$

$$I_0 = \frac{1}{3}(I_A + I_B + I_C)$$

Vector (V_Q) (2)

where V_{XG} = V_{AG}, V_{BG}, or V_{CG}

I_X = I_A, I_B or I_C

Z_{1L}, Z_{0L} = positive and zero sequence line impedance in relay ohms.

Z_{CG} = Zone reach setting in secondary ohms for ϕGF fault

V_Q = quadrature phase voltages, i.e., V_{CB}, V_{AC} and V_{BA} for ϕA, ϕB and ϕC units, respectively.

3.2.2 Three-Phase

Three-phase fault detection (see Figure 3-3) is accomplished by the logic operation of one of the three ground units, plus the 3ϕF output signal from the faulted phase selector unit.

However, for a 3-phase fault condition, the computation of the distance units will be:

V_{XG} - $I_X Z_{CP}$ (3)

and (V_Q) (4)

where V_{XG} = V_{AG}, V_{BG}, or V_{CG}

I_X = I_A, I_B or I_C

Z_{CP} = Zone reach setting (PLTP, Z1P Z2P, and Z3P) in secondary ohms for multi-phase faults.

V_Q = Quadrature phase voltages, i.e., V_{CB}, V_{AC} and V_{BA} for ϕA, ϕB and ϕ C units, respectively.

3.2.3 Phase-to-Phase

The phase-to-phase unit (see Figure 3-4) responds to all phase-to-phase faults, and some single-phase-to-ground faults. Equations (5 and 6) are for operating and reference quantity, respectively. They will produce output when the operating quantity leads the reference quantity.

$$(V_{AB} - I_{AB}Z_{CP}) \qquad (5)$$

$$(V_{CB} - I_{CB}Z_{CP}) \qquad (6)$$

3.3 MEASUREMENT ZONES

MDAR performs line measurement within 3 zones of the transmission line (Zone 1, Zone 2, Zone 3), and one optional pilot zone. When the MDAR functional display “STYP” is set at “3ZNP”, it will perform the 3-zone non-pilot function.

When the MDAR trips, the trip contacts will be sealed-in as along as the trip coil current flow exists. The trip contacts can be delayed dropout (by 50 ms) after the trip current is removed, providing a jumper (JMP4) is connected on the Microprocessor module.

3.3.1 Zone 1 Trip

For Zone 1 phase faults, the Z1P unit will identify the fault and operate. The 3ϕ fault logic is supervised by the load restriction logic via AND131C and AND 131 (Figure 3-18a) and is also supervised by the selectable OSB, as shown in Figure 3-5. Output of Z1P satisfies AND-2 and provides a high-speed trip (HST) signal from OR-2 to operate the trip output telephone relay. The trip circuit is monitored by a seal-in reed relay (S), which is in-series with each trip contact in the tripping circuits. The S relay will pick up if the trip current is higher than 0.5 Amp. The operation of the “S” contact will turn-on the breaker trip indicators (with memory), and feeds back to OR-4 to hold the trip relay in operation until the breaker trips and 52a contact opens (not shown in Figure 3-5). The TRSL signal plus the output signal from AND-2 turns on the Zone 1 phase trip indicator (Z1P). The breaker trip and Zone 1 phase trip indicators are memorized. They can be reset by external RESET voltage or through remote communication. By pushing the RESET pushbutton, the flashing LED will be reset, but the fault information will still remain in memory.

The Z1P 3ϕ trip logic AND-131 is supervised by both the conventional OSB and the subsequent OSB logic when the OSB is set to “YES”, for more security on some special power system applications. ZIP logic AND-2 is also supervised by the FDOP (Forward Directional Overcurrent Phase unit) when the OSB is set to “YES” for more security on some special power system applications.

Similar operations exist for Zone 1 single-phase-to-ground faults. The Z1G unit sees the fault and operates; the IoM and FDOG units also operate, satisfying AND-3. Tripping occurs via OR-2 with Zone 1 ground trip indication Z1G. Logic AND-3 is also supervised by the signal of RDOG (reverse directional overcurrent ground) for security purposes.

The Z1G unit is also supervised by the signal of unequal-pole-closing and RDOG.

A two-out-of-three “leading phase blocking” logic is included for solving the overreach problem of the single-phase ground distance units, which may respond to a ϕϕG fault.

The high-speed trip (HST) signal also is connected to the reclosing initiation logic.

Either or both Zone 1 phase and Zone 1 ground function(s) can be disabled by setting the Z1P and/or Z1G to the position. Zone 1 trip can be delayed by setting T1 = YES. The delay time is 2 cycles for a non-pilot 3PT backup, with another system operating in SPT mode.

3.3.2 Zone 2 Trip

For Zone 2 phase faults, the Z2P unit will see the faults and operate the Zone 2 phase timer (T2P). The Z2P output plus the T2P timer output satisfy AND-18, as shown in Figure 3-6. The AND-18 output provides time delay trip signal TDT via OR-3. Signal TDT picks up OR-4 (Figure 3-5) and operates the trip relay. The tripping and targeting are similar as described in Zone 1 trip except for Zone 2 phase time delay trip indicator (Z2P).

Similar operation occurs for Zone 2 single-phase-to-ground faults. The Z2G unit sees the fault and operates. This, plus the operation of the IoM, FDOG and T2G satisfy AND-19, and provide the TDT signal via OR-3 with Zone 2 ground time delay trip indicator (Z2G).

The single-phase ground distance units may respond to a ϕϕG fault. The output of the Z2G unit plus the operation of the ϕϕ selection will trip the Z2P via OR-157, T2P and AND-18. Leading phase blocking is unnecessary for an overreach Zone device.

The TDT signal can be connected to the reclosing block logic. The settings for Zone 2 timers (phase and ground units) are independent, as follows:

- T2P (Zone 2 phase)
- T2G (Zone 2 ground)

The range of the timers is as follows:

- T2P and T2G (0.1 to 2.99 seconds or Block)

Either or both Zone 2 phase and Zone 2 ground function(s) can be disabled by setting Z2P and/or Z2G to the BLK position.

3.3.3 Zone 3 Trip

For Zone 3 phase faults, the Z3P (forward or reverse looking, depending on the Z3FR setting) unit will identify the faults and operate the Zone 3 phase timer T3P. The Z3P output plus the T3P timer output satisfy AND-20 (as shown in Figure 3-7). The AND-20 output provides time delay trip signal (TDT) via OR-3. Signal TDT picks up OR-4 (Figure 3-5) and operates the trip relay. The tripping and targeting are similar to Zone 1 trip, except for the Zone 3 phase time delay trip indicator (Z3P).

For Zone 3 single-phase-to-ground faults, Z3G identifies the fault and operates. This, plus the operation of the IOM, satisfies AND-7; the TDT signal then trips via OR-3 with Zone 3 ground time delay trip indicator Z3G. The TDT signal can be connected to the reclosing block logic. For security, the Z3G unit is also supervised by the signal of FDOG when it is set for forward looking (or by the signal of RDOG when it is set for reverse looking) via logic OR-171B, AND-171C or AND 171D (as shown in Figure 3-7).

A similar operation for ϕϕG faults (shown in Zone 2), is applied to Zone 3, through OR-170, T3P and AND-20 gates.

The settings for Zone 3 timers (phase and ground units) are independent, as follows:

- T3P (Zone 3 phase)
- T3G (Zone 3 ground)

The range of the timers is as follows:

- T3P and T3G (0.1 to 9.99 seconds or Block)

Either or both Zone 3 phase and Zone 3 ground function(s) can be disabled by setting Z3P and/or Z3G to the BLK position.

3.3.4 Zone 1 Extension

This scheme provides a higher speed operation on end zone faults without the application of pilot channel.

If the MDAR functional display “STYP” is set on Z1E position, the Z1P/Z1G unit will provide two outputs: one is overreach which is set at 1.25 x Z1 reach by the microprocessor, and one is the normal Z1 reach. A single shot instantaneous reclosing device should be used when applying this scheme. The targets Z1P/Z1G will indicate either Z1 trip and/or Z1E trip operations. The other functions (e.g., Z2T, Z3T, ac trouble monitoring, overcurrent supervision, IT, CIF, unequal-pole closing load pickup control, load-loss acceleration trip, etc.) would remain the same as in the basic scheme (3ZNP).

For a remote internal fault (refer to Figure 3-8), either Z1P or Z1G will see the fault since they are set to overreach. High speed trip will be performed via the normal Z1T path (Figure 3-5), i.e., AND-2 (or AND-3), OR-2. HST signal operates the instantaneous reclosing scheme. The breaker recloses and stays closed if the fault is automatically cleared.

Target Z1P and/or Z1G will be displayed. Once the breaker trip circuit carries current, it operates the logic OR-5 (not shown), produces output signal TRSL, and satisfies logic AND-26 for 5000 ms (Figure 3-8). The output signal of AND-26 will trigger the Z1P/Z1G reach circuit, constricting their reaches back to the normal Zone 1 for 5000 ms. During the reach constricting periods, if the breaker is reclosed on a Zone 1 permanent fault, it will retrip again. If the breaker is reclosed on an end-zone permanent fault, the normal Z2T will take place.

For a remote external fault, either Z1P or Z1G will see the fault since they are set to overreach. High speed trip will be performed. HST signal operates the instantaneous reclosing scheme. The breaker recloses and stays closed if the fault has been isolated by the adjacent line breaker. However, if the adjacent line breaker fails to trip, the normal remote back up will take place.

NOTE: The reaches of Z1E are based on the Zone 1 settings multiplied by a factor of 1.25 (e.g., 1.25 x Z1P and 1.25 x Z1G).

3.4 MDAR NON-PILOT FEATURES

The following features are standard with the Non-Pilot MDAR

3.4.1 3-Zone Distance Phase and Ground Relay with Reversible Zone 3 Phase and Ground

There are four impedance units per zone: one phase-to-phase unit and three phase-to-ground units. Zone 3 can be set to forward or reverse for carrier keying or back-up tripping in pilot system applications.

3.4.2 Directional or Non-Directional Inverse Time Overcurrent Ground Backup Logic

The overcurrent ground backup (GB) unit is to supplement the distance ground protection on high resistance ground faults. It provides an inverse time characteristic which is similar to the conventional CO characteristics (see Figure 2-1 thru 2-7). The time curves can be selected by the GBCV Setting. The time dial is set by the “GTC” value. The unit can be selected as directional by using the “GDIR” (YES) setting and the pickup value by GBPU. The directional GB function uses the torque control approach, as indicated in Figure 3-9. The GB function can be disabled by setting the GBCV to the OUT position.

The directional unit is determined by the setting of “DIRU” which can be set to zero sequence voltage (ZSEQ), dual (DUAL, zero sequence voltage and/or zero sequence current) or negative sequence (NSEQ, negative sequence voltage and negative sequence current) for polarization (see 3.4.11, Selectable Ground Directional Unit, ZSEQ / NSEQ / DUAL).

3.4.3 Loss of Potential Supervision (LOP)

The ac voltage monitoring circuit is called loss-of-potential circuit. In order to prevent undesirable tripping due to the distance unit(s) pickup on loss-of-potential, the following logic is used:

- (V_{AN} or V_{BN} or V_{CN} <7Vac) or (3Vo>7Vac) and not ΔI or not ($3I_O > I_{OS}$)

This means that the LOPB will be set if any one of the voltages is below 7Vac (without ΔI), or if the system detects 3Vo without 3Io (or $3I_O > I_{OS}$) as shown in Figure 3-10. The (loss-of-potential condition satisfies AND-1; output signal of AND-1 starts the 8/500 ms timer. The timer output will satisfy AND-1C if there is no output from AND-1B. Output signal of AND-1C will block all the distance unit (Z) tripping paths via AND-2, AND-3, AND-4, AND-5, AND-6, AND-172 (also blocks AND-191 and AND-187 for Pilot Systems), if LOPB is set at YES. Although all distance units are blocked for tripping, the ground backup (GB) and high-set overcurrent units (ITP and ITG) are operative and converted to non-directional automatically. The LOPB blocking function can be disabled by setting the LOPB functional display at NO position. The output of the LOP timer will de-energize the alarm 1 (AL1) relay and cause the failure alarm.

When applying the LOPB to YES, it is the intent to block all distance units from tripping, should LOP condition exist. However, under a special system condition (refer to Figure 3-11), both circuits are energized without load current; with no source at terminal B, fault at F where F is near terminal A, Zone 2 relay at terminal B will be blocked by LOP, and may fail to trip. This is because the relay at B sees no current, and a low voltage condition exists before circuit breaker A opens. Another special system condition involves two parallel lines with two symmetrical sources at both ends. For an evolving flashover fault, at a point equidistant from both terminals, the conventional LOPB logic will block trip, because the first external fault generates “3V0 and not $3I_0$“on the protected line. Logic AND-1A, 1B, -1C, and -1E 150/0, 0/3500 ms timers circuit (in Figure 3-10) are for solving these problems. This logic unblocks the LOPB circuit and provides a 3500 ms trip window for the distance units to trip if the fault current is detected within 150 ms after LOP has been set up. This logic has no effect on the conditions:

- if ΔI signal occurs ahead of LOP, or
- if LOP and ΔI signals occur simultaneously

NOTE: The LOPB setting detects a blown fuse condition.

The distance units are designed to be blocked under the loss-of-potential condition, but the high set (ITP and ITG) and ground backup (GB) are functional and converted to non-directional automatically (see also 3.4.6).

3.4.4 Loss of Current Monitoring (LOI)

The ac current monitoring circuit uses IoM (and not Vo) as criterion, as shown in Figure 3-12. Under ct short circuit or open circuit condition, IoM (and not Vo) satisfies AND-23; the output signal of AND-23 starts the 500/500 ms timer. The timer output turns “ON” the non-memory LOI indicator, which is shown in the Metering mode, and drops out the AL1 relay (Failure Alarm). If the LOI condition exists and LOIB is set at YES, the trip will be blocked after the 500 ms timer times out.

3.4.5 Overcurrent Supervision

For MDAR, as shown in Figure 3-13, the distance units do not require overcurrent supervision; because the relay normally operates in a background mode, they will not start the Zone 1 and pilot impedance computation until a phase current or a phase voltage disturbance is detected. This approach can minimize the load problem when setting the phase overcurrent units. However, the 3-phase units are supervised by the load restriction logic, and the 21BI unit is restricted by the setting of I_L units, consequently, the 3-phase units are supervised by the I_L setting. For increasing the security. The application of LOPB supervision function is also normally recommended.

For coordination purposes the ground trip units (Z1G, Z2G, Z3G, PLTG, and FDOG) are supervised by the medium set ground overcurrent unit (IoM). The Ios setting and RDOG are used for carrier send in a Pilot Blocking system.

3.4.6 Instantaneous Forward Directional Overcurrent Trip/Highset Trip Logic

The instantaneous overcurrent units (IAH, IBH, ICH and IOH) are normally set forward directional and high to detect those faults which occur in the Zone 1 area, therefore, their tripping will occur via OR-2 for HST, as shown in Figure 3-14. These high set trip functions can be disabled by setting the ITP (phase) and/or ITG (ground) to the OUT position. The directional unit (ITP and ITG) will be automatically converted to non-directional protection if the LOP condition occurs and the setting of LOPB = YES.

3.4.7 Close-Into-Fault Trip (CIFT) and Stub-Bus Protection (SBP)

There are three low voltage units (LVA, LVB and LVC) in MDAR. Each unit senses the phase voltage condition in the background mode. The unit can be set from 40 to 60 volts, in 1.0 volt steps. For any phase voltage below its preset value, the LV logic will produce a logic “1” output signal. The low voltage units are used in CIFT and weakfeed logic in MDAR.

In order to supplement distance unit operation, when the circuit breaker is closed into a fault and line side potential is used, the Close-Into-Fault Trip (CIFT) circuit operates as shown in Figure 3-15. It includes logic AND-22, OR-3 and 100/180 ms and 16/0 ms timers. If any overcurrent unit (IAL, IBL, ICL or IOM) operates OR-11, at the same time as one of the phase voltages (VA, VB,VC) is below the preset level of the LV units. Then logic AND-22 is satisfied and produces a trip signal (for 180 ms) after circuit breaker closes (52b contact opens). Tripping will be via OR-3, with RB and CIF targets.

The stub bus protection feature protects a line terminal with the potential device on the line-side. With the line disconnect switch open, the distance units will lose their reference voltage, and may not function correctly when a fault occurs on the short part of the bus between the ct location and the opened disconnect switch. The logic for stub bus protection is independent of the operation of the circuit breaker(s) and the line voltage condition. Also, it requires the information from the disconnect switch (89b). The stub bus protection logic, as shown in Figure 3-15, includes the contact convertor for the 89b switch and AND-22E and OR-22B logic.

The application of "close-into-fault" and "stub-bus protection" are selected by setting the value field of CIF to CIFT/STUB/BOTH/NO.

3.4.8 Unequal-Pole-Closing Load Pickup Logic

The ground units may pick up on a condition of load pickup with unequal breaker pole closing. The high speed ground units (Z1G, FDOG and RDOG and PLTG) should be supervised under this condition. This can be achieved (as shown in Figure 3-16) by inserting a 0/20 ms timer (controlled by the 52b signal) to supervise the Z1G trip AND-3. It should be noted that the 20 ms time delay will have no effect on a normal fault clearing.

3.4.9 Selectable Loss-of-Load Accelerated Trip Logic (LLT)

The load-loss speedup Zone 2 trip logic senses remote 3-pole clearing on all faults except 3ϕF to complement or substitute for the action of the pilot channel, to speed up trip at the slow terminal. Logic includes AND-24, AND-25, OR-13, 0/32, and 10/0 ms timers (as shown in Figure 3-17). Under normal system conditions, 3-phase load currents are balanced, the low set overcurrent units (IAL, IBL, ICL satisfy both AND-24 and OR-13). On remote internal faults, Z2P or Z2G picks-up and satisfies the third input to AND-25 via OR-6. However, the signal from AND-24 is negated to AND-25, therefore, AND-25 should have no output until the remote end 3-pole trips. At this time, the local end current will lose one or two phases, depending on the type of fault (except for the 3-phase fault). The AND-24 output signal changes from "1" to "0" and satisfies AND-25. After 10 ms, this output by-passes the T2 timer, and provides speedup Zone 2 trip. The (10/0 ms) time delay is for coordination on external faults with unequal pole clearing. The 0/32 ms timer is needed for security on external faults without load current condition. Target LLT will turn on after a LLT trip. The LLT function is selected by setting "YES, FDOG, NO", where YES = LLT with Z2 supervision; FDOG = LLT with both Z2 and (FDOG/I_{OM}) supervision; the NO = LLT function is not used.

3.4.10 Current or Voltage Change Fault Detector (ΔI, ΔV) and GS

The MDAR relay normally operates in the Background mode, where it experiences phase current or voltage disturbances. During background mode, the four input currents (I_A, I_B, I_C and I_P) and the three voltages (V_A, V_B, V_C) are sampled at a rate of 8 per cycle to test a line fault. When a phase disturbance (ΔI or ΔV) is detected, the relay enters a fault mode for several cycles or longer, to perform phase and ground unit distance computation for each goal. The criteria for determining a disturbance in the MDAR design are as follows:

1) Each phase ΔI: if $[I_{Kn} - I_{(K-1)n}] > 1.0$ amp.
And $[I_{Kn} - I_{(K-1)n}] / I_{(K-1)n} \times 100\% > 12.5\%$
2) Each phase ΔV: if $[V_{Kn} - V_{(K-1)n}] > 7.0$ volts
and $[V_{Kn} - V_{(K-1)n}] / V_{(K-1)n} \times 100\% > 12.5\%$
3) ΔI_0: if $[(3I_0)_{Kn} - (3I_0)_{(K-1)n}] > 0.5$ amp.
Where n = 1, 2, 3, 4, 5, 6, 7, 8 and
K = number of cycles

For every voltage or current disturbence, the General Start (GS) relay will pick up for 3 cycles for starting external (fault) recorder.

3.4.11 Selectable Ground Directional Unit (ZSEQ/NSEQ/DUAL)

The ground directional unit (DIRU) contains three selections (ZSEQ, NSEQ and DUAL), which determine the operation of the forward directional overcurrent ground (FDOG) and reversed directional (RDOG). If the ZSEQ is selected, both FDOG and RDOG units will be operated as a zero-sequence voltage polarizing element. Forward direction is identified by the angle, if $3I_0$ leads $3V_0$, between 30° and 210°. The sensitivity of this element is $3I_0 > 0.5$A and $3V_0 > 1.0$ Vac. If NSEQ is selected, both FDOG and RDOG will be operated by negative sequence quantities. The maximum sensitivity for the forward directional unit is when I_2 leads V_2 by 98°, with $V_2 \geq 1.0$ Vac and $3I_2 \geq 0.5$A.

If DUAL is selected, the FDOG and RDOG will be determined by either zero-sequence voltage polarizing element, as the setting of ZSEQ or current polarizing directional element (I_P), which is connected to 1FT-14/12 and 1FT-14/11 and is from power transformer neutral (ct). The maximum torque angle between $3I_0$ and I_P equals zero degrees, i.e., the forward direction is identified when $3I_0$ leads I_P by 0° to 90° or lags by 0° to 90°. The sensitivity of this element is $3I_0 > 0.5$ and $I_P > 0.1$ Amps.

3.4.12 Instantaneous Forward Directional Overcurrent Unit (FDOG)

The instantaneous forward directional overcurrent ground function (FDOG) is a directional unit depending on the setting of DIRU as described in the preceding segment (3.4.11). FDOG is supervised by the I_{om} setting and controls Zone 1, Zone 2 and Zone 3 ground units for security purposes.

3.4.13 Instantaneous Reverse Directional Overcurrent Ground Function (RDOG)

Similar to FDOG, the instantaneous reverse directional overcurrent ground function (RDOG) supervises the ground units to prevent false trip.

3.4.14 Programmable Reclosing Initiation and Reclose Block

The MDAR system provides the following contact output for Reclosing Initiation and reclosing block functions (see Figure 3-19):

- RI1, used for Reclosing Initiation on single pole trip
- RI2, used for Reclosing Initiation on 3-pole trip
- RB, used for Reclosing Block

The operation of RI1, RI2 and RB contacts is controlled by the setting of the programmable Reclosing Initiation logic (as shown in Figure 3-19). The operation of either RI1, RI2, or RB must be confirmed by the signal of TRSL, which is the trip output of MDAR operation.

The External Pilot Enable Switch (see Figure 4-1, TB-5 terminals 9 and 10), is used for enabling the pilot system externally. The PLT setting is similar to the external pilot enable switch, except it is set from the front panel (or remotely set via communication chain).

The most popular Reclosing Initiation practice is to have Reclosing Initiation on high speed (pilot, Zone 1 and high set) trip only. Programming can be accomplished by closing the pilot enable switch and setting the PLT to YES (see Figure 3-19). AND-84 will produce logic to operate the RI2 relay when receiving signals from TRSL and AND-89. The program is further controlled by the TTYP setting: TTYP setting OFF: 3PRN provides no output, therefore, will not operate RI2.

TTYP setting 1PR: 3PRN will provide output “1” on single-phase-to-ground fault only and will operate RI2.

TTYP setting 2PR: 3PRN will provide output “1” on single-phase-to-ground fault or 2-phase faults, and will operate RI2.

TTYP setting 3PR: 3PRN will provide output “1” on any type of fault, and will operate RI2.

The Z1RI, Z2RI and Z3RI settings are provided for programming on applications where the Reclosing Initiation on Zone 1, Zone 2 or Zone 3 trip is desired. Logic AND-62A is controlled by the signal of 3PRN, therefore, the setting of 1PR, 2PR and 3PR also affect the Z1RI, Z2RI and Z3RI.

In general, the Reclosing Block (RB) relay will operate on TDT (Time Delay Trip) or OSB (Out-of-Step Block condition). However, it will be disabled by the setting of Z1RI, Z2RI, and Z3RI signal.

The RI1 relay is normally used for the single-pole trip scheme. A Breaker Failure Reclosing Block (BFRB) feature is available for pilot systems if RB is required for breaker failure squelch.

3.4.15 Output Contact Test

A “Push-to-Close” feature is included in order to check all output relay contacts, which include TRIP, BFI, RI1, RI2, RB, AL1, AL2, GS, Carrier Send and Carrier Stop. The relay contact check is supplementary to the self-check because the Microprocessor self-check routine cannot detect the output hardware. In order to enable the contact test, jumper (JMP5) on the Microprocessor module must be connected. (See Appendix H, 1.1.13, Step 35 for detailed procedures.)

3.4.16 Sixteen Fault Data

The MDAR system saves the latest sixteen fault records for all zones. The latest two fault records can be accessed either via the front panel or via the communication port. Fault records 3 thru 16 can only be accessed via the communication port. On the front panel, the “LAST FAULT’ information is of the last fault, the “PREVIOUS FAULT” information is of the previous fault. These displays contain target information. When targets are available, the LAST

FAULT LED flashes. It flashes once per second if only the LAST FAULT contains targets. It will flash twice per second if two or more fault records are contained. These records can be deleted by applying a rated voltage to the Ext. Reset Terminals (TB5/5 and TB5/6), or through a remote communication interface. By pressing the Reset pushbutton, the LED will be reset to the Metering mode and the fault information will still be retained.

The activation of fault data storage is controlled by the selection of TRIP/Z2TR/Z2Z3 in the FDAT function, where:

TRIP ---start to store fault data only if trip action occurs.

Z2TR ---start to store fault data if Zone 2 units pick up or any trip action occurs.

Z2Z3 ---start to store fault data if Zone 2 or Zone 3 units pick up or any trip action occurs.

3.4.17 Out-of-Step Block (OSB) Logic

The Out-of-Step Blocking (OSB) logic (power swing block supervision) in MDAR is a double blinder scheme. It contains two blinder units, providing 4 blinder lines. The nature of the logic (shown in Figure 3-18a) is that the outer blinder 21BO must operate 50ms or more ahead of the inner blinder 21BI, in order for an OSB condition to be identified. The OSB signal is a negated input to the AND-131 (Z1P), AND-147 (Z2P), AND-160 (Z3P), and AND-176 (PLTP) for supervising the 3-phase distance trip. In addition to controlling the OSB logic, the blinder units also may be used to supervise distance relay tripping. Phase distance unit tripping cannot take place unless 21BI operates. This prevents operation of the distance relay on load. The OSB signal is also applied to the reclosing logic for initiating RB.

The following quantities are used for the blinder sensing:

Blinder Line	Polarizing	Operating
Left	$-j(V_{XG} + I_X R_C$ (PANG–90°)	I_X (PANG–90°)
Right	$j(V_{XG} - I_X R_C$ (PANG–90°)	I_X (PANG–90°)

where VXG = Phase to ground voltage, V_{AG} or V_{BG}

I_X = Phase current in ϕA or ϕB

R_C = Setting of the unit (R_T or R_U). RT for inner blinder (21BI), RU for outer blinder (21BO).

PANG = The positive sequence line impedance angle.

Operation occurs if the operating voltage leads the polarizing voltage. The characteristics are as shown in Figure 3-18b.

Both inner and outer blinders are included in phases A and B for OSB detection on the SPT application. Blinder reaches are determined by the setting of RT and RU, respectively.

3.4.17.1 Security Logic for Subsequent Out-of-Step (OS) Condition

Model power system tests, when using a motor-generator-set, show that the Zone 1 impedance unit may overreach or respond to a reversed fault. This was attributable to motor-generator set instability following delayed clearing on an external fault. The Zone 1 relay, in all cases, identified the fault location and type correctly and responded much later to the swing condition.

Logic was added utilizing the inner blinder and Zone 1 sensing sequence, plus a 50 ms timing action (as shown in Figure 3-18a), AND-131A, AND-131B, AND-131C and OR-122A, to differentiate between a fault and a subsequent out-of-step condition. This logic will not affect normal Zone 1 trip time, nor will it affect normal out-of-step blocking.

3.4.18 Optional Single-Pole-Trip (SPT) Logic and Outputs

The logic for Single-Pole-Trip operation provides the following functions (see Figure 3-20):

- Single-pole-trip (SPT) and single-pole reclosing initiate (RI1) on single-phase-to ground faults.
- Three-pole-trip (3PT) with three-pole-reclosing initiate (RI2) on all multi-phase faults.
- Three-pole-trip with or without three-pole reclosing initiate on all faults if the functional display trip-mode selector “TTYP” is not set on the SPR or SR3R position.
- Three-pole-trip and reclosing block (RB) on unsuccessful reclosing.

- Three-pole-trip and reclosing block on “sound phase fault” (SϕF) during single-phasing.
- Three-pole-trip and reclosing block when the single phasing limit timer (62T, 300-5000,in 50 ms steps) is timed out to prevent overheating on generator(s).

When applying SPT, the functional display TTYP settings (OFF/3PR/SPR/SR3R) provide the following operating modes (in Table 3-3).

3.4.19 Oscillographic Data (Optional)

The oscillographic data has 8 samples per cycle, 1 cycle pre-trigger and 7 cycles post-trigger. It includes 16 events and 24 digital intermediate targets (test points). The data can be accessed via the communication port.

The oscillographic data is controlled by the selection of TRIP/Z2TR/Z2Z3/dVdI in the OSC function, where:

TRIP ---start data taken only if trip action occurs

Z2TR ---start data taken if Zone 2 units pick up or any trip action occurs.

Z2Z3 ---start data taken if Zone 2 or Zone 3 units pick up, or any trip action occurs.

$\Delta V \Delta I$ ---start data taken if ΔI, ΔV, Zone 2 or Zone 3 units pick up, or any trip action occurs.

NOTE: See 4.9 for dVdI setting.

3.5 PILOT SYSTEM

The MDAR functional display (see Section 4, Table 4-1, Sheet 1 of 3) Function Field “STYP” is used for pilot system selection, as follows:

- Non-pilot, 3 zone distance
- Zone 1 extension (non-pilot)
- POTT (Permissive Overreach Transfer Trip/ Simplified Unblocking).....(pilot)
- PUTT (Permissive Underreach Transfer Trip).....(pilot)
- BLK (Blocking).....(pilot)
- POTT or Simplified Unblocking Weakfeed.....(pilot)

The following settings are recommended for POTT and BLOCKING systems:

OSC	-	Z2Z3
FDAT	-	TRIP
FDGT	-	longer than 3 cycles
PLTP/PLTG	-	150% overreach the next bus
Z1P/Z1G	-	80% of the protected line
Z3P/Z3G	-	100% of the reversed line
Z3FR	-	REV

3.5.1 Permissive Overreach Transfer Trip (POTT)/Simplified Unblocking

If the functional display “STYP” is set at the POTT position, MDAR will perform either the POTT scheme or the Simplified Unblocking scheme, depending on the applied pilot channel.

The basic operating concepts of a POTT scheme are:

(1) Pilot relays (PLTP/PLTG) are set to overreach the next bus.

(2) Pilot channel is a frequency shift type device; its signal may be through either metallic wire or microwave.

3) Transmitter frequency should be different at each terminal: channel is normally operated on a guard frequency; and the channel frequency will be shifted from guard to trip when the pilot relay(s) are operated; and pilot trip is performed when the pilot relay(s) operate(s) and a pilot trip frequency signal from the remote end is received.

The basic operating concepts of a Simplified Unblocking scheme are the same as the POTT scheme, except for differences in application.

Pilot channel is a frequency-shift type power line carrier. The transmitter frequency must be different at each terminal. It is normally operated on a blocking frequency and will be shifted to an unblocking frequency when the pilot relay(s) operate(s). The carrier receiver should provide logic for which, in the event of loss-of-channel or low SNR ratio, the pilot trip circuit is automatically locked out after a short time delay. Pilot trip is provided, however, if the tripping distance relay(s) operate(s) during this short time period between loss-of-channel and pilot trip lockout. ABB type TCF-10B receiver provides this logic; it provides a 150 ms trip window, then automatic lockout after loss-of-channel. Provision for a second high-speed pilot trip is provided, for the situation when a permanent fault causes a permanent loss-of-channel and the breaker closes onto the fault.

Indication for low signal and loss-of-channel condition will not be provided for this simplified unblocking scheme. (This function would normally be incorporated in the power line carrier equipment.)

The operating concepts of the pilot distance measurement units (PLTP/PLTG) are the same as for the non-pilot zone distance measurement units, and are supervised by the same LOPB, OSB, IOM, FDOP, and FDOG, units, as shown in Figure 3-21. The pilot phase and/or pilot ground function(s) can be disabled by setting the PLTP and/or PLTG to the OUT position.

The POTT and Simplified Unblocking schemes include the following kinds of logic:

a. Tripping logic (Figure 3-22)

(1) For a forward external fault, the local pilot relay (PLTP and/or PLTG) sees the fault, operates and keys. The output from OR-40 will satisfy the first input to AND-30. Assuming that reverse block (TBM) logic does not operate and pilot enable is set, then three out of four inputs of AND-30 are satisfied, but pilot trip should not occur since the remote transmitter still sends a guard (or blocking) frequency signal.

(2) For an internal fault, the pilot relays at both ends (PLTP and/or PLTG) see the internal fault and operate; in addition, the overcurrent supervision output(s), together with the received trip (or unblocking) frequency signal CR via AND-44 (in Figure 3-23), satisfy AND-30 (in Figure 3-22). Pilot trip signal PT will be applied to OR-2 from AND-30. High speed pilot trip (HST) would be obtained. Targets of pilot phase trip (PLTP) and/or pilot ground trip (PLTG) will be turned-on after the breaker trips.

b. Carrier Keying Logic (Figure 3-23)

(1) Forward Fault Keying

For a forward internal or external fault, the local pilot relay (PLTP and/or PLTG) sees the fault and picks up, operates OR-40, AND-45, OR-18, and AND-35 if pilot enable is set, and functional display “STYP” is set at POTT position. Output signal from AND-35 will operate the reed relay (CARSND), key the local transmitter, shift the transmitting frequency from guard to trip (or from a blocking to an unblocking), to allow the remote pilot relay system to trip.

(2) Echo Keying

Since the POTT and the Simplified Unblocking schemes require the receiving of a permissive signal from the remote end, for pilot trip, provision should be made for covering the condition when the remote breaker is opened.

When the remote breaker is opened, the inputs of AND34B (Figure 3-23) will satisfy the NOT FORWARD, NOT REVERSE and 52b=1 conditions. Any carrier RCVR (CR) will produce an output from AND 34B and also a SEND signal from AND 35 via OR-18. This echo keying will be stopped by itself after 150 ms due to the input timer of AND 34B.

(3) Signal Continuation

This logic includes the signal of TRSL, 0/150 ms timer, OR-18, and AND-35. The 0/150 ms signal continuation time is required to keep the local transmitter at the trip frequency (or unblocking) for 150 ms after the local end high speed trips which includes pilot trip, Zone 1 trip, and high-set overcurrent trip, in case of sequential trip on the system. This logic will be disabled by the signal via TDT, the 0 / 300 ms timer (AND-34A) on any time delay trip operation, and will also be disabled by CIF trip (AND 49A).

c. Carrier Receiving Logic (Figure 3-23)

This logic includes OR-15 (not shown) and AND-44. Output “trip” (or unblocking) frequency signal from the carrier receiver operates the logic OR-15 and will produce a carrier trip (CR) signal from AND-44.

d. Channel Indicators (Figure 3-23)

The memorized SEND indicator will be displayed after the breaker trips and the frequency shifts to trip or unblocking by the transmitter during the fault. The memorized RCVR indicator will be displayed after the breaker trips and a carrier trip signal is received from the receiver.

e. TBM, Transient Block and Unblock Logic

For a loop system or a paralleled line application, power reversal may introduce problems to the pilot relay system especially when a 3-terminal line is involved, since the distance units may have to be set greater than 150% of ZL in order to accommodate the infeed effect from the tapped terminal. They may see the external fault on the parallel line when the third source is out of service. The transient block and unblock logic (TBM) is used to solve this problem.

There are some other typical cases of the protected line being tripped by a ground directional relay upon clearing of a fault in the adjacent (but not parallel) line. When the adjacent line breaker trips, it interrupts the current in the faulted phase as well as the load current in the unfaulted phases. Dependent on the direction of this load current, and the contact asymmetry of the breaker, there can be a short pulse of load-derived I_o with possible “tripping direction” polarity, which provides an electrical forward-torque to the ground directional relay. Therefore, it is desired to increase the security and the transient block timer (0/50) logic will be included automatically in the application if STYP=POTT is set. ***For POTT application, the Z3FR setting should be set to “REV” and Z3P, Z3G should be set to 100% of the line impedance.***

f. Channel Simulation

The test function selection provides the capability to simulate the TK switch function for keying action via OR-18 and AND-35 without the operation of pilot relay units, and to simulate the RS switch function for receiving of a trip or unblocking frequency signal action without the operation from the remote transmitter.

g. Programmable Reclosing Initiation (Figure 3-19)

The basic programmable RI application is as described in Section 3.4.14. However, on pilot systems, to activate the RI2 on any 3-pole high-speed trip, the external pilot enables switch should be ON, and the PLT and Z1RI should be set to YES. The operation will occur via the logic AND-89, AND-84 and OR-84A (as shown in Figure 3-19).

3.5.2 Permissive Underreach Transfer Trip (PUTT)

The basic operating concepts of a PUTT scheme are:

(1) Pilot relays (PLTP/PLTG) are set to overreach. The pilot channel is a frequency-shift type device, and the transmitter frequency should be different at each terminal; its signal may be passed through metallic wire or microwave.

(2) Channel is normally operated with a guard frequency, the channel frequency will be shifted from guard to trip when the Zone 1 reach relay (Z1P/Z1G) operates, and pilot trip is performed when the pilot relay (PLTP and/or PLTG) operates, together with the receiving of a carrier trip signal from the remote end.

PUTT includes the following logic: the functional display (STYP) should be set to PUTT position.

a. Pilot Tripping Logic

The Pilot Tripping Logic for the PUTT scheme is exactly the same as for the POTT scheme (Figures 3-21, 3-22).

b. Carrier Keying Logic

(1) Forward fault keying (Figure 3-24)

For a forward end zone fault, the PUTT scheme will not key except when the internal fault is within Zone 1. This means that the PUTT scheme keys only on Zone 1 faults. Keying flows via AND-46, OR-18 and AND-35.

(2) Signal continuation (Figure 3-23)

Same as for POTT scheme.

The TBM logic is not required because the carrier keying units are set underreach.

NOTE: For open breaker condition, the echo keying will not work due to lack of the “SEND” signal from the remote terminal for an end zone fault. The remote terminal relies on Zone 2 to clear the fault.

c. Programmable Reclosing Initiation (Figure 3-19)

Same as for POTT scheme.

d. Carrier Receiving Logic (Figure 3-23)

Same as for POTT scheme.

e. Channel Indicators (Figure 3-23)

Same as for POTT scheme.

3.5.3 Directional Comparison Blocking Scheme (BLK)

The basic operating concept of a Directional Comparison Blocking system (BLK) are:

(1) Pilot relays (PLTP/PLTG) are set to overreach; the Zone 3 relays (Z3P/Z3G) must be set in the reverse direction to detect the reverse external faults and for carrier start.

(2) Pilot channel is an “ON-OFF” type power line carrier. Transmitter frequency at each terminal can be the same. Channel is normally OFF until the carrier start relay senses the fault and starts the transmitter.

(3) Pilot trip is performed when the pilot relay(s) operate(s) and a carrier blocking signal is not received.

The BLK system, as shown in Figure 3-25, includes the following logic (functional display “STYP” should be set at the BLK position):

a. Tripping Logic (Figure 3-25)

(1) For a forward internal fault, the local pilot relay (PLTP and/or PLTG) sees the fault; output signal of OR-40 disables and stops the carrier start circuit (the ΔI and ΔV starts the carrier before the distance unit picks up), via OR-16, S.Q. Timer (0/150 ms) and AND-50, to prevent the local transmitter from starting. (The receiver receives the signal from both local and remote transmitters.) At the same time, output of OR-40 will satisfy one input of AND-48 and also starts the channel coordination timer (BLKT), range 0 to 98, in 2 ms steps. (See Segment 5.1.8e for BLKT setting.) After the preset time of the channel coordination timer, logic AND-47 will satisfy AND-48, if there is no received carrier signal from either remote or local on internal faults, and if the local transient block circuit (TBM) does not setup. Then AND-48 output will satisfy AND-52 and will produce pilot trip via OR-2 (Figure 3-24). Pilot trip target would be the same as for POTT.

(2) For a forward external fault, the local pilot relay (PLTP and/or PLTG) sees the fault, and operates in the same manner as for the forward internal faults. However, at the remote terminal, the carriers units ΔI/ΔV/Z3P(R)/Z3G(R)/RDOG also sees this external fault and turns-on the transmitter via OR-41, AND-51, AND-50, OR-18, and AND-35, sending a blocking signal to the other terminals. The local receiver receives the blocking signal, disables the operation of AND-47; therefore, AND-48 will produce no carrier trip signal for AND-52.

b. Carrier Keying Logic

(1) Reverse fault keying (Figure 3-25)

For a reverse fault, the ΔI and ΔV as well as the local reverse-looking relay Z3P(R)/Z3G(R) or RDOG sees the fault, operates the CARSND relay and starts the transmitter, sending a blocking signal to the other terminals.

NOTE: T**he use of ΔI and ΔV for carrier start provides more security to the blocking scheme.**

This keying circuit includes logic OR-50A, AND-50, AND-173, OR-41, AND-51, OR-18 and AND-35. The logic of AND -50B and the 32/0 ms timer circuit stops the internal fault “SEND” on a weakfeed condition. The signal of 52b to OR-16 is for disabling the “SEND” circuit when the breaker is open and line side potential is used.

Since the present keying practice on BLK system uses either the contact open (negative or positive removal keying) or contact close (positive keying) approach, a form-C dry contact output for keying is provided in MDAR.

(2) Signal continuation and TBM logic

For a reverse fault, both the local carrier start relay(s) and the remote pilot relay(s) see the fault and operate. The local carrier start relay(s) start the carrier and send a blocking signal to block the remote pilot relay from tripping. After the fault is cleared by the external breaker, the remote breaker may have a tendency to trip falsely if the carrier start unit resets faster than the pilot trip unit. The 0/50 ms timer between the OR-41 and AND-51 holds the carrier signal for 50 ms after the carrier start units have been reset for improving this problem. This logic also provides transient block and unblock (TBM) effect on power reversal.

The subsequent out-of-step condition (as described in Section 3.4.17.1), may cause the reverse looking units to fail to operate on external faults, and introduce false pilot tripping at the other end. Enhanced logic has been added to the design as shown in Figure 3-25, which includes OR-41C, 32/0 ms timer, AND-41B and OR-41. It utilizes the not FDOP (or FDOG) and LV condition (LV units set at 40 to 60 vitalist initiate the TBM circuit; and sends a blocking signal to the remote end. Set OSB to YES for supervising AND-41B when this enhanced logic is required in the application. Set WFEN to YES if this terminal may become a weakfeed condition.

(3) Internal fault preference and squelch

On a close-in fault, the carrier start unit may operate and start the transmitter. This operation may block the system from pilot tripping. The negating signal from OR-16 to AND-50 will provide an internal fault preference feature for solving this problem. The squelch 0/150 ms timer is required for improving the problem if the local breaker tripped faster than the remote breaker on an internal fault. The logic holds the carrier key circuit on the "stop" mode for 150 ms after any high speed tripping, including pilot trip, Zone 1 trip and instantaneous overcurrent trip.

c. Carrier Receiving Logic (Figure 3-25)

Carrier signal from the receiver output will be directly applied to AND-47 to disable the pilot tripping function.

d. Channel Indication (not shown in Figure 3-25)

Since the carrier channel turns "ON" for external faults only, the channel indicators (SEND and RCVR) should not be sealed-in.

e. Channel Simulation

Same as for POTT scheme.

f. Programmable Reclosing Initiation (Figure 3-19)

Same as for POTT scheme.

3.5.4 POTT or Simplified Unblocking Weakfeed (see 3.10.3)

3.6 PILOT GROUND

Pilot ground is more dependable on high resistance faults because it is supplemented with FDOG and IOM (refer to Figure 3-26).

Pilot ground is more secure on POTT/unblocking schemes on some special power system conditions, such as shown in Figure 3-27. A $\phi\phi$G fault is on the paralleled line section. Due to the system condition, fault current flows in the protected line would be I1+I2 from A to B, and Io from B to A. The operation of pilot distance relays would be a phase relay at A and a ground relay at B. The result would be erroneous directional comparison of an external fault as an "internal" one. The POTT/unblocking scheme will incorrectly trip out of the protected line.

MDAR POTT/Unblocking pilot ground unit (PLTG/FDOG) is supervised by the reverse-looking ground unit (RDOG). The "Reverse-Block" logic is as shown in Figure 3-32. At terminal A, the RDOG disables the PLTG/FDOG trip/key functions via AND-35 and AND-30. At terminal B, it will receive no carrier signal for permissive trip. The reverse-block logic also provides the conventional TBM feature to prevent false operation on power reversal. It should be noted that a "Block-the-Block" logic is also included in the circuit, as shown in Figure 3-32. The Block-the-Block logic is to prevent the Reverse-Block logic from overblocking (see the following system condition). If the breaker is unequal-pole closing on a ϕG fault, say pole-A, pole B and C close at a later time (refer to Figure 3-28). If, due to breaker contact asymmetry, the first breaker contact to close is the one of the faulted-phase, the zero-sequence (or negative sequence) polarizing voltage will initially have a polarity opposite to its fault-derived polarity, the reverse-looking ground unit could pick-up for a short period, issue a blocking order, and maintain it for 50 ms consequently, the correct tripping will be delayed. The Block-the-Block logic would prevent this delaying. The Reverse-Block logic also includes the reverse looking Z3P/Z3G units as shown in Figure 3-32.

3.7 3-ZONE DISTANCE PHASE AND GROUND WITH INDEPENDENT PILOT PHASE AND GROUND

There are four impedance units per zone: one phase-to-phase unit and three phase-to-ground units (see also Section 3.3). The following table shows the role of each distance unit per pilot zone scheme.

Distance Units			
Scheme	Z1P/Z1G	Z3P/Z3G (Reverse)	PLTP/PLTG
POTT/ UNBLOCK		----	Key/Trip
PUTT	Start Key	----	Trip
BLOCK	----	Start Key	Trip and Stop Key

NOTE: Beyond pilot logic functions, Z1P/Z1G and Z3P/Z3G perform basic Zone 1 and Zone 3 functions.

3.8 INVERSE TIME DIRECTIONAL OR NON-DIRECTIONAL (SELECTABLE) OVERCURRENT GROUND BACKUP.

(See Section 3.4.2)

3.9 INSTANTANEOUS FORWARD DIRECTIONAL OVERCURRENT FUNCTION FOR HIGH RESISTANCE GROUND FAULT SUPPLEMENT TO OVERREACH PILOT.

Supplemental protection is provided on overreaching pilot systems to detect high resistance ground faults. The instantaneous forward directional overcurrent ground function (FDOG) works in conjunction with the pilot ground distance unit. The FDOG directional unit is determined by the setting of DIRU (ZSEQ/NSEQ/DUAL). Refer to Section 3.4.11 for the setting of DIRU. FDOG is supervised by the Iom setting. A coordination timer FDGT (T/0) is provided to allow preference for pilot ground distance (mho) unit operation. The delay time (T) can be set from 0 to 15 cycles in 1 cycle steps. It is recommended to set the FDGT timer to 3 cycles or longer for security reasons.

3.10 INSTANTANEOUS REVERSE DIRECTIONAL OVERCURRENT GROUND FUNCTION.

Similar to FDOG, the instantaneous reverse directional overcurrent ground function (RDOG) supplements the pilot zone logic.

3.10.1 Supplement to Reverse Z3G Trip.

In the blocking system, RDOG, supervised by IOS, provides additional ground fault detection (high resistance) beyond what is available by Z3G (reverse looking) for carrier start.

3.10.2 Carrier Ground Start on Blocking Scheme

In the POTT/UNBLOCK systems, RDOG supervises PLTG and prevents keying or tripping on reverse faults.

3.10.3 Weakfeed System Application

For weakfeed applications, an inherent part of the logic requires reverse fault detection; Z3P/Z3G and RDOG supply this requirement.

3.11 LOSS-OF-POTENTIAL SUPERVISION (LOP, See Section 3.4.3)

3.12 LOSS-OF-CURRENT MONITORING (LOI, See Section 3.4.4)

3.13 OVERCURRENT SUPERVISION (See Section 3.4.5)

3.14 INSTANTANEOUS OVERCURRENT TRIP (See Section 3.4.6)

3.15 HIGH-SET INSTANTANEOUS DIRECT TRIP, INCLUDING THREE-PHASE AND ONE GROUND OVERCURRENT UNITS FOR SPT/3PT APPLICATION (See Section 3.4.6)

3.16 CLOSE-INTO-FAULT TRIP AND STUB BUS PROTECTION (See Section 3.4.7)

3.17 UNEQUAL-POLE CLOSING LOAD PICKUP LOGIC (See Section 3.4.8)

3.18 SELECTABLE LOSS-OF-LOAD ACCELERATED TRIP LOGIC (LLT) (See Section 3.4.9)

3.19 CURRENT CHANGE FAULT DETECTOR (See Section 3.4.10)

3.20 VOLTAGE CHANGE FAULT DETECTOR (See Section 3.4.10)

3.21 3-TERMINAL LINE APPLICATION

For a 3-terminal BLK application, since the frequency of the three transmitters are the same, any one transmitter starting will block the pilot system from tripping, therefore, logic for the 3-terminal BLK pilot system would be the same as that used for the 2-terminal BLK system. However, for POTT/PUTT/UBLK systems, since the transmitter frequency is different at each terminal, logic for the second receiver (RCVR-2) should be added to the system when the application involves 3-terminals. Functional display “3TRM” should be set at “YES” position when the 3-terminal line is applied.

a. Additional Logic For POTT and Simplified Unblocking (Figure 3-29)

This logic includes contact converters (CC) for RCVR-2, AND-55, and logic for the second receive indication. The second receiver output operates the contact converter (or voltage). Output of AND-55 provides carrier trip signal (CR) to satisfy AND-30 via AND-64 and allows pilot tripping.

b. Additional Logic for PUTT (Figure 3-30)

The additional logic for this scheme would be similar to that as described for POTT scheme, except logic includes AND-56, AND-57 and 50/ms timer. This is because only the Zone 1 reach relay keys the transmitter on internal faults. For a close-in Zone 1 fault, only the local terminal can key its transmitter and the other two cannot. This logic provides a CR pilot trip signal for 50 ms for system security. For a fault which can be detected by relays at two terminals, AND-55 logic can be satisfied, then pilot trip will be performed via the logic in the usual way.

3.22 WEAKFEED TRIP APPLICATION

a. Block/Weakfeed

The logic for a weakfeed terminal is not required for the BLK system because the BLK system requires no permissive trip signal from the remote end, even though the remote end is a weakfeed terminal. The strong end has no problem tripping for an internal fault. The weak end is usually assumed either as a “no feed” source, for which it does not need to trip on an internal fault, or it can pilot trip sequentially.

NOTE: Refer to Figure 3-25, logic AND-41B and OR-41C, WFEN should be set to YES if OSB is set to YES and this terminal may become a weak condition.

For the bench test, at the conditions of V = 0 and I = 0, the carrier keying contacts will be closed for the settings of OSB = YES and WFEN = NO. In an actual system, 52b will be applied to OR41C, because of V = 0 and I = 0, and the carrier keying signal will not be sent.

b. PUTT/Weakfeed

The logic for a weakfeed terminal is not required for the PUTT system. Because the PUTT system uses underreaching relay(s) only for pilot trip keying, it is impossible to apply this scheme to protect a system which may have weakfeed condition.

c. POTT/ Weakfeed

For POTT and unblocking schemes, at the weak source terminal, the Z3P/Z3G distance relays should be set for reverse-looking, and the undervoltage units (LVA, LVB, LVC) should be used. The basic operating principle of the weakfeed trip logic for the POTT and simplified unblocking scheme is as follows:

(1) Echo key for trip permission (Figure 3-31)

On internal faults, the strong source end sends the trip (or unblocking) frequency signal to the weak end, and its pilot trip relay(s) will trip, once it receives echo trip permission from the weak end. The pilot trip relay(s) at the weak end cannot pick up due to not enough internal fault energy, and does not perform the normal keying function. With one weakfeed condition, when the weak end receives a trip or unblocking signal, the output from the receiver operates the echo key logic AND-65, providing both pilot relay (from OR-40) and reverse-looking relay (from OR-41) do not pick-up, and if system disturbance is detected (ΔV or ΔI). Output of AND-65 will key the weak terminal transmitter to the trip or unblocking frequency via OR-18, AND-35. On weak end reverse external fault, the strong source end sends the trip (or unblocking) frequency signal to the weak end, and its pilot trip relay(s) is waiting to receive the echo trip permission from the weak end. However, at the weak end, the echo key logic AND-65 will not operate, and because of the reverse looking relay operation, it sends no echo signal to the strong end. Both the strong/weak ends will not trip on this external fault.

(2) Weak end trip on internal fault (Figure 3-31)

The output of AND-65 (start echo keying) together with no output from OR-40 (pilot trip relays), and with output from OR-44 (low voltage condition) will satisfy AND-66; weak-feed trip will be performed after 50 ms via OR-2. The timer delay is for coordination because the voltage trip units are non-directional.

3.23 LOGIC FOR RB ON BF SQUELCH

For a pilot system, the BFI signal can be used to stop (for a blocking system) or start (for permissive schemes) the carrier channel and allow the remote terminal to trip should the local breaker fail to trip. The problem is how to inhibit the remote terminal from reclosing.

MDAR solves this problem by the RB on BF squelch logic in the RI/RB software. This logic is as shown in Figure 3-19, which includes AND-61A and a 132/0 ms timer. The logic will initiate RB at 132 ms (about 8 cycles) after the fault is detected by DI or DV, if the pilot is enabled and the TRSL signal is received on any 3-pole high speed trip operation (Zone 1 trip, pilot trip or high set trip).

3.24 OPTIONAL OUT-OF-STEP (OOS) LOGIC (Refer to Section 3.4.17.1)

3.25 OPTIONAL SINGLE-POLE TRIP (SPT) LOGIC AND OUTPUTS (Refer to Section 3.4.18)

In addition to the foregoing features and options, the MDAR Pilot Zone system includes many of the same special functions as the Non-Pilot system, i.e.:

- RS-232C port (See Sections 4.3 and 4.7).
- Line voltage, current and phase angle monitor (See Section 4.4.2).
- Reclosing initiation and reclose block outputs. Refer to Section 5.3 for RI Guidance, except set the relay to PLT = YES and apply a rated voltage to PLT/ENABL terminals TB5/9(+) and TB5/10(-).
- Fault Locator function, and current change fault detector (See Section 1.5).
- Self-check function (See Section 1.6).

3.26 MDAR Ordering Information

The MDAR equipment is identified by the Catalog Number on the MDAR nameplate which can be decoded by using Table 3-1.

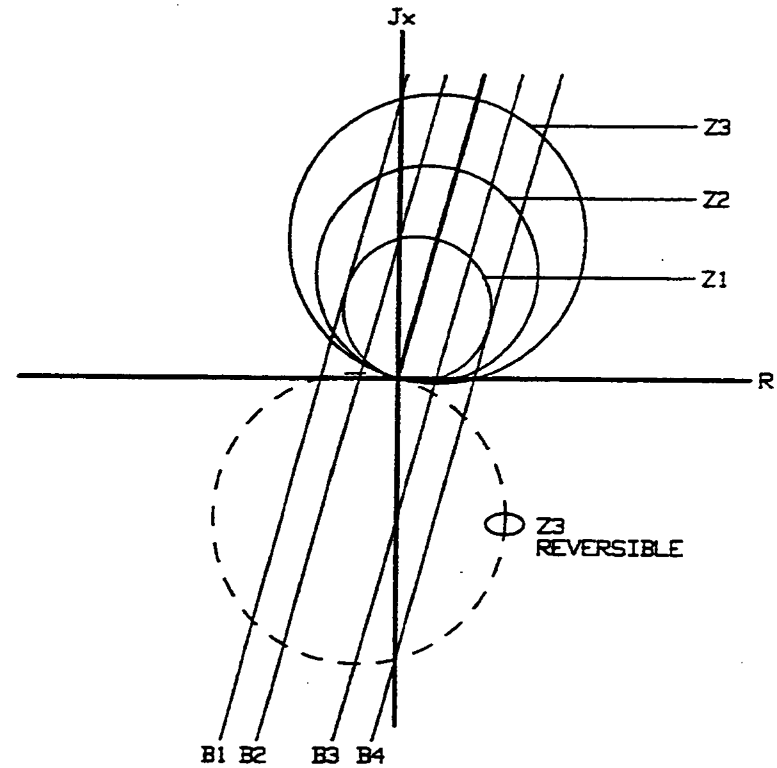
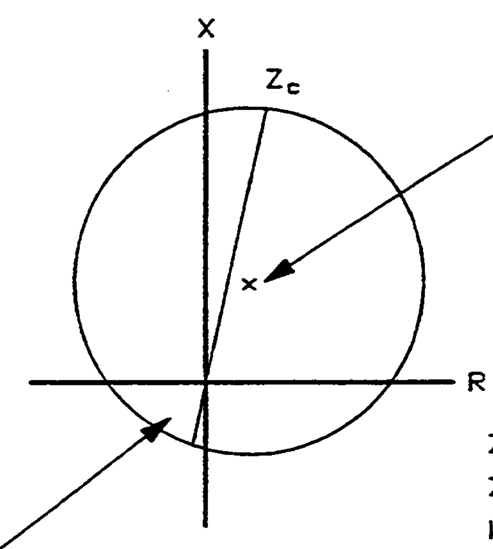


Figure 3-1. MDAR Characteristics/R-X Diagram.



CENTER =

$$\frac{1}{2}\left\{ Z_c - \frac{Z_s}{2k_1 + \frac{Z_{0L}}{Z_{1L}} k_0 + \frac{I_L}{I_F}} \right\}$$

OFFSET=

$$\frac{Z_s}{2k_1 + \frac{Z_{0L}}{Z_{1L}} k_0 + \frac{I_L}{I_F}}$$

Z_C = SETTING IMPEDANCE
Z_S = SOURCE IMPEDANCE
k_1 = POS. SEQ. CURRENT DISTR. FACTOR
k_0 = ZERO SEQ. CURRENT DISTR. FACTOR
z_{0L} = POS. SEQ. LINE IMPEDANCE
z_{1L} = ZERO SEQ. LINE IMPEDANCE
I_L = PREFAULT LOAD CURRENT
I_F = FAULT CURRENT

Sub 1
9654A13

Figure 3-2. Mho Characteristic for Phase-to-Ground Faults.

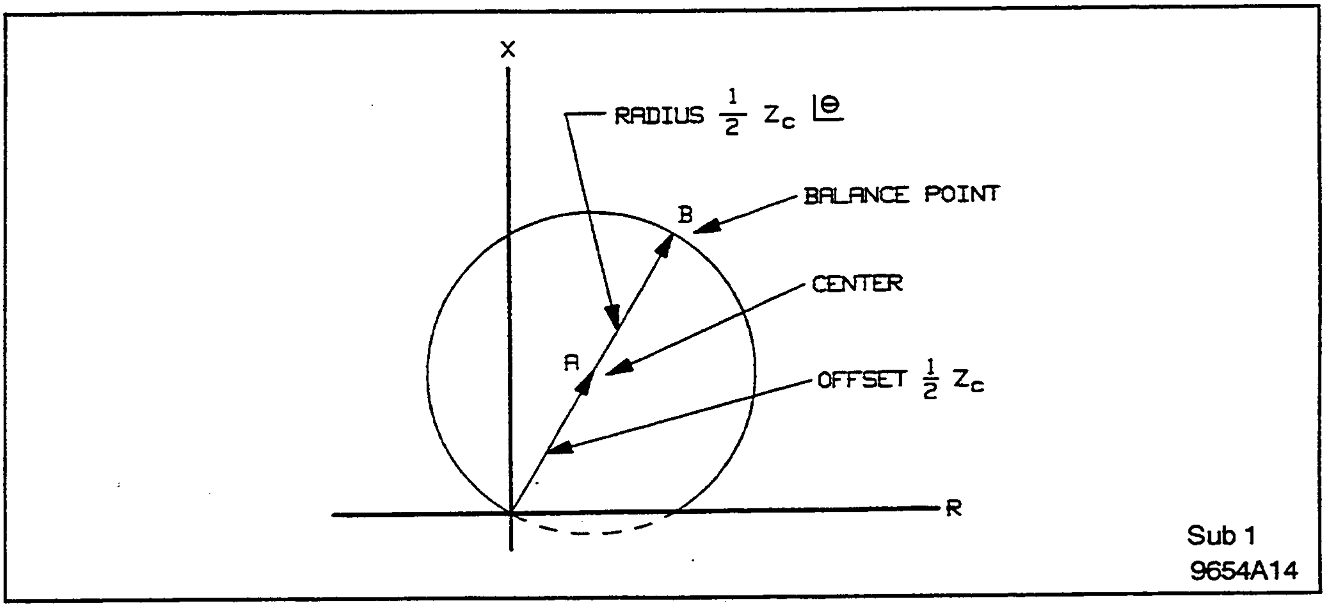


Figure 3-3. Mho Characteristics for Three-Phase Faults (No Load Flow).

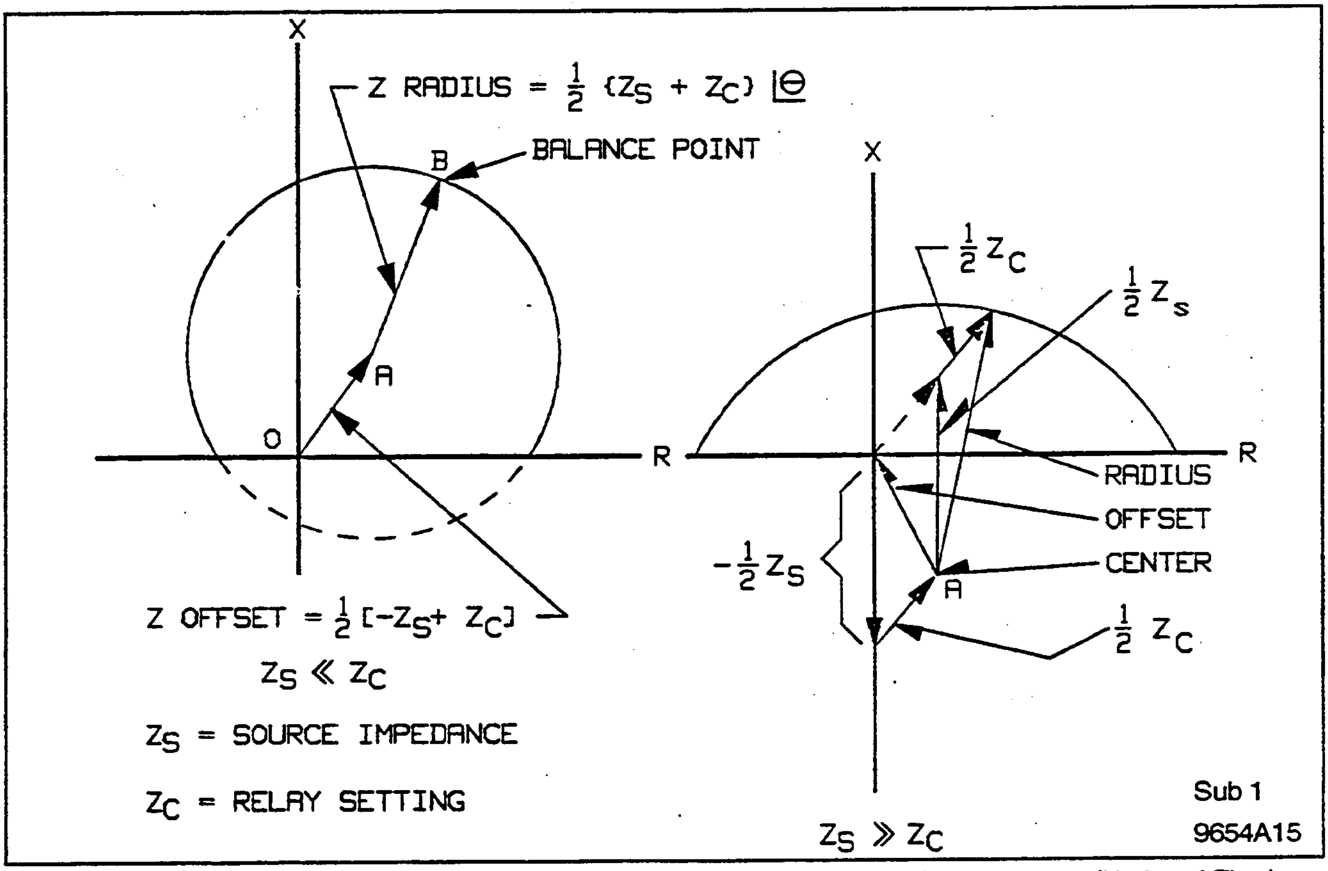


Figure 3-4. Mho Characteristics for Phase-to-Phase and Two Phase-to-Ground Faults (No Load Flow).

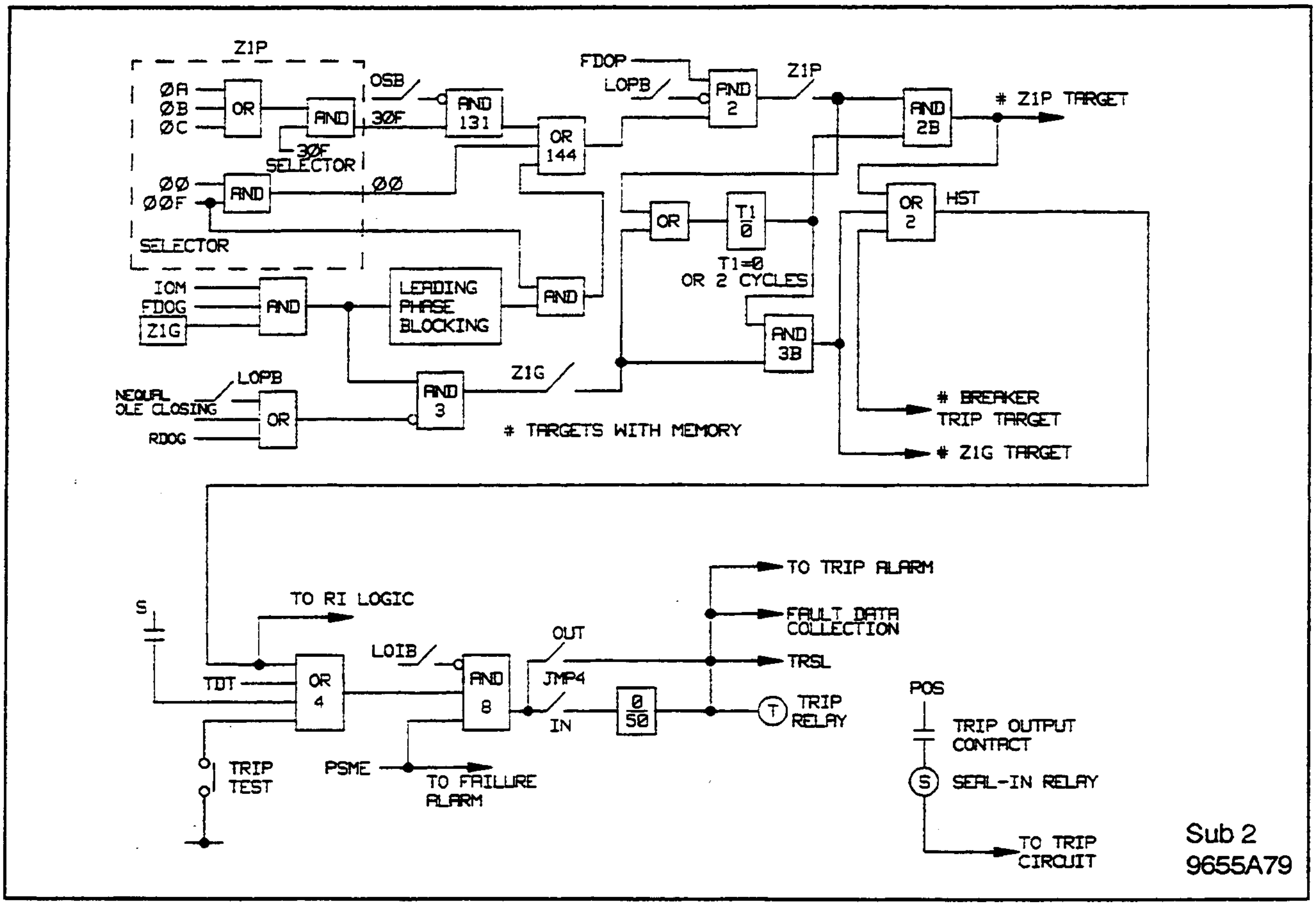


Figure 3-5. MDAR Zone 1 Trip Logic.

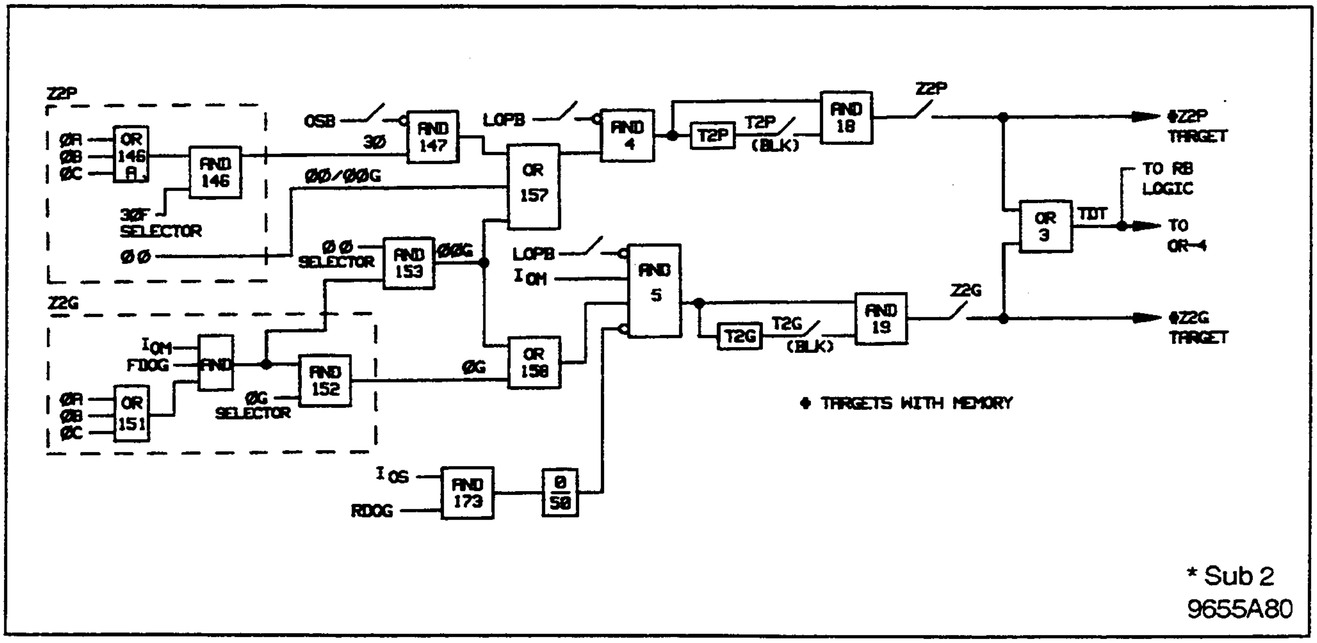


Figure 3-6. MDAR Zone 2 Trip Logic.

* Denotes changed

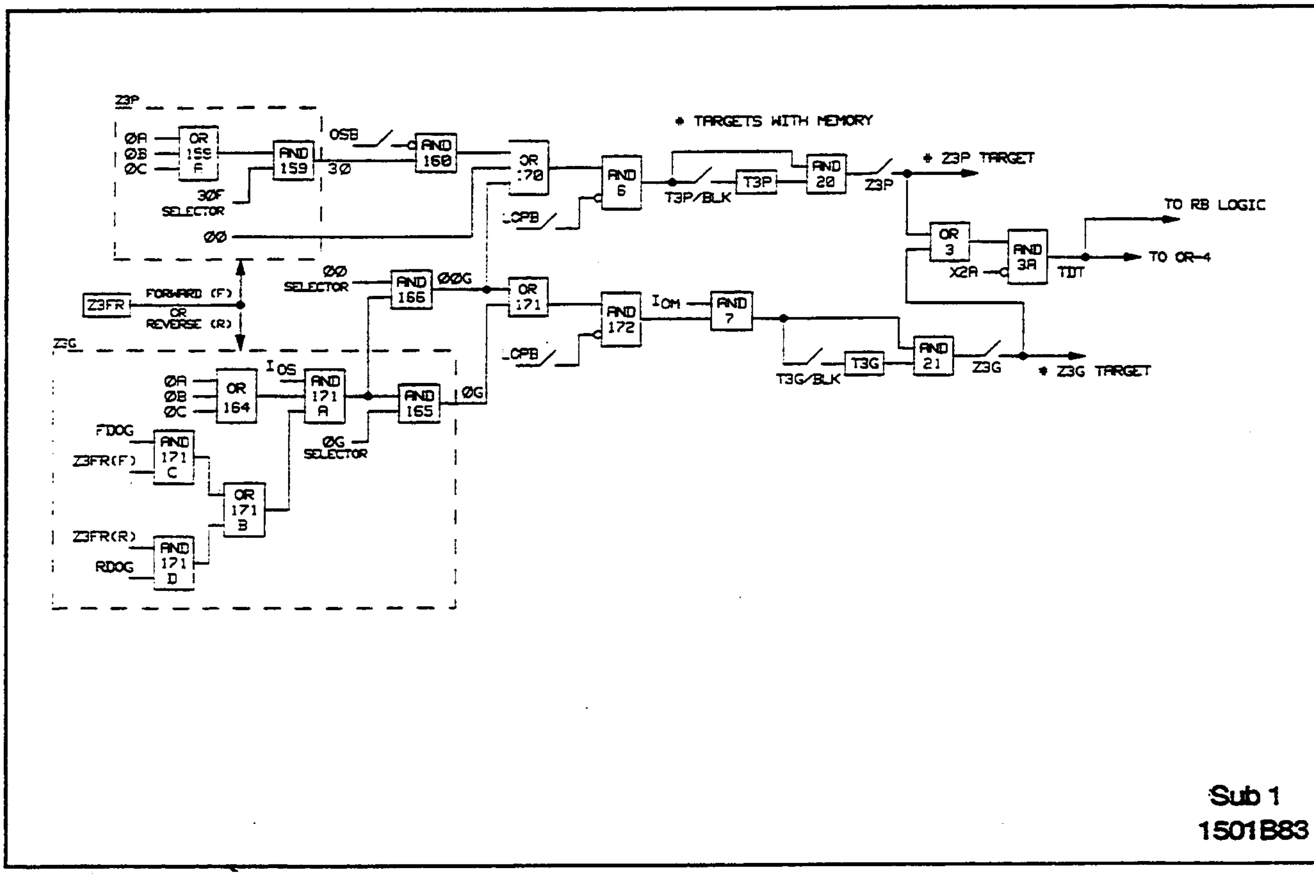


Figure 3-7. MDAR Zone 3 Trip Logic.

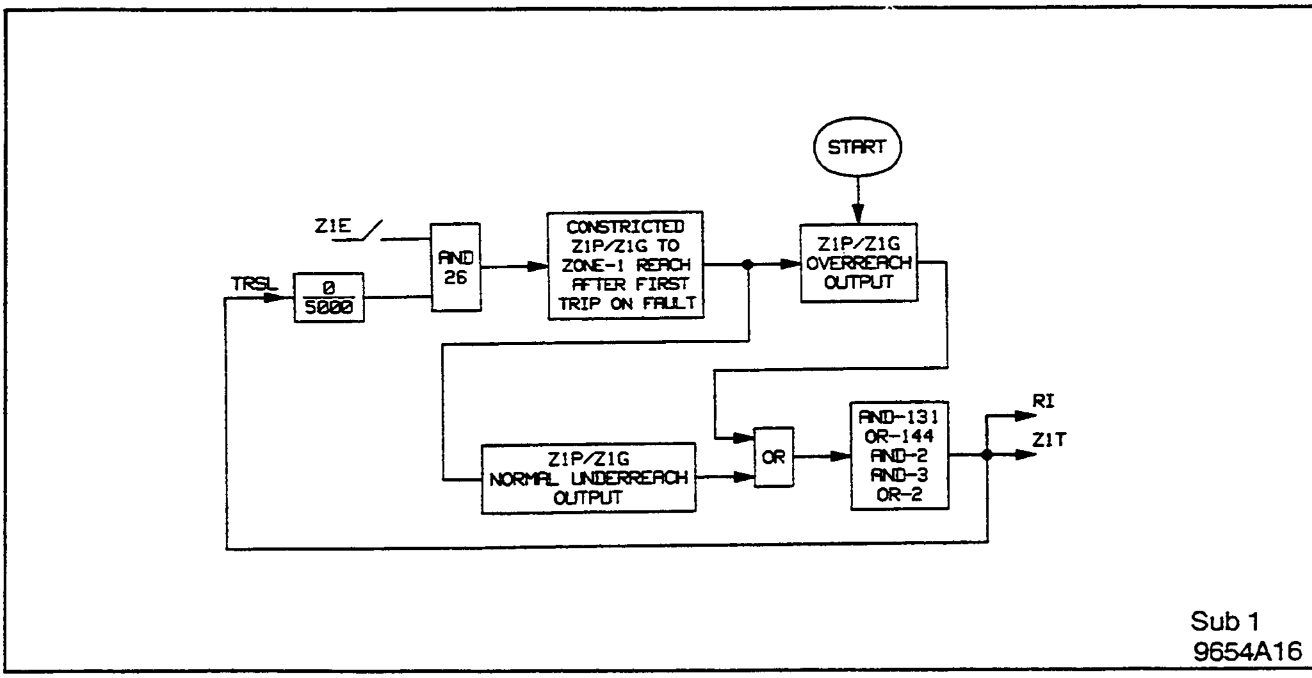


Figure 3-8. MDAR Zone 1 Extension Scheme.

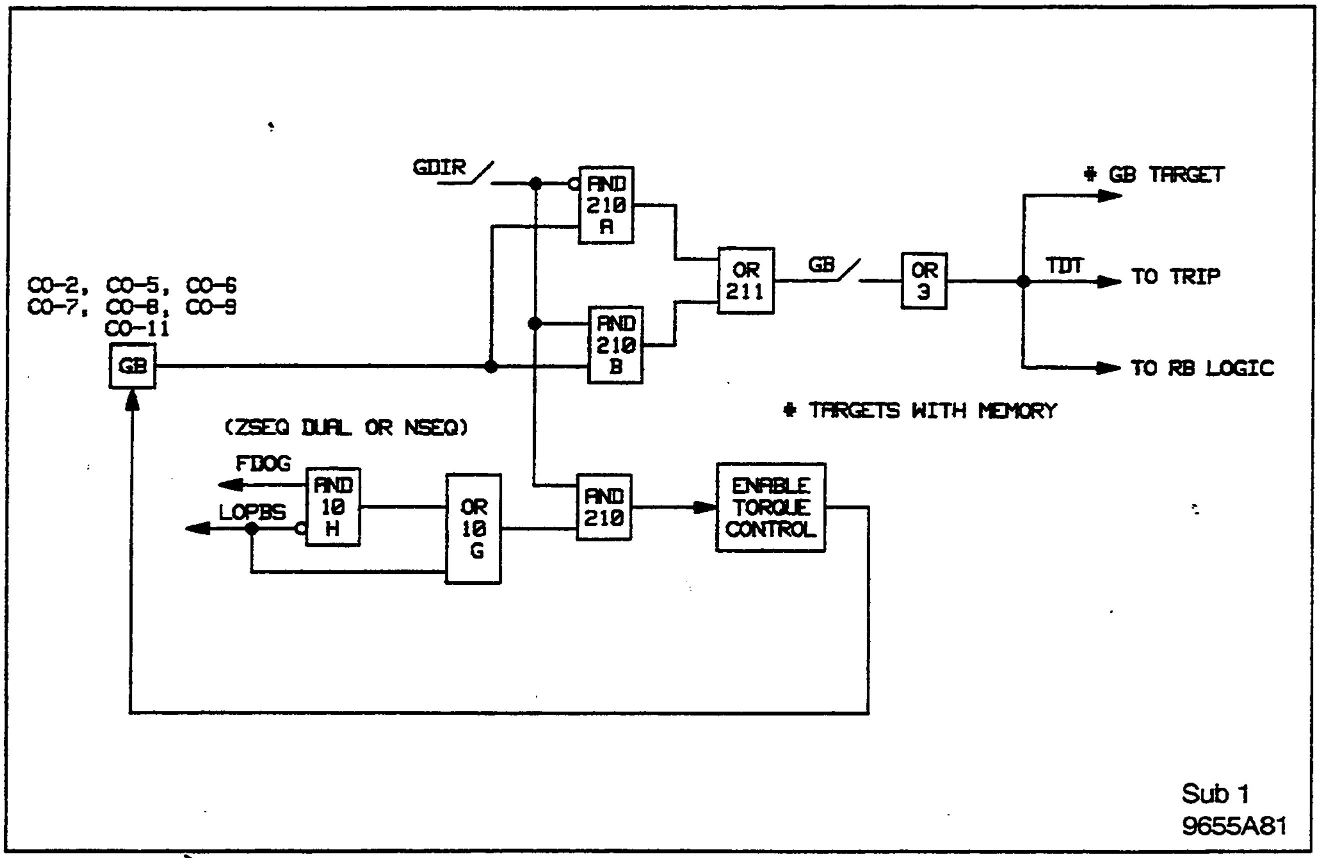


Figure 3-9. Inverse Time Overcurrent Ground Backup Logic.

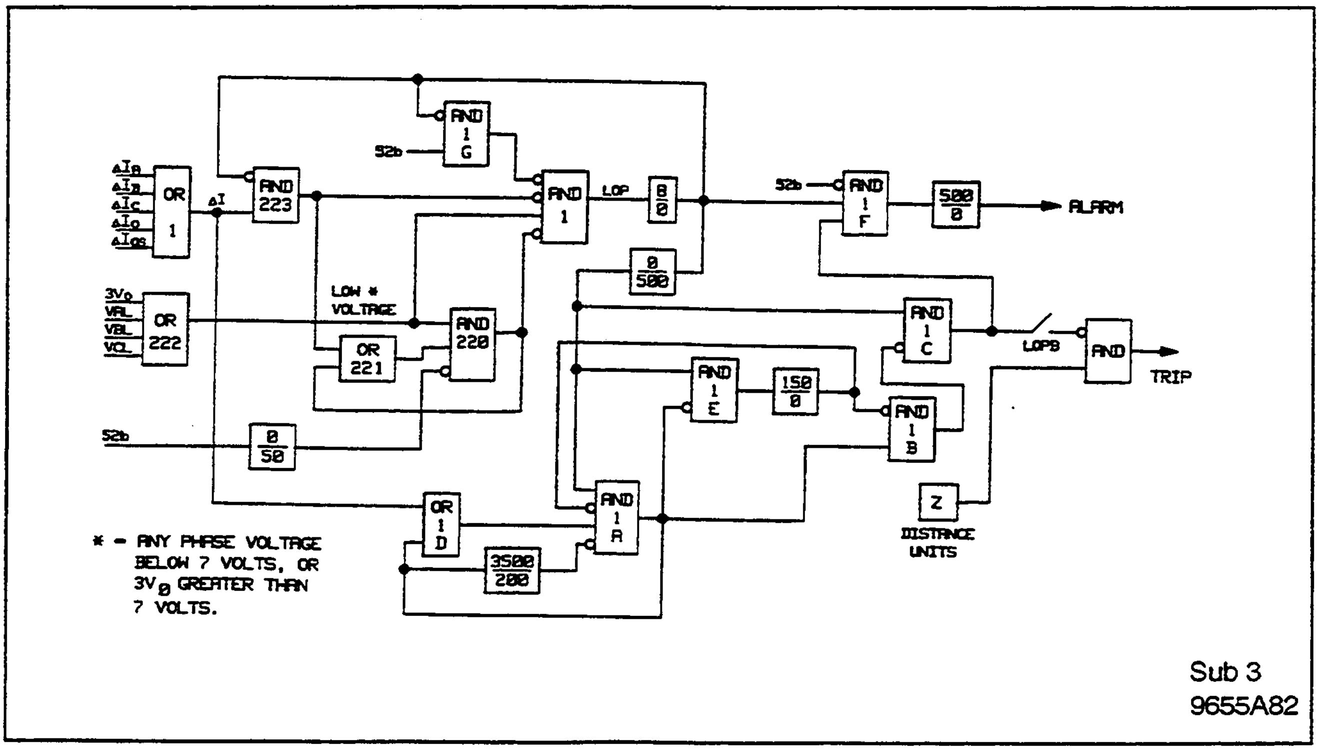


Figure 3-10. Loss-of-Potential Logic.

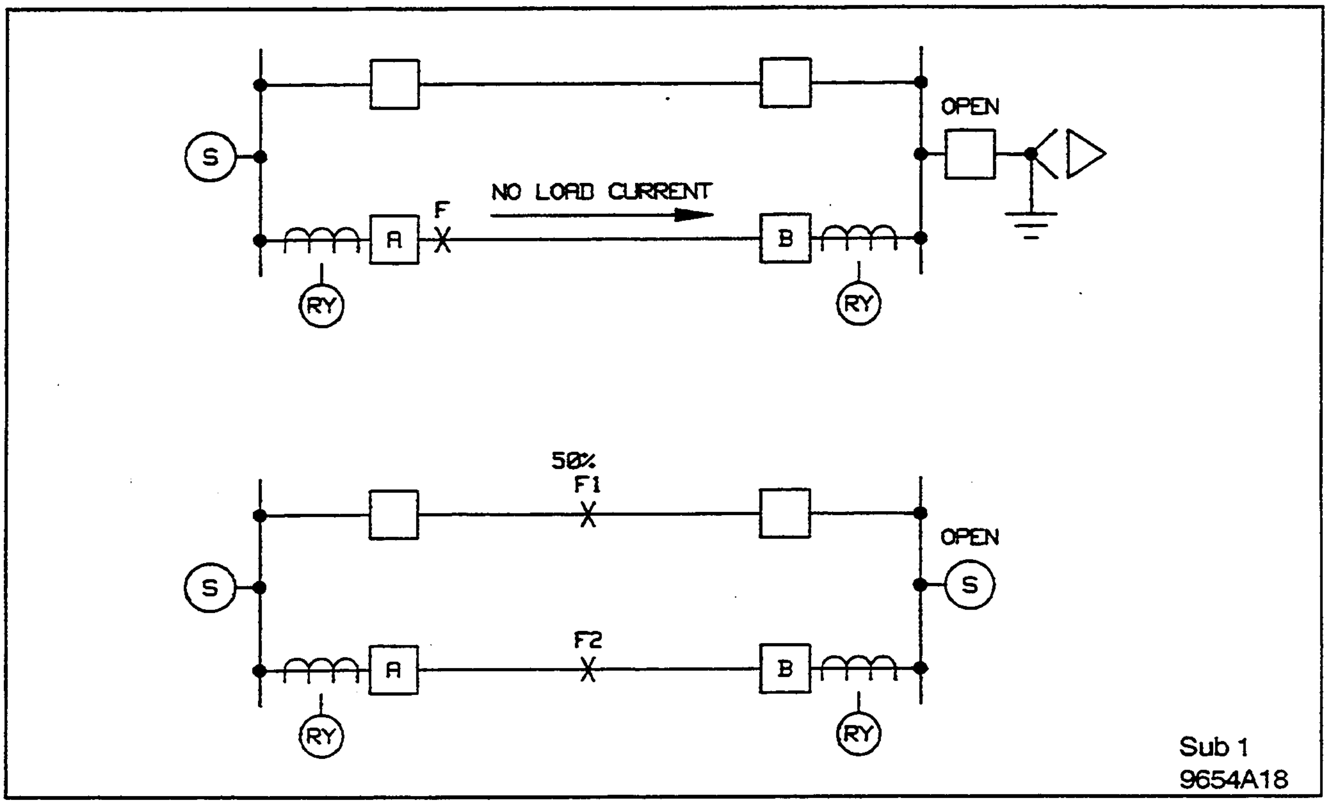


Figure 3-11. Loss of Potential Logic (System Diagram).

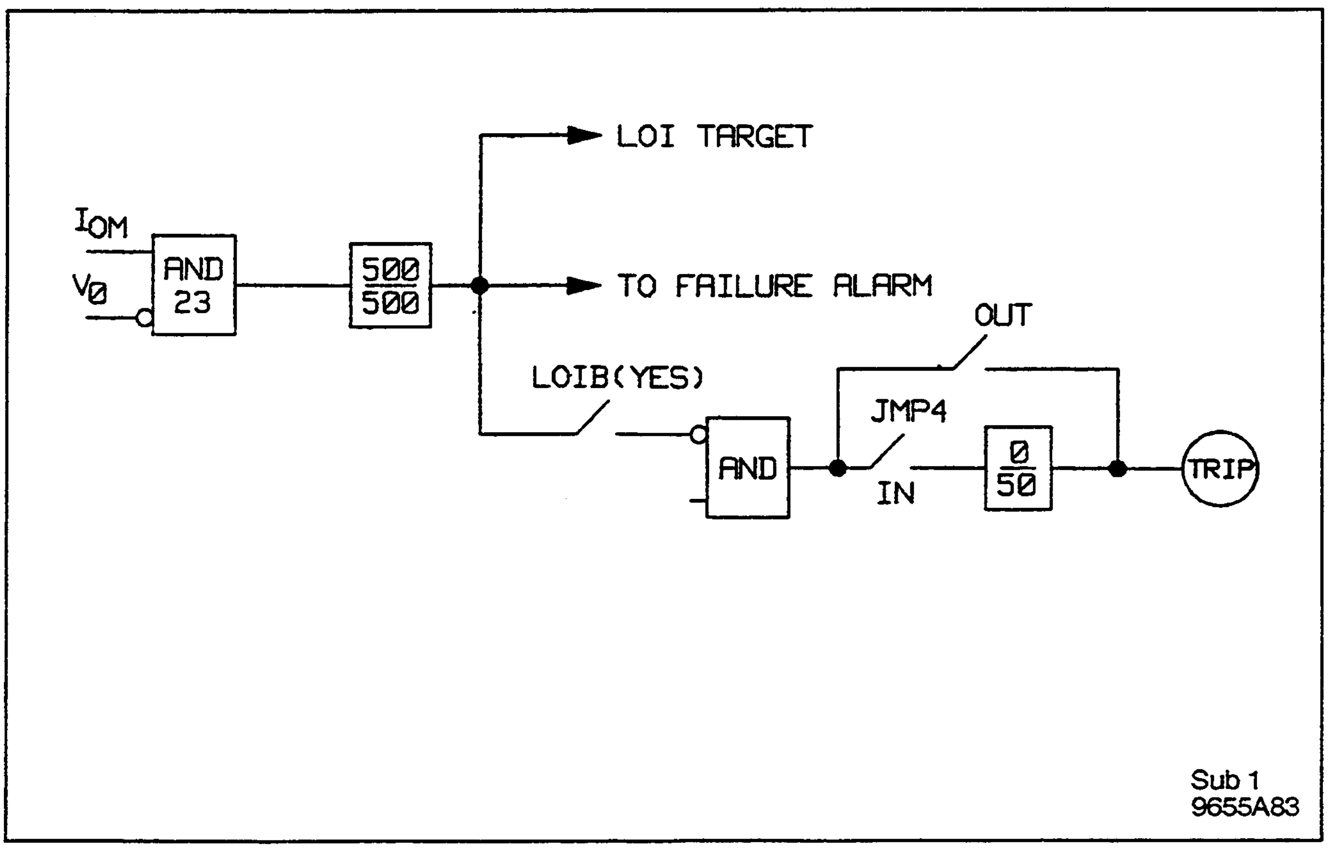
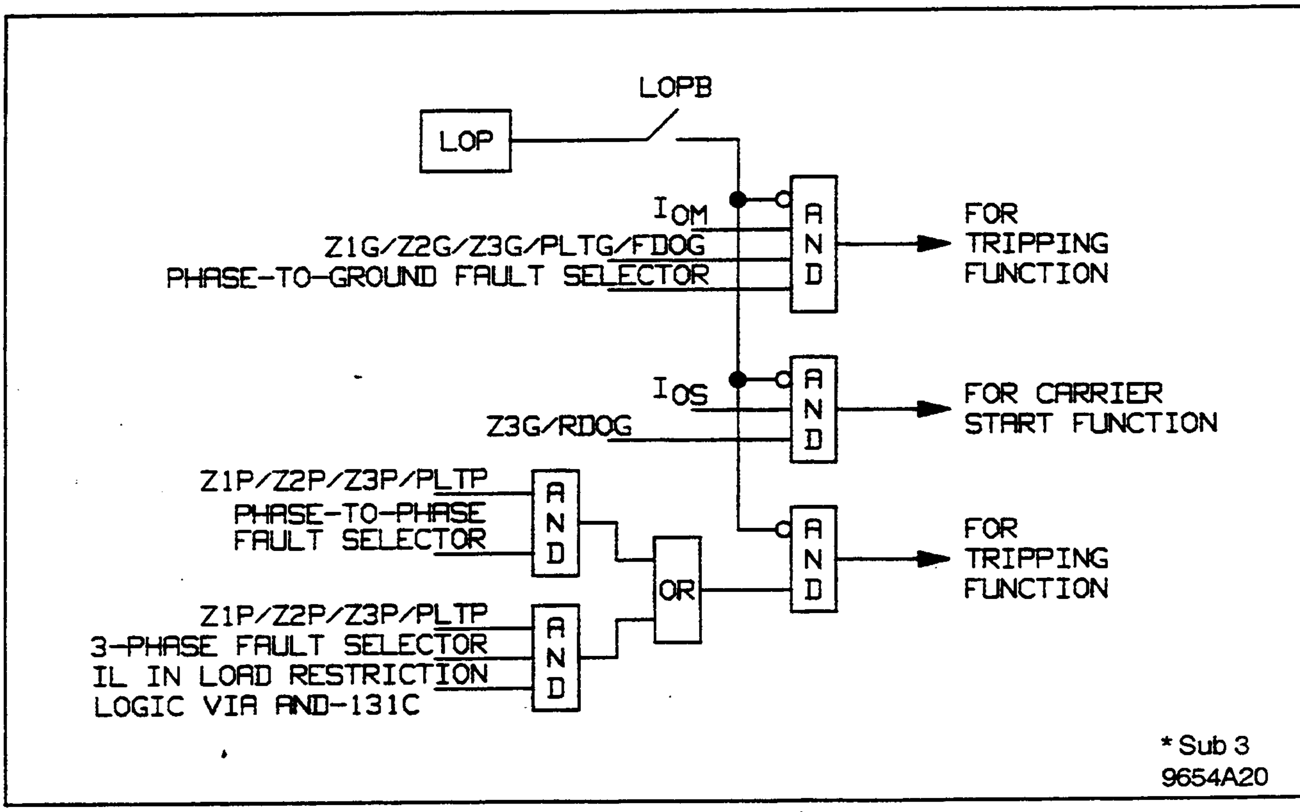


Figure 3-12. AC Current Monitoring Logic.



* Denotes change

Figure 3-13. Overcurrent Supervision.

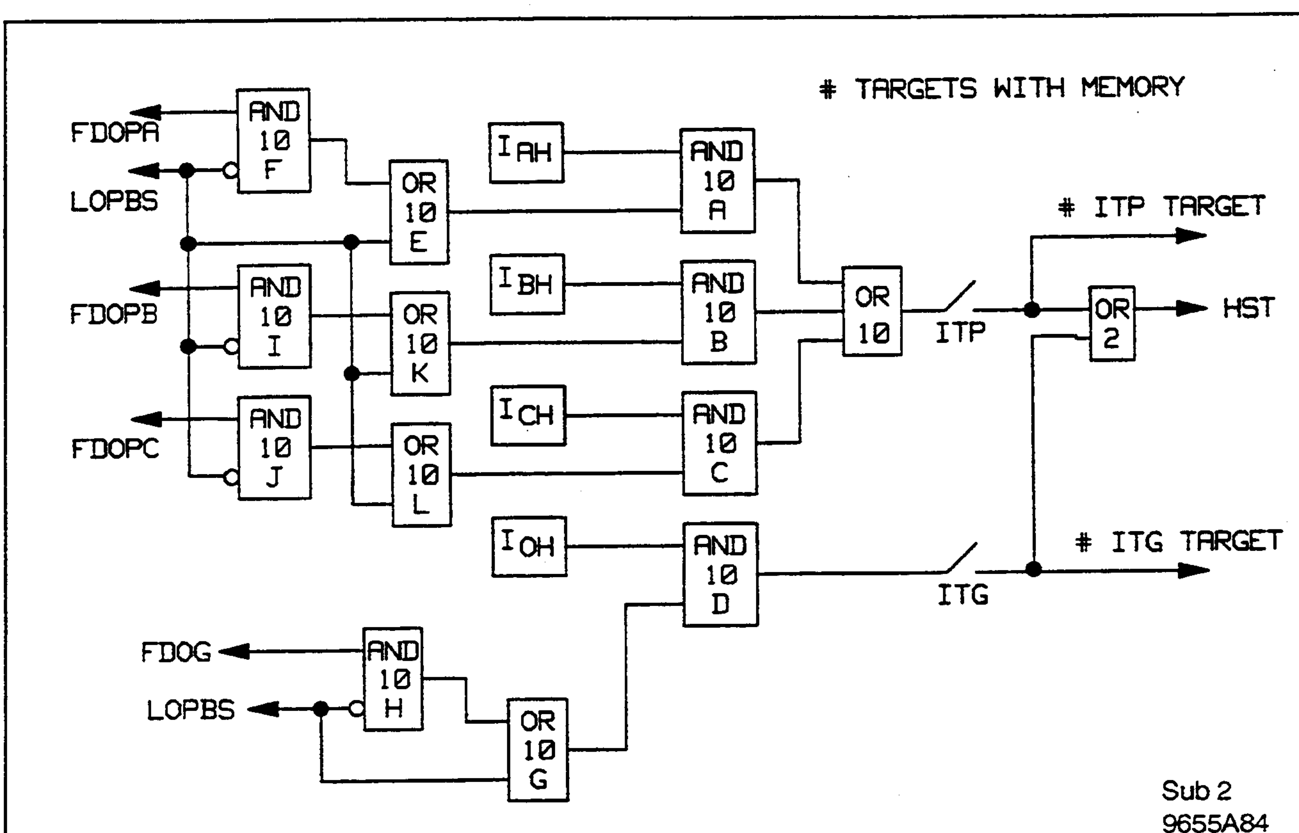


Figure 3-14. Instantaneous Overcurrent Highset Trip Logic.

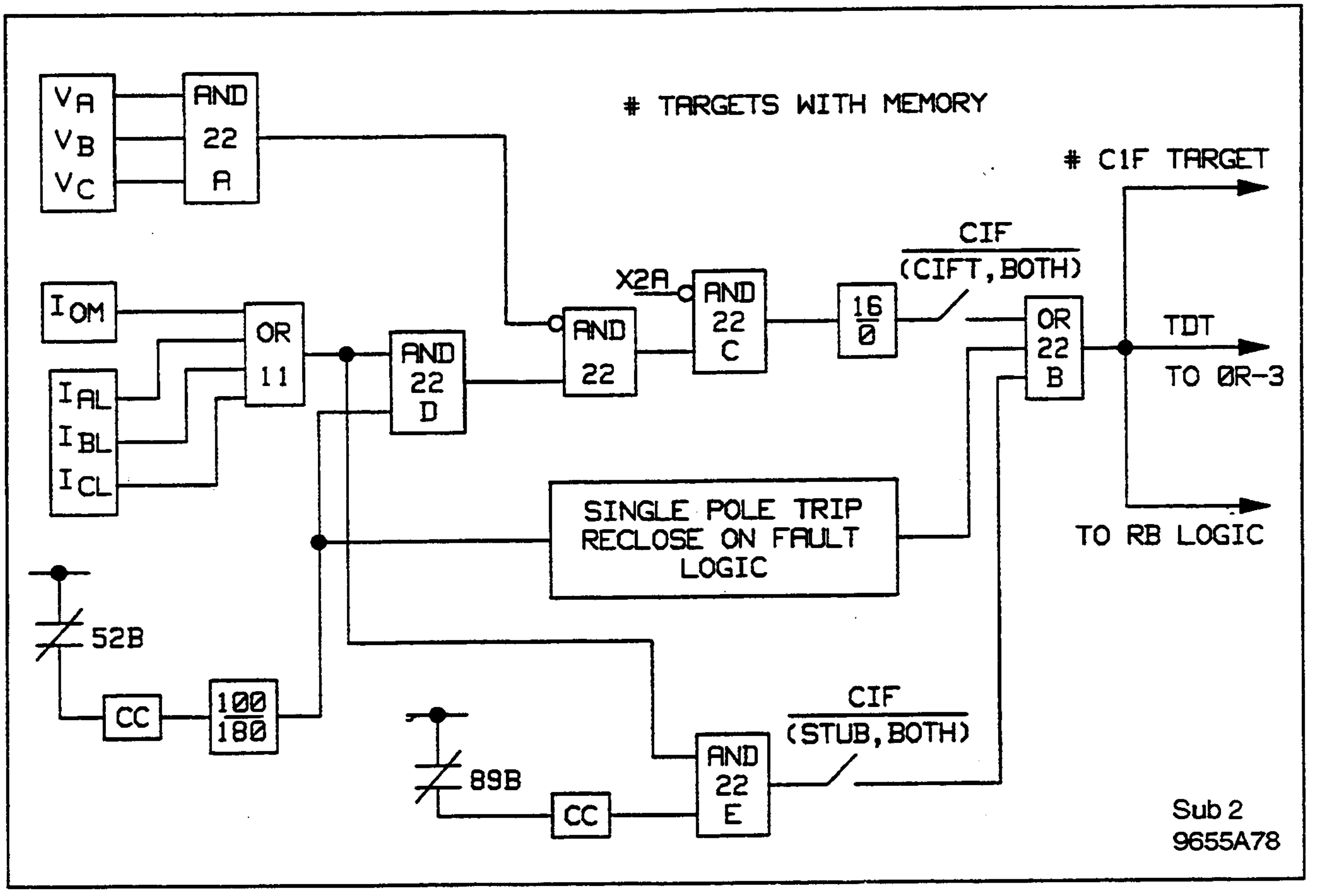


Figure 3-15. MDAR Close-Into-Fault Trip (CIFT) and Stub Bus Protection Logic.

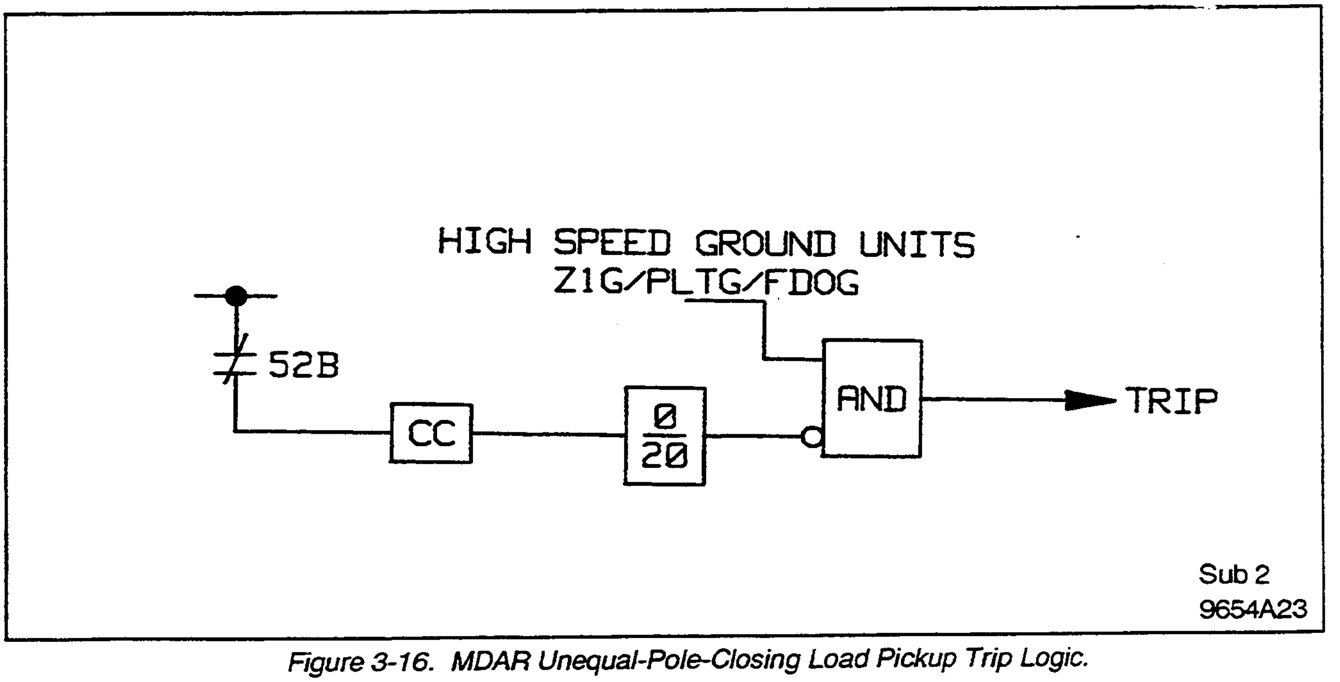


Figure 3-16. MDAR Unequal-Pole-Closing Load Pickup Trip Logic.

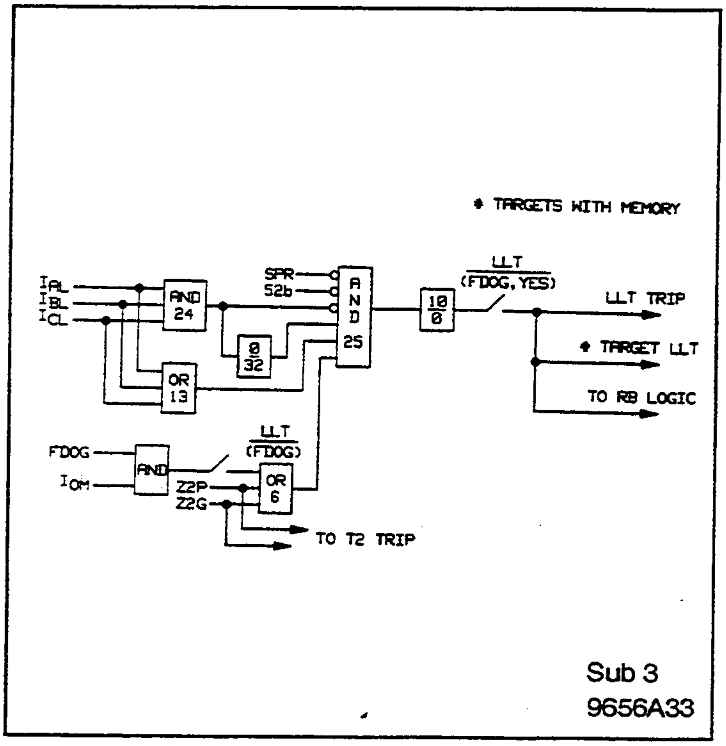


Figure 3-17. Load Loss Accelerated Trip Logic.

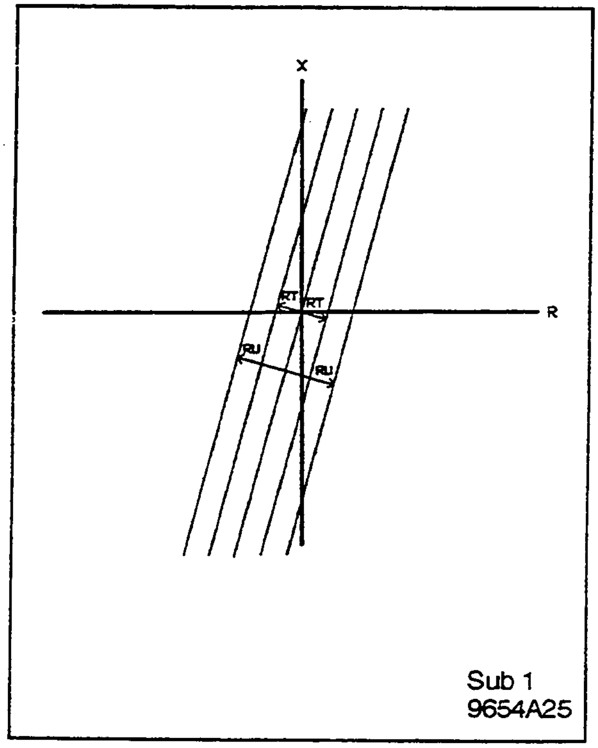


Figure 3-18b. Out-of-Step Block Logic (Blinder Characteristics).

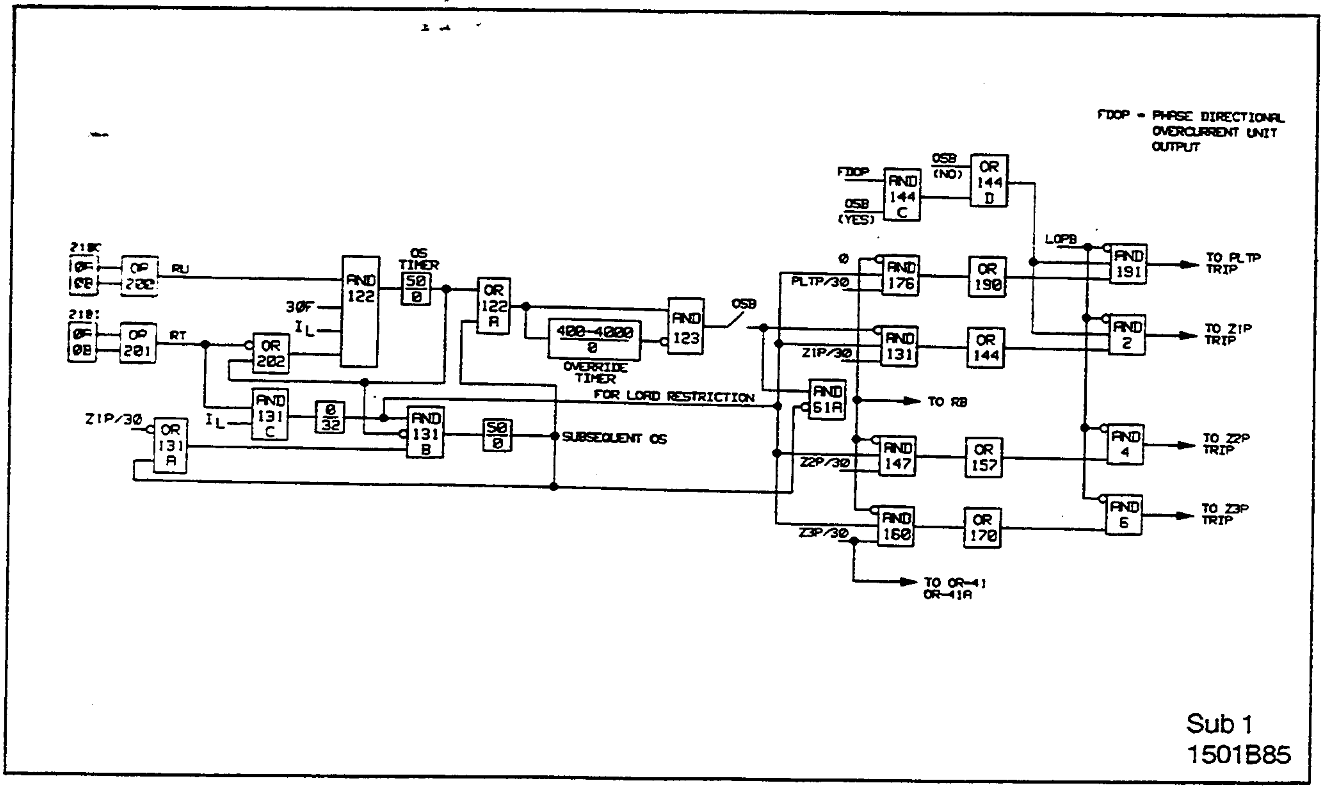
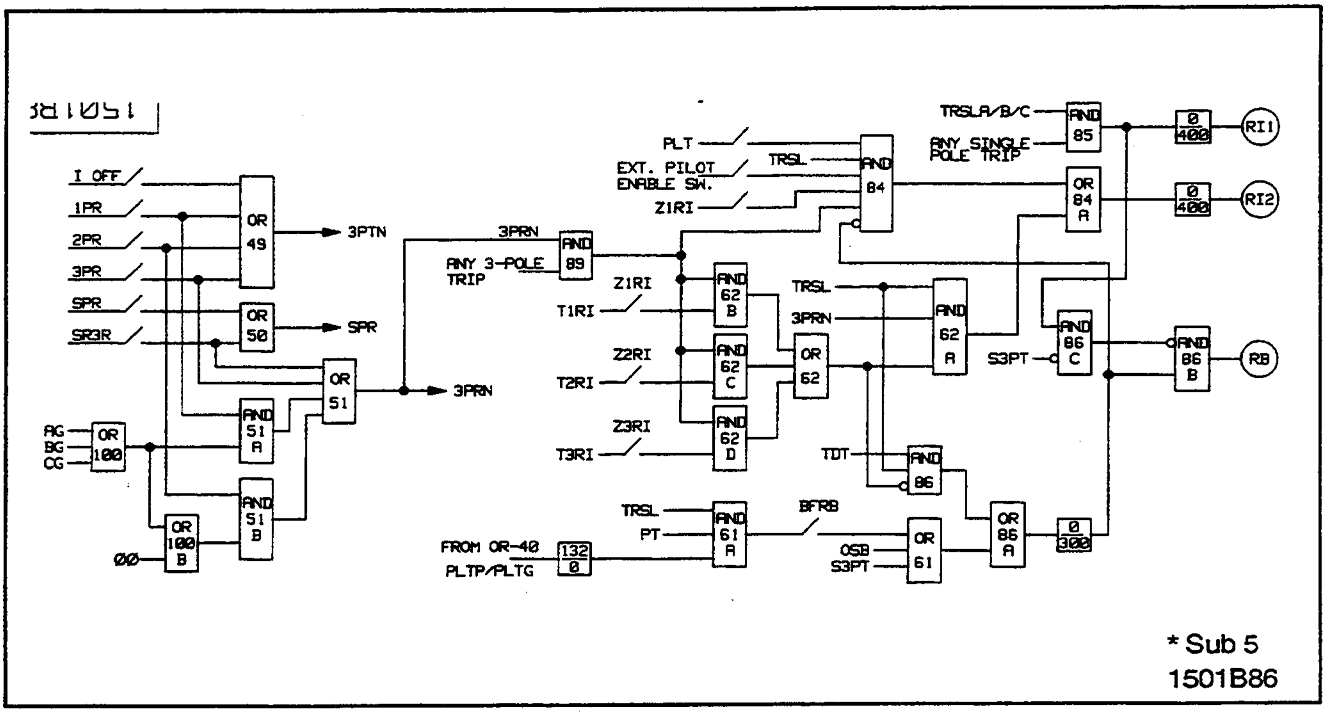


Figure 3-18a. Out-of-Step Block Logic.



* Denotes Change

Figure 3-19. Reclosing Initiation Logic.

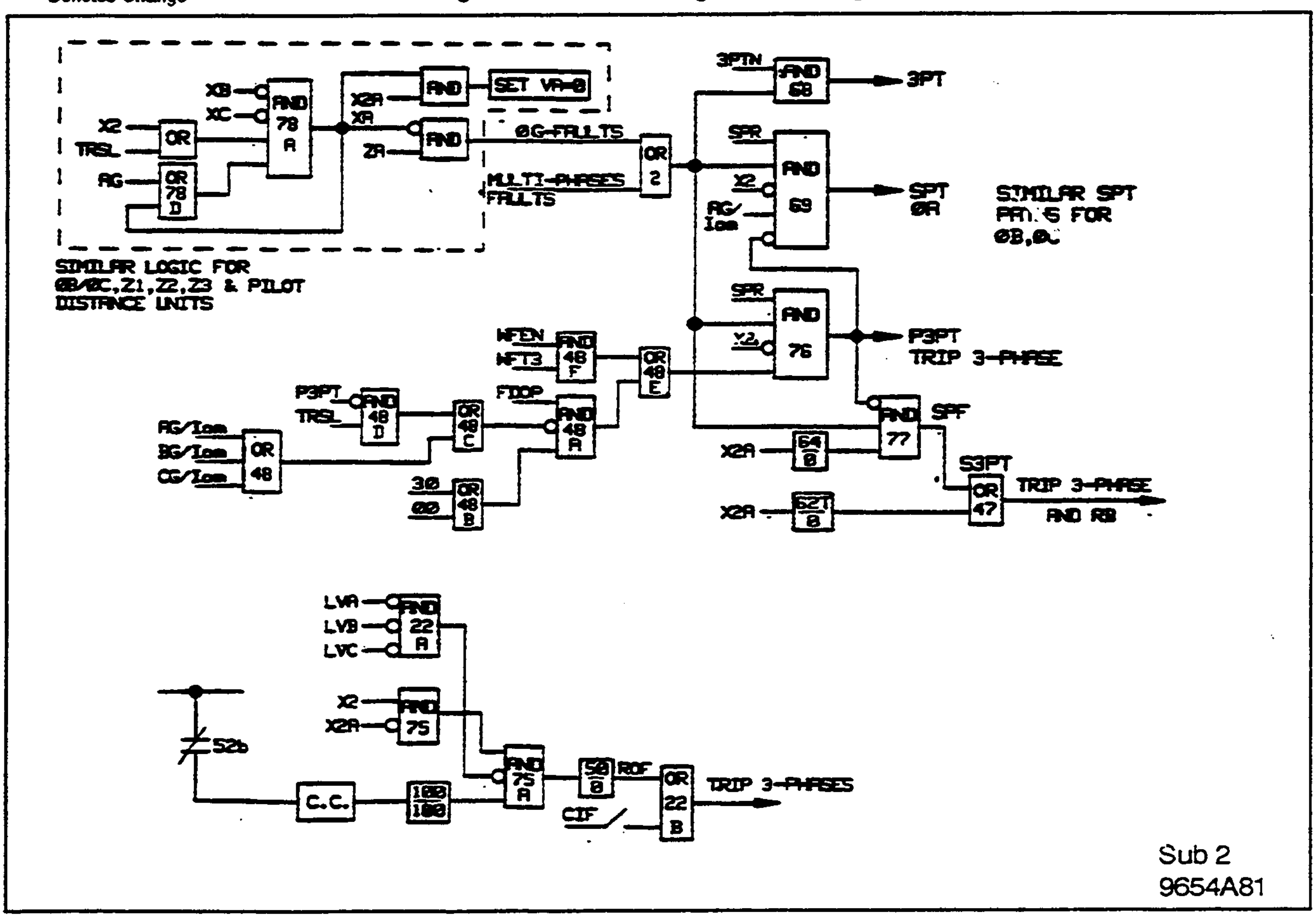


Figure 3-20. Single Pole Trip Logic.

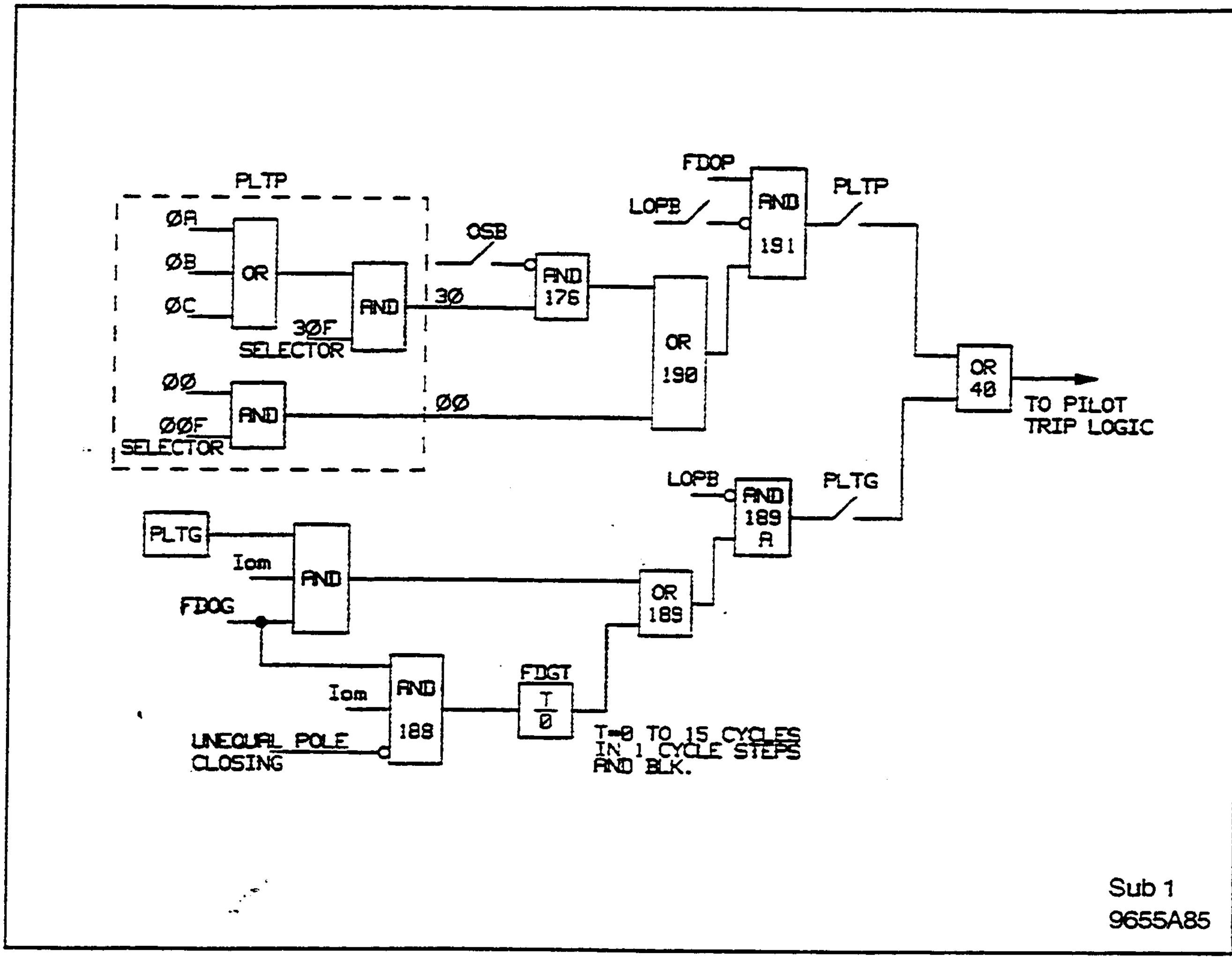


Figure 3-21. POTT/Unblocking Pilot Relay.

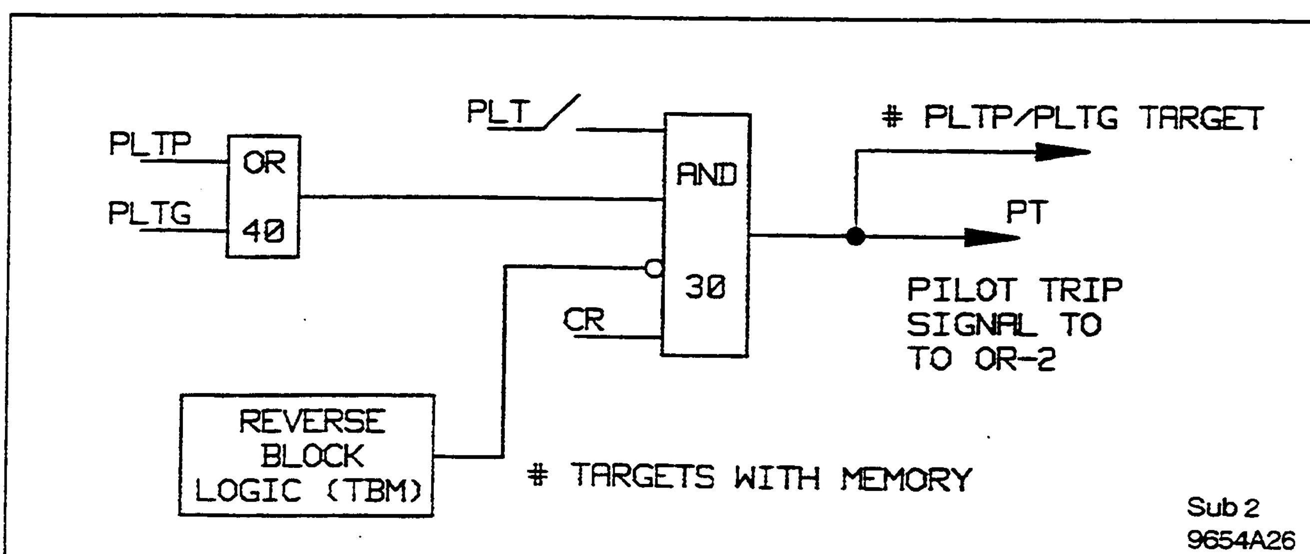


Figure 3-22. POTT/Unblocking Pilot Trip Logic.

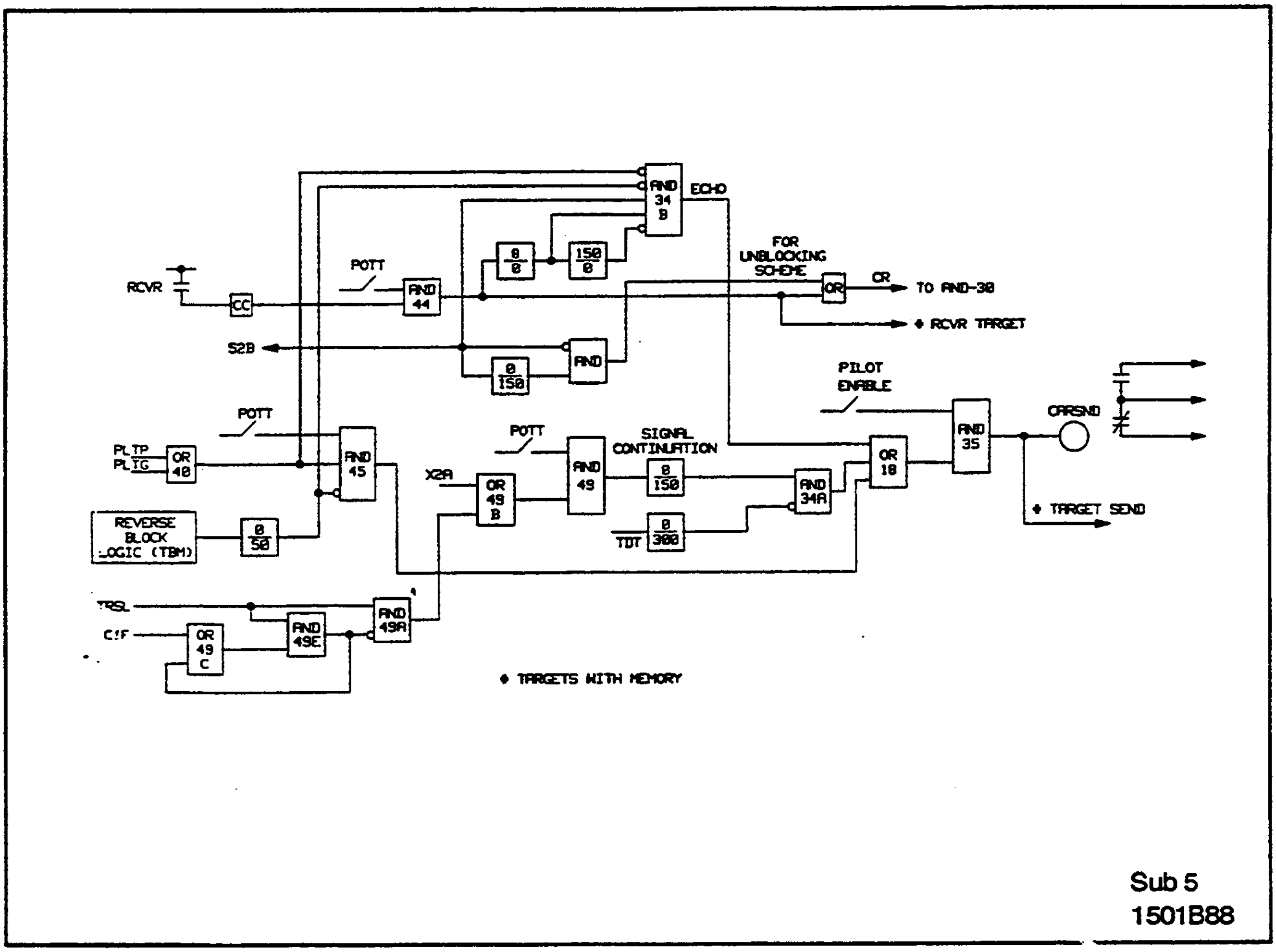


Figure 3-23. Carrier Keying/Receiving Logic in POTT/Unblocking Schemes.

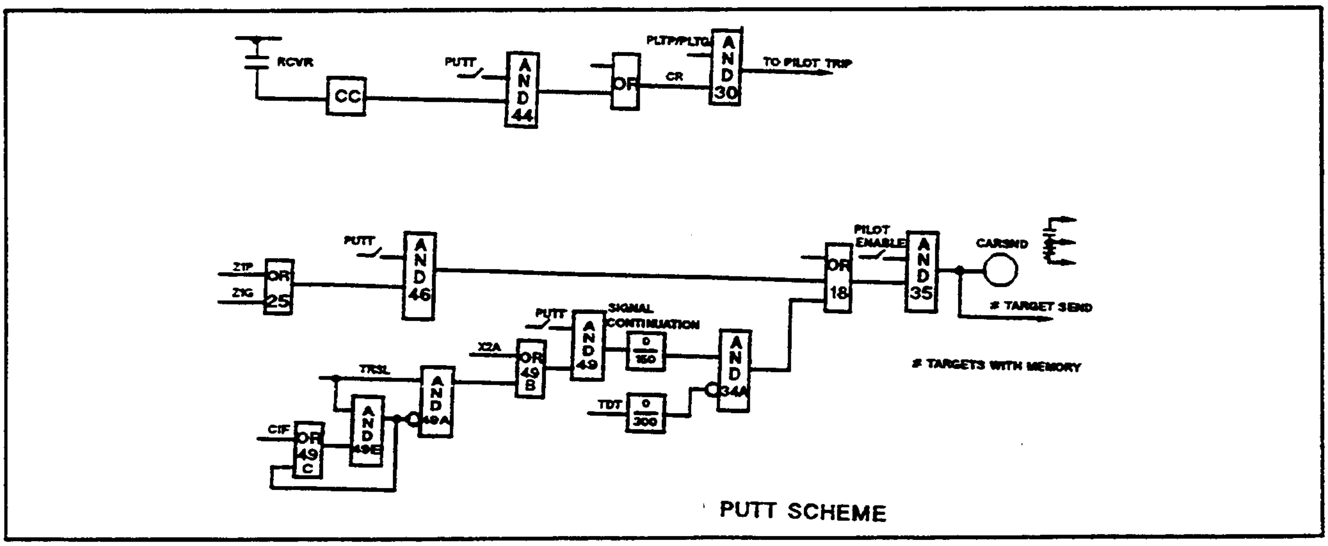
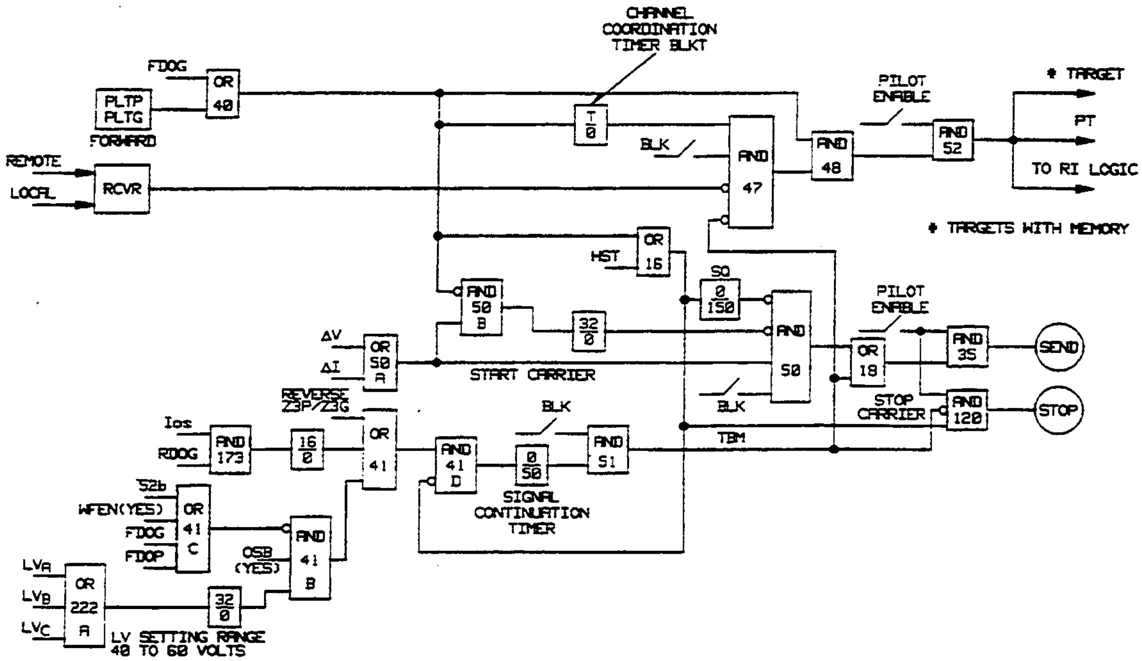


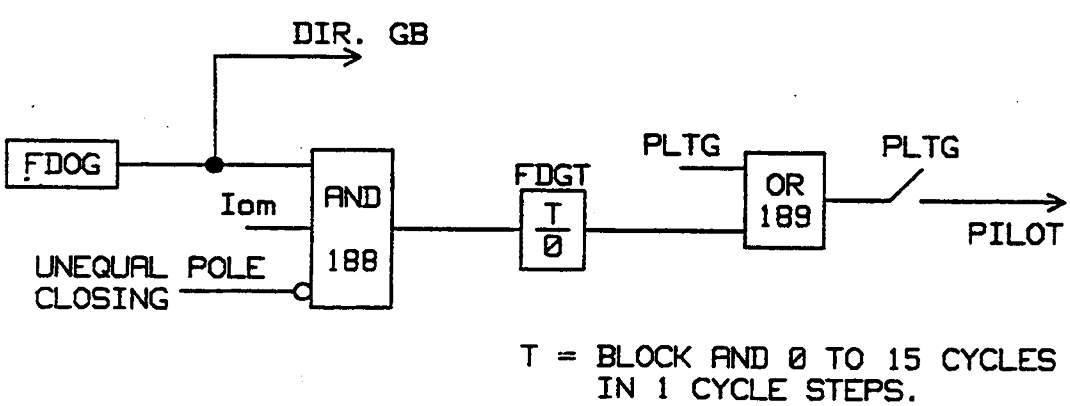
Figure 3-24. PUTT Scheme.



* Sub 4
1501B89

Figure 3-25. Blocking System Logic.

* Denotes Change



Sub 1
9655A86

Figure 3-26. PLTG Supplemented by FDOG.

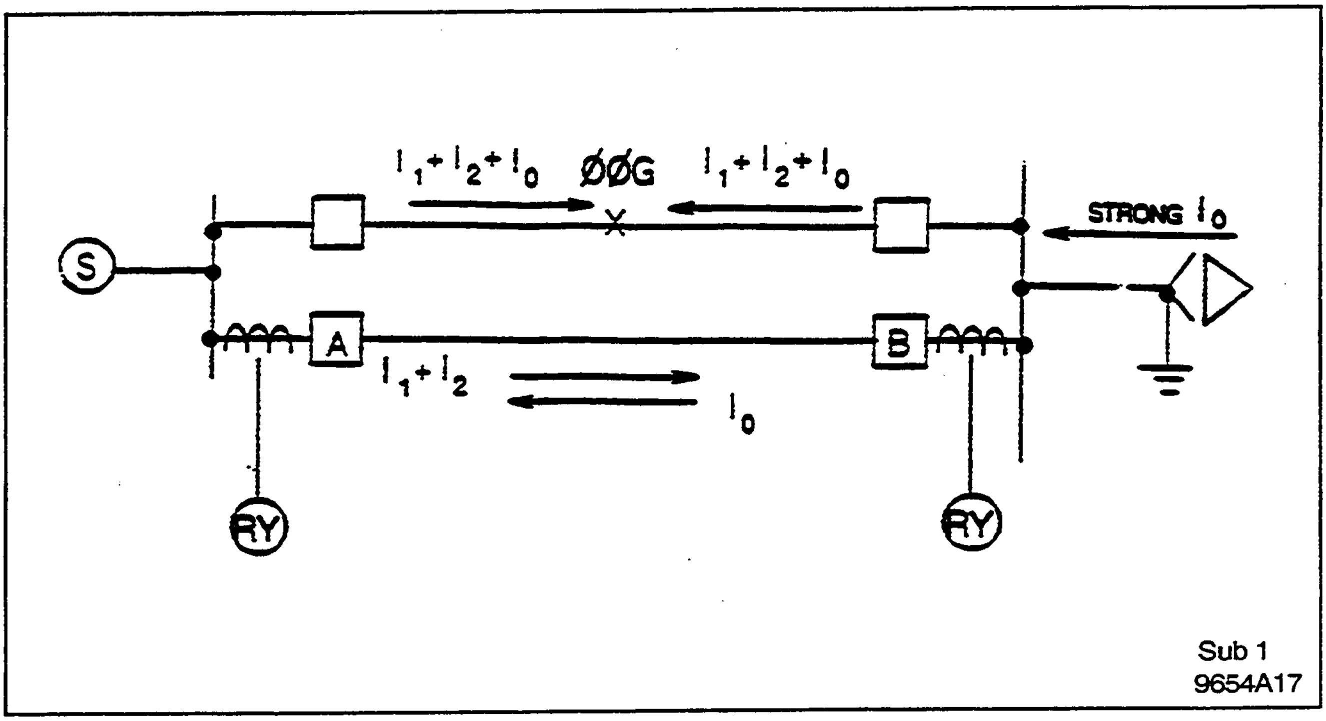


Figure 3-27. Power Reversed on POTT/Unblocking Schemes.

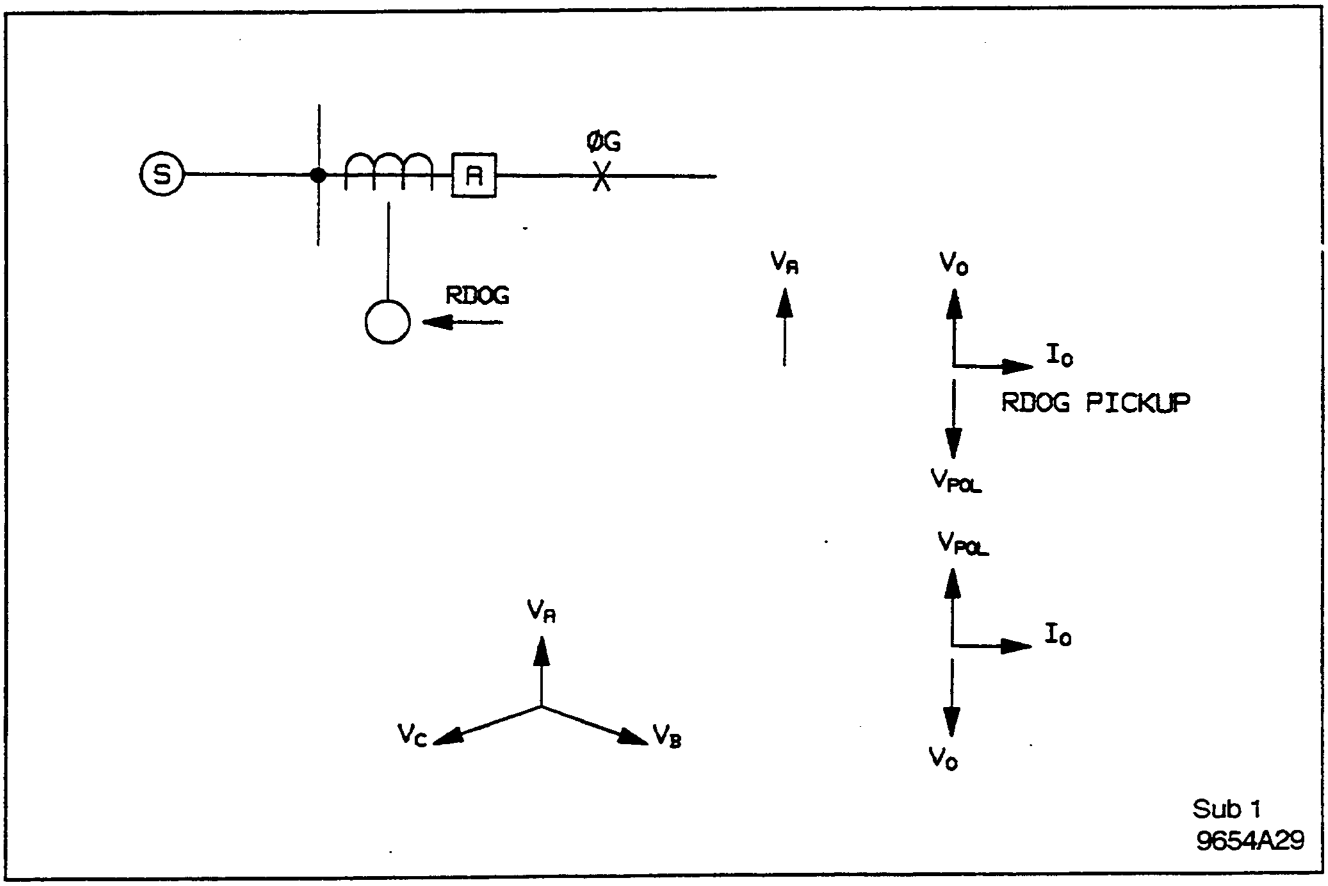


Figure 3-28. Unequal Pole Closing on Fault.

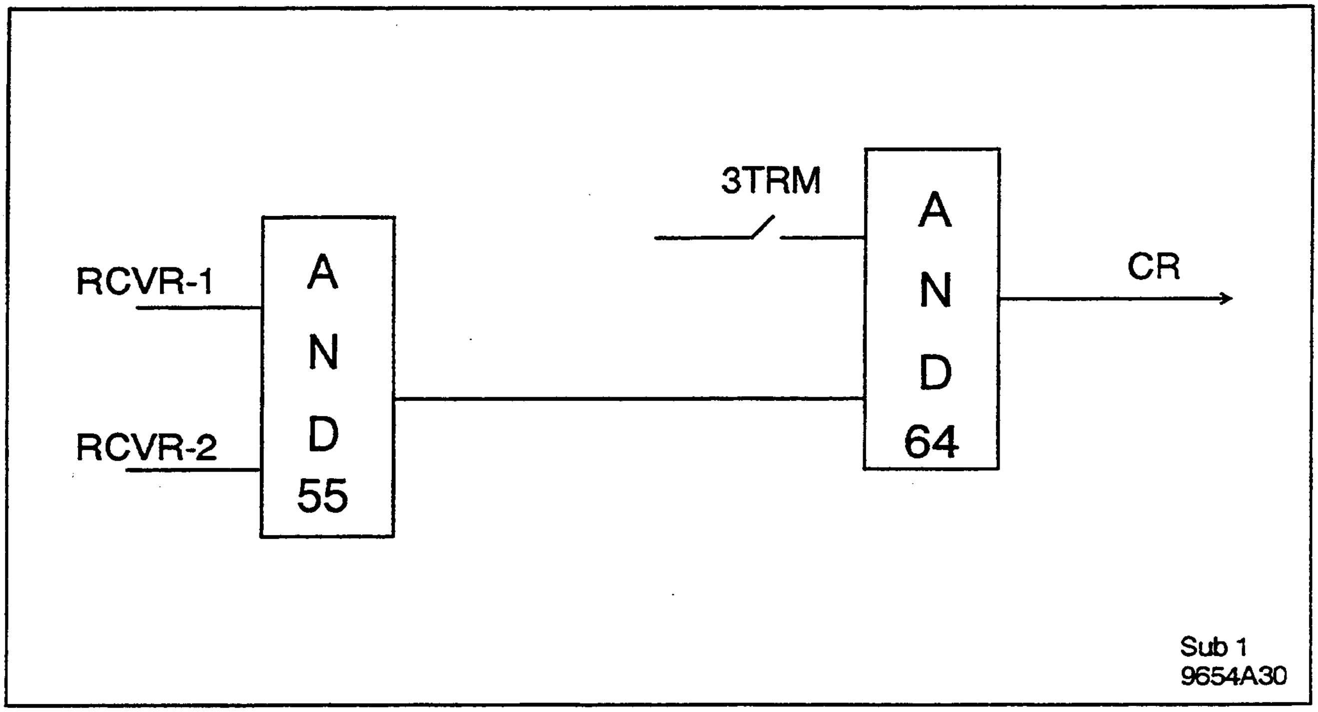


Figure 3-29. Additional Logic for POTT/Unblocking Schemes on 3-Terminal Line Application.

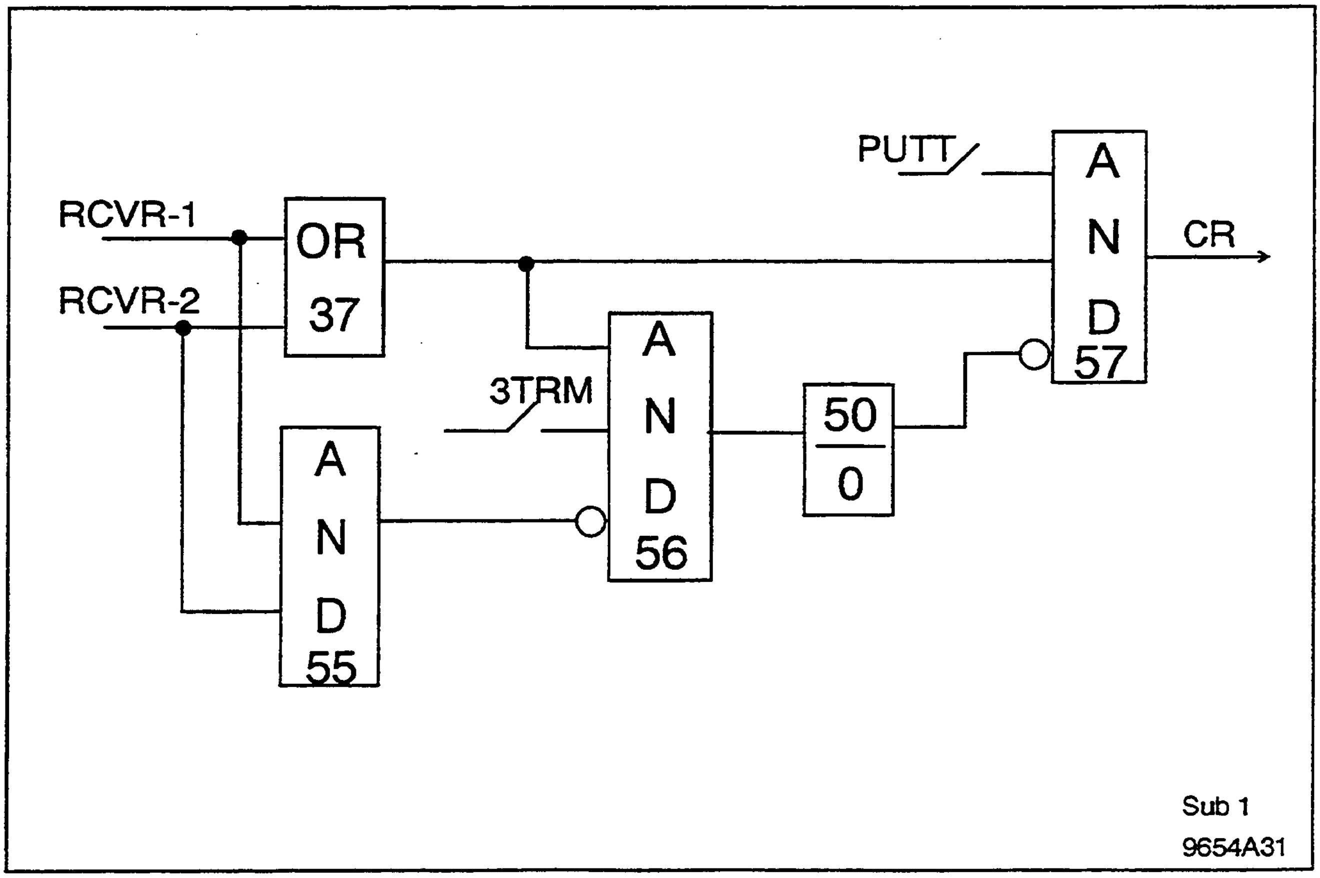


Figure 3-30. Additional Logic for PUTT Scheme on 3-Terminal Line Application.

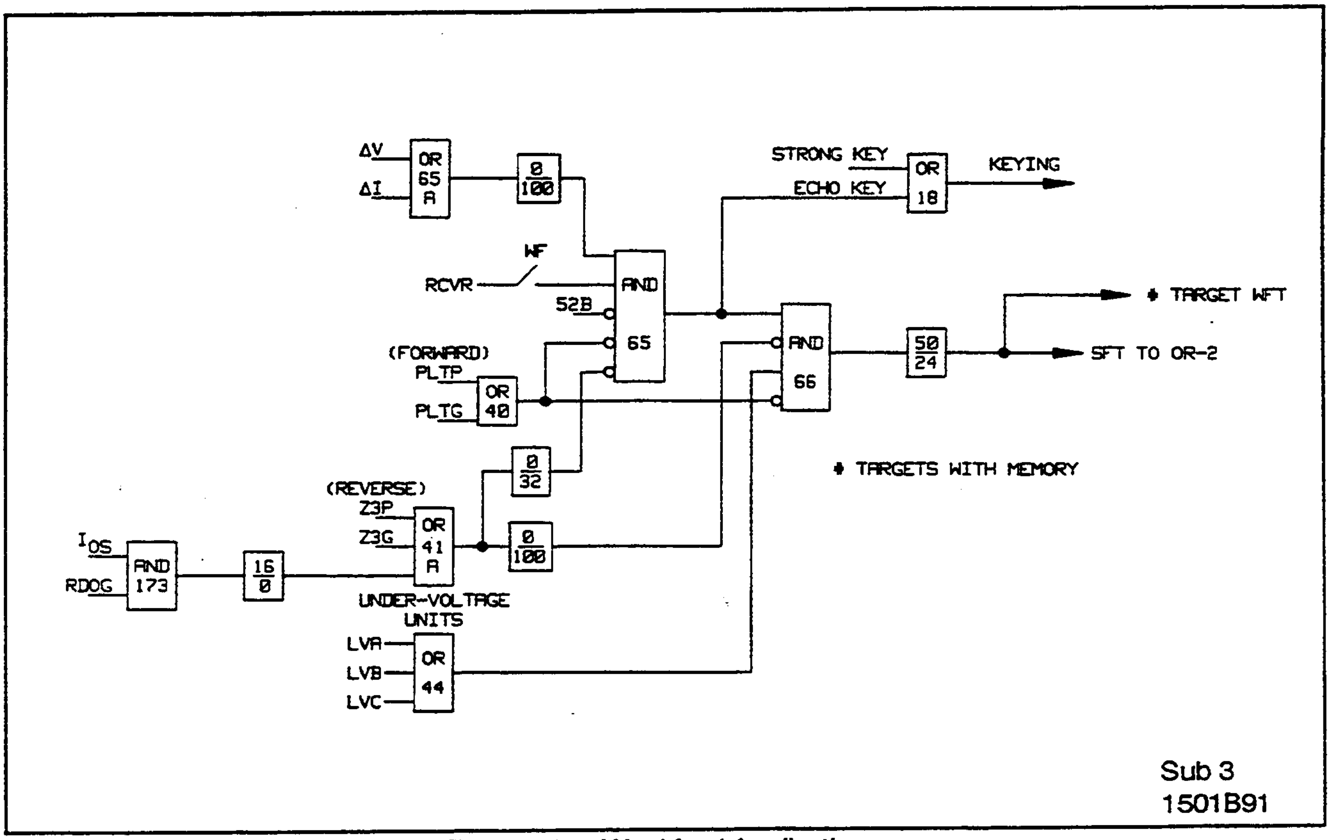


Figure 3-31. Weakfeed Application.

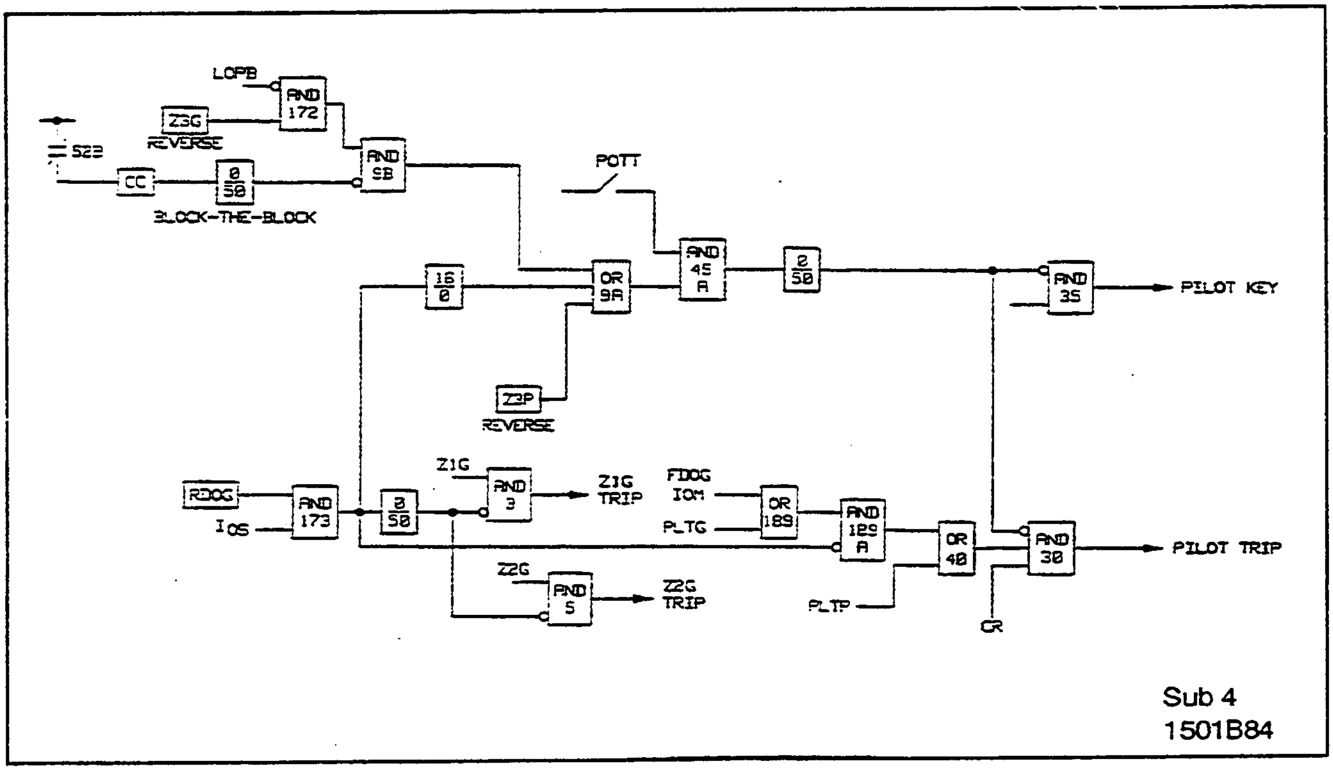


Figure 3-32. Reversible Zone 3 Phase and Ground (Reverse Block Logic).

TABLE 3-1. MDAR CATALOG NUMBERS

		Typical Catalog Number *
MDAR DIGITAL RELAY SYSTEM (50/60 HZ)	**MD**	**3 B 1 S P F R G**
TRIP		
Three Pole Trip	3	
Single Pole Trip	1	
Three Pole Trip w/Programmable Contacts**	8	
CURRENT INPUT		
1A	A	
5A	B	
BATTERY SUPPLY VOLTAGE		
48/60 Vdc	4	
110/125 Vdc	1	
220/250 Vdc	2	
POWER SWING BLOCK		
Power Swing Block	S	
No Power Swing Block	N	
PILOT SYSTEM/CHANNEL INTERFACE		
Pilot System-Channel Interface	P	
Non-Pilot System, No Channel Interface	N	
TEST SWITCHES		
FT-14 Switches	F	
No FT-14 Switches	N	
COMMUNICATION DEVICE		
RS-232C	R	
INCOM	C	
None	N	
ADDITIONAL FEATURES		
Oscillographic Data Storage	G	
No Oscillographic Data Storage	N	
Software Version 1.XX	Z	

* See Drawing 2420F01
**Available in later 2.XX Version

TABLE 3-2. MDAR ACCESSORIES

1. FT-14 TEST PLUG	
• Right-Side	1355D32G01
• Left-Side	1355D32G02
2. TEST FIXTURE AND EXTENDER BOARD	
• Inner Chassis Test Fixture (5 Amp)	2409F39G01
• Inner Chassis Test Fixture (1 Amp)	2409F39G02
• External Board Assembly	1609C55G01

TABLE 3-3. SINGLE-POLE-TRIP OPERATING MODES

"TTYP" SET AT POSITION	TRIP MODE	RECLOSING INITIATE
OFF	3PT on all faults	No reclosing
1PR	3PT on all faults	RI2 on ϕG faults only
2PR	3PT on all faults	RI2 on ϕG/$\phi\phi$/$\phi\phi$G faults
3PR	3PT on all faults	RI2 on all faults
SPR	SPT on ϕG faults 3PT on others	RI1 on ϕG faults only no reclosing on others
SR3R	SPT on ϕG faults 3PT on others	RI1 on ϕG faults RI2 on others

Section 4. INSTALLATION, OPERATION AND MAINTENANCE

4.1 SEPARATING THE INNER AND OUTERCHASSIS

It is recommended that the user of this equipment become acquainted with the information in these instructions before energizing the MDAR and associated assemblies. Failure to observe this precaution may result in damage to the equipment.

All integrated circuits used on the modules are sensitive to and can be damaged by the discharge of static electricity. Electrostatic discharge precautions should be observed when operating or testing the MDAR.

CAUTION

Use the following procedure when separating the inner chassis from the outer chassis; failure to observe this precaution can cause personal injury, undesired tripping of outputs and component damage.

a. Unscrew the front panel screw.

b. If the MDAR does not have FT-14 switches, but has a power switch on the front panel, turn "OFF" the power switch before sliding out the inner chassis.

c. If the MDAR has FT-14 switches:

1) Remove the FT-14 covers (one on each side of the MDAR).

2) Open all FT-14 switches.

WARNING: Do Not Touch the outer contacts of any FT-14 switch; they may be energized.

3) Slide out the inner chassis.

4) Close all FT-14 switches.

5) Replace the FT-14 covers.

d. Reverse procedures above when replacing the inner chassis into the outer chassis.

4.2 TEST PLUGS AND FT-14 SWITCHES

Test Plugs are available as accessories (see Table 3-2); they are inserted into the FT-14 switches for the purpose of System Function Tests. When the Test Plugs are inserted, the terminals FT-14/13 (BP) and FT-14/14(BN) must remain closed.

4.3 EXTERNAL WIRING

All external electrical connections pass through the Backplate (Figure 4-1) on the outer chassis. If the MDAR is used without the FT-14 switch, six 14-terminal connectors on the Backplate (TB1 through TB6) are used. If the FT-14 switch (option) is included, using the two peripheral areas of the MDAR cabinet, then only four of the 14-terminal connectors (TB2 through TB5) are used. Three DIN connectors (J11, J12, J13) allow for the removal of the outer chassis (Backplane module) from the inner chassis (Interconnect module).

Electrical inputs to the Backplane module, which are routed either directly through the Backplate or through the FT-14 switch to the Backplate, include (Figure 4-1):

- V_A, V_B, V_C and V_N
- I_A/I_{AR}, I_B/I_{BR}, I_C/I_{CR}, and I_P/I_N
- BP (48, 125 or 250 Vdc) and BN (negative)

Analog input circuitry consists of four current transformers (IA, IB, IC, and IN), three voltage transformers, (VA, VB and VC), and low-pass filters. The seven transformers are located on the Backplane PC Board (see Appendix A). The primary winding of all seven transformers are directly-connected to the input terminal TB6/1 through 12 (see Functional Block Diagram, Appendix J); the secondary windings are connected through the Interconnect module to the Filter module.

As shown in Figures 4-1 and 4-2, dry contact outputs for breaker failure initiation (BFI), reclosing initiation (RI), reclosing block (RB), failure alarm (AL1), trip alarm (AL2), SEND and STOP are located on the Backplane PC Board. Optical isolators are for Pilot Enable, External Reset, Receiver #1 and #2, 52a, 52b, SBP (89b) and studs for chassis ground (GND) and location for the Communication Interface are also shown.

As shown in Figure 4-3, the power system ac quantities (Va, Vb, Vc, Vn, Ia, Ib, Ic and In), as well as the dc source are connected to the left side FT-14 switch (front view). All the trip contact outputs are connected to the right-side FT-14 switch (front view). Switches 13 and 14 on FT-14 may be used for disabling the Breaker Failure Initiation/Reclosing Initiation (BFI/RI) control logic. (See also external connections, Block Diagram, Appendix J.)

The INCOM or RS232 PONI (Product Operated Network Interface) communication box is mounted through the Backplate of the outer chassis and connected to the Backplane module, and remote settings (see 4.7).

4.4 MDAR FRONT PANEL DISPLAY

The front panel display consists of a vacuum fluorescent display, seven LED indicators, seven pushbutton switches, and five test points (as shown in Figure 1-1).

4.4.1 Vacuum Fluorescent Display

The vacuum fluorescent display (blue color) contains four alphanumeric characters for both the function field and the value field. All the letters or numbers are fourteen segment form (7.88mm x 13mm in size).

4.4.2 LED Indicators

There are seven LED indicators on the front panel display:

- 1 “relay-in-service” indicator
- 1 “value accepted” indicator
- 5 display-select indicators

When the “Relay-in-Service” LED illuminates, the MDAR Relay is in service, there is dc power to the relay and the relay has passed the self-check and self-test. The LED is turned “OFF” if the Relay-in-service relay has at least one of the internal failures shown in the “Test” mode, and the trip will be blocked.

The “Value Accepted” LED flashes only once, to indicate that a value has been entered successfully.

The five indicators used for the display selection are:

- Settings
- Volts/Amps/Angle
- Last Fault
- Previous Fault
- Test

One of these indicators is always illuminated, indicating the mode selected. The display will be blocked momentarily every minute for the purpose of self-check; this will not affect the relay protection function.

4.4.3 Pushbutton Switches

The front panel contains seven pushbutton switches:

- Display Select
- Reset Targets
- Function Raise
- Function Lower
- Value Raise
- Value Lower
- Enter (recessed for security purposes)

The “Display Select” pushbutton is used to select one of the five display modes, which is indicated when the proper LED illuminates. When a fault is detected, the “Last Fault” flashes once per second. If two faults are recorded, the “Last Fault” flashes twice per second, and the prior fault will be moved from “Last Fault” to “Previous Fault”. The new fault data will be stored in the “Last Fault” register. By depressing the “Reset Targets” pushbutton, the flashing LED indicators are cleared, and the LED will revert back to the Metering mode. The information in the “Previous Fault” and “Last Fault” will not be reset from the front panel pushbutton switch, but will be reset from External Reset (TBS/5 and TBS/6) and the remote reset through the Communication Interface.

The “Function Raise” and “Function Lower” pushbuttons are used to scroll through the information for the selected display mode. The “Value Raise” and “Value Lower” pushbuttons are used to scroll through the different values available for each of the five functions. The “Enter” pushbutton is used to enter (in memory) a new value for settings.

4.4.4 Test Points

Five test points are provided to check the dc power supply. Refer to these test points on the front panel display:

- -24V
- + 5V
- -12V
- +12V
- Common

Each measurement is taken by inserting one dc probe (voltmeter) into Common, and the other dc probe at the voltage being measured.

4.5 FRONT PANEL OPERATION

The front (operator) panel provides a convenient means of checking or changing settings, and for checking relay unit operations after a fault. Information on fault location, trip types, phase, operating units, and breakers which tripped become available by using the pushbuttons to step through the information. Targets (fault data) from the last two faults are retained, even if the relay is deenergized. The operator is notified that targets are available by a red flashing LED on the front panel; in addition, alarm 2 output-relay contacts are provided for the external annunciators.

The operator can identify nonfault voltage, current and phase angle on the front panel display. Settings can be checked easily, however, any change to the settings requires the use of the pushbuttons. When relay is in the normal operating mode, it is good practice to set the LED on the Volts/Amps/Angle mode.

4.5.1 Settings Mode

In order to determine the MDAR settings that have been entered into the system, continually depress the “DISPLAY SELECT” pushbutton until the “SETTINGS” LED is illuminated. Then depress the “FUNCTION RAISE” or “FUNCTION LOWER” pushbutton, in order to scroll through the MDAR SETTINGS functions (see Table 4-1). For each settings function displayed, depress the “VALUE RAISE” or “VALUE LOWER” pushbutton in order to scroll through the MDAR values available for the particular function. (Each value that appears, as each different function appears in the function field, is considered to be the “current value” used for that particular function.)

In order to change the “current value” of a particular settings function, “RAISE” or “LOWER” the FUNCTION field until the desired function appears (e.g., “RP”). Then “RAISE” or “LOWER” the values in the VALUE field until the desired value appears. If the “ENTER” pushbutton (recessed for security purposes) is depressed, the value which appears in the VALUE field will replace the “current value” in memory; but only if the “VALUE ACCEPTED” LED flashes once to indicate that the value has been successfully entered into the system.

For reasons of security, a plastic screw is used to cover the ENTER pushbutton. A wire can be used to lock the plastic screw and to prevent any unauthorized personnel from changing the settings.

4.5.2 Metering (Volts/Amps/Angle) Mode

When the Volts/Amps/Angle LED is selected by the “Display Select” pushbutton, the phase A, B, C voltages, currents and phase angles are available for on-line display during normal operation. All measured values can be shown by scrolling the “Raise” or “Lower” pushbutton in the FUNCTION field. The values on the display are dependent on the settings of RP (read primary); RP= YES for the primary side values and RP = NO for the secondary values. Conditions such as loss-of-potential, loss-of-current and out-of-step blocking can also be monitored. The function names and values are shown in Table 4-2.

NOTE: All displayed Phase Angles use V_A as reference.

4.5.3 Target (Last and Previous Fault) Mode

The MDAR system saves the latest 16 faults records. The “LAST FAULT” information is of the most recent fault, the “PREVIOUS FAULT” information is of the fault prior to the “LAST FAULT”. These displays contain the target information along with the “frozen” data at the time of trip. The “LAST FAULT” register shows one or two records stored by flashing the LED once or twice per second, respectively. These records can be deleted by External Reset voltage TB/5 (+) and TB5/6 (-) or through a remote communication interface. The front panel (RESET) pushbutton allows the user to reset the flashing LED to Metering position only. It will not erase the fault in formation.

Different types of faults with related descriptions are shown in Table 4-3. As soon as a fault event is detected, the most recent two sets of target data are available for display. If the FDAT is set at “TRIP”, the “Last Fault” is the data associated with the most recent trip event. The “Previous Fault” contains the data from the prior trip event. If a single fault occurs, the “Last Fault” LED flashes. If a reclosing is applied and the system trips, the original “LAST FAULT” information will be transferred to the “Previous Fault” memory. The latest trip information will be stored in the “Last Fault” memory, and its LED flashes twice per second. If FDAT is set at Z2TR, two events (Zone 2 pickup or trip) will be stored. If FDAT is set at Z2/Z3, the two events will be either Zone 2 pickup or Zone 3 pickup or any type of trip. The same description applies to a remote communication which can store up to 16 events.

4.5.4 Test Mode (Self-Check Routine)

The software of the MDAR relay contains several self-check routines (see Section 1.6). When the “Test” mode is selected by the “Display Select” pushbutton, the failure modes (represented by their corresponding bits) are shown in the VALUE field, as follows:

- Bit 0 External RAM Failure
- Bit 1 EEPROM Warning
- Bit 2 ROM Failure
- Bit 3 EEPROM Failure (NON-Volatile memory)
- Bit 4 Analog Input Circuit Failure
- Bit 5 Microprocessor Failure

Data types are as follows:

- bit
- byte = 8 bits
- word = 16 bits
- longword = 32 bits

All bits are expressed in HEX byte form. For example, if the display shows “Test 1B”, whose binary representation is 00011011, this means that the relay failed the self-check in the area of External RAM (bit 0), EEPROM (one-out-of-three failure, bit 1), (two-out-of-three failure, bit 3) and Analog Input Circuit (bit 4). Normally, the test mode should show “Test 0", meaning that the relay has passed the self-check routines.

When the selector is in TEST mode, scroll the function field by the Raise pushbutton. The Value field display shows RS1 (Carrier Receiver #1), RS2 (Carrier Receiver #2), RS1, 2 (Carrier Receiver #1 and #2), and TK (Carrier Send) for the use of MDAR functional test. Refer to the Pilot Acceptance Test (Appendix H, Section 1.1.13) for more detailed information. If jumper (JP5) on the microprocessor module is IN, the following ten functions will be shown:

- TRIP
- AL1
- BFI
- AL2
- RI1
- GS
- RI2
- SEND
- RB
- STOP

All of these contact outputs can be tested by pressing the “ENTER” pushbutton. (see Appendix I, Section 1.13).

4.6 JUMPER CONTROLS

The following jumpers are set at the factory; the customer normally does not need to move the jumpers. Refer to Table 4-4 for the recommended jumper positions.

4.6.1 Backplane Module

An external jumper should be wired to terminals 13/14 of switch FT-14.

When switch FT-14/13 or FT-14/14 is opened, the BFI and RI output relays are deenergized to prevent BFI and RI contact closures during system function test.

4.6.2 Interconnect Module

The factory sets jumpers (JMP1 through JMP6 and JMP13) for 48 Vdc or 125 Vdc input source.

JMP7 & 9 are used for Stub Bus Protection (SBP). If SBP is not used, move JMP7 & 9 to 8 & 10 position for the second set of AL2-2 use.

CAUTION

If the customer intends to use a voltage other than 48 Vdc or 125 Vdc, see Interconnect Module Schematic, Appendix B.

4.6.3 Microprocessor Module

The following jumpers are normally set during factory calibration:

• JMP1, JMP8, JMP9	for EEPROM and RAM circuitries, and are normally set to position 1-2.
• JMP2	normally set to position 2-3 for standard application. Set to position 1-2 for programmable output contact selection (future application).
• JMP3, JMP10, JMP11 JMP12	Not used
• JMP4	set to “IN” for trip contact with dropout time delay.

- JMP5 set to “IN” for output contact tests.
- JMP6 normally set to “OUT” position; set to “IN” when making A/D converter calibration.

NOTE: Should the customer need to gain access to any of the jumpers (above), see Section 4.10, and Appendix E.

4.7 COMMUNICATION INTERFACE

Two options are available for interfacing between MDAR and a variety of local and remote communication devices.

- RS-232C - for single point computer communication
- INCOM®/PONI[1] - for local network communication

An IBM® AT®or XT compatible computer, with software provided (WRELCOM), can be used to monitor the settings, 16 fault data, 16 intermediate data, and metering information. For a remote setting, SETR should be set to “YES”; then the settings can be changed (remotely) with a user-defined password. If a user loses his assigned password, a new password can be installed by turning the MDAR relay’s dc power supply “OFF” and then “ON”. MDAR allows a change of password within the next 15 minutes, by using a default “PASSWORD”.

When in the remote mode, the computer can disable the local setting by showing SET = REM (in the Metering mode). Then, the setting cannot be changed locally. In this situation, the only way to change a setting locally would be to turn the dc power “OFF” and then “ON”. The computer will allow for a local setting change within 15 minutes.

4.8 SIXTEEN FAULT TARGET DATA

The MDAR saves the latest 16 fault records, but only the latest two fault records can be accessed from the front panel. For complete 16 fault data, one of the communication interface devices are necessary. The activation of fault data storage is controlled by setting FDAT. (Refer to Section 3.4.19 for detailed information.) The 16 intermediate fault targets are a standard feature. The activation of data storage is based on the setting of the optional OSC (see next section). If OSC is not included, intermediate data is provided one sample per cycle.

1. INCOM” ® is a registered trademark of the Westinghouse Electric Corporation, Inc., which stands for INtegrated COMmunications. The “PONI” acronym stands for Product Operated Network Interface.

4.9 OSCILLOGRAPHIC DATA (Optional Feature)

Sixteen sets of oscillographic data are stored in MDAR. Each set includes seven analog traces (Va, Vb, Vc, Ia, Ib, Ic and In), with one cycle pre-fault and 7-cycle fault information, and 20 sets of digital data based on 8 samples per cycle.

The oscillographic data (OSC) collection can be set for TRIP, Z2TR, Z2/Z3, and dVdI. For setting of OSC = TRIP, data are collected for the trip events. The data collection is started from dVdI if the trip occurs within 7 cycles. For OSC = Z2TR, the data collection is triggered by Zone 2 pickup or any types of trip. For OSC = Z2/Z3, the collection is triggered by either Zone 2 or Zone 3 pickup (including the Zone 3 reverse setting) or trip. For OSC = dVdI, the data collection is caused by any line disturbance, e.g., a sudden phase current change (by 1 amp) or a ground current change (by 0.5 Amp), or a voltage change (ΔV) greater than 7Vdc.

NOTE: Setting at dVdI is not recommended because a lot of meaningless data will be stored, such as breaker opening or closing, etc.

4.10 ROUTINE VISUAL INSPECTION

With the exception of Routine Visual Inspection, the MDAR relay assembly should be maintenance-free for one year. A program of Routine Visual Inspection should include:

- Condition of cabinet or other housing
- Tightness of mounting hardware and fuses
- Proper seating of plug-in relays and subassemblies
- Condition of external wiring
- Appearance of printed circuit boards and components
- Signs of overheating in equipment

4.11 ACCEPTANCE TESTING

The customer should perform the MDAR Acceptance Tests (see Appendix I) on receipt of shipment.

4.12 NORMAL PRECAUTIONS

Troubleshooting is not recommended due to the sophistication of the Microprocessor unit.

CAUTION

With the exception of checking to insure proper mating of connectors, or setting jumpers, the following procedures are normally not recommended. (If there is a problem with the MDAR, it should be returned to the factory. See *PREFACE.)*

4.13 DISASSEMBLY PROCEDURES

a. Remove the inner chassis from the outer chassis, by unscrewing the center lockscrew (on the front panel), and unsnapping the two covers from the (optional) FT-14 switches, if the FT-14 switches are a part of the MDAR system.

NOTE: The inner-chassis (sub-assembly) slides in and out of the outer chassis from the front. Mating connectors inside the case eliminate the need to disconnect external wiring when the inner chassis is removed.

b. Remove the (optional) FT-14 switches, mounted by two screws on the side walls.

c. Remove the front panel (with the Display module) from the inner chassis, by unscrewing four screws behind the front panel.

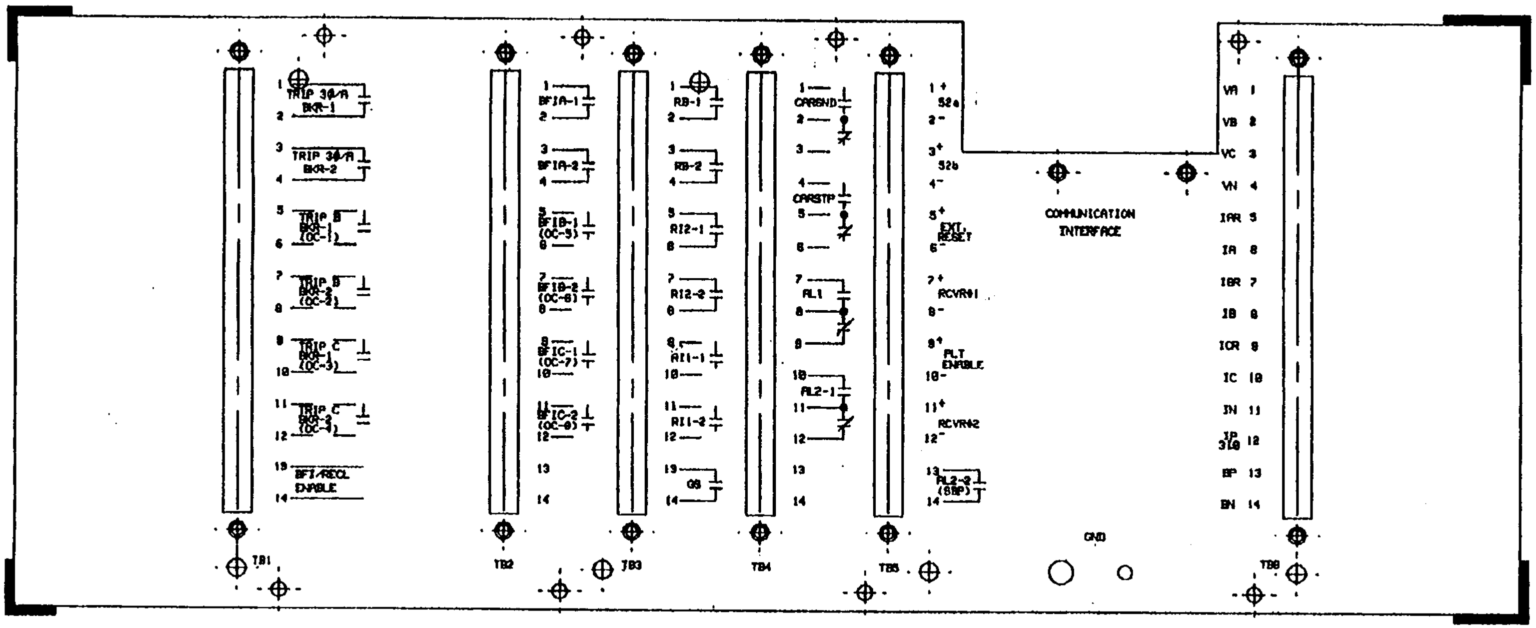
d. Remove the Microprocessor module, by loosening six mounting screws, and unplugging the module from the Interconnect module.

e. Remove the Option (module), if the option module is part of the MDAR system, by unscrewing 2 mounting screws from the center support bar, and unplugging the Option module from the Interconnect module.

f. Remove the Power Supply and Filter modules, by first removing the Microprocessor module and the support cross bar.

g. Remove the Backplate, by unscrewing the mounting hardware from the rear of the Backplate.

h. Gain access to the Backplane and Transformer modules, by removing the Backplate.



* Sub 6
1354D22
Sheet 4 of 5

Figure 4-1. MDAR Backplate.

* Denotes Change

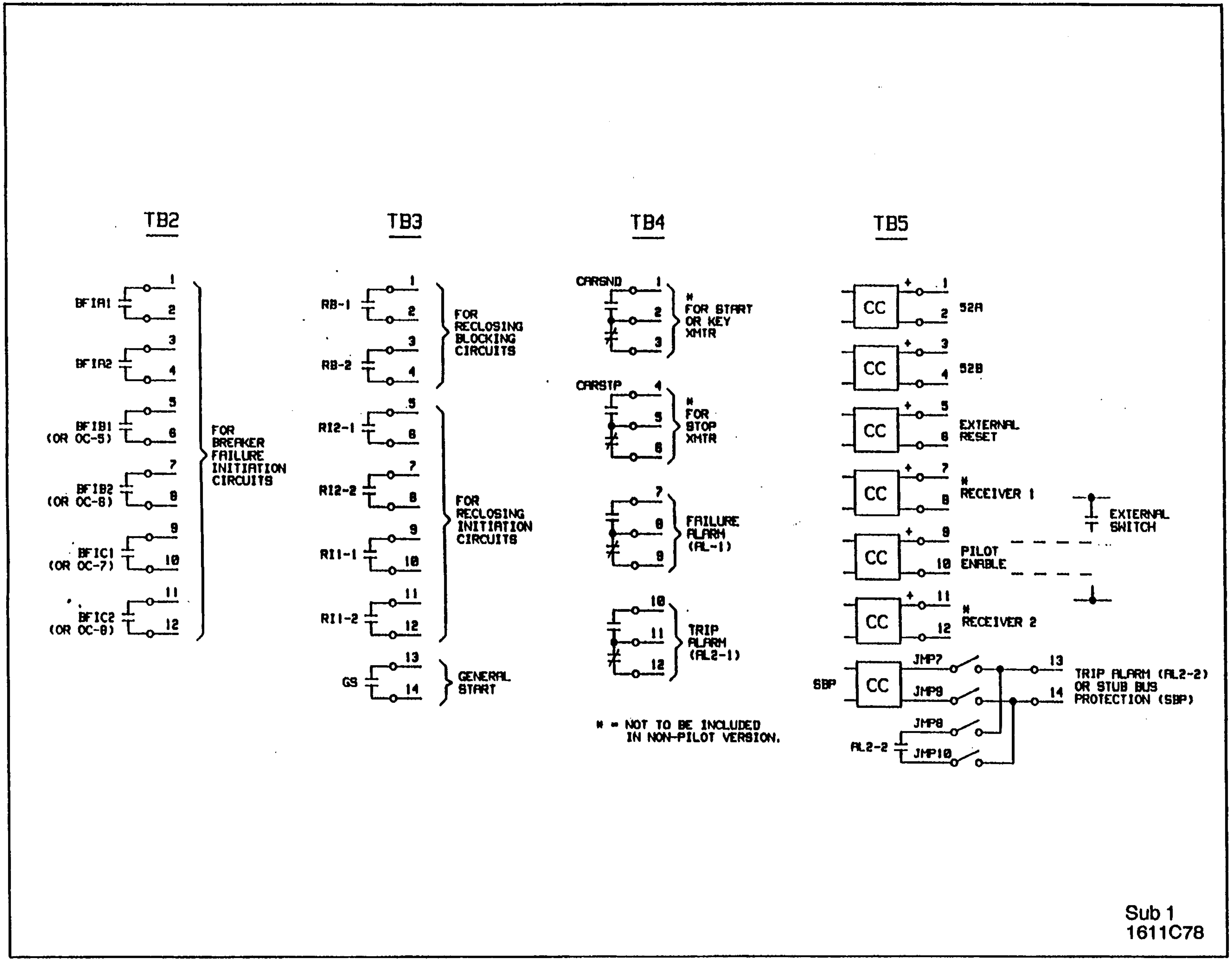


Figure 4-2. MDAR Backplane PC Board Terminals

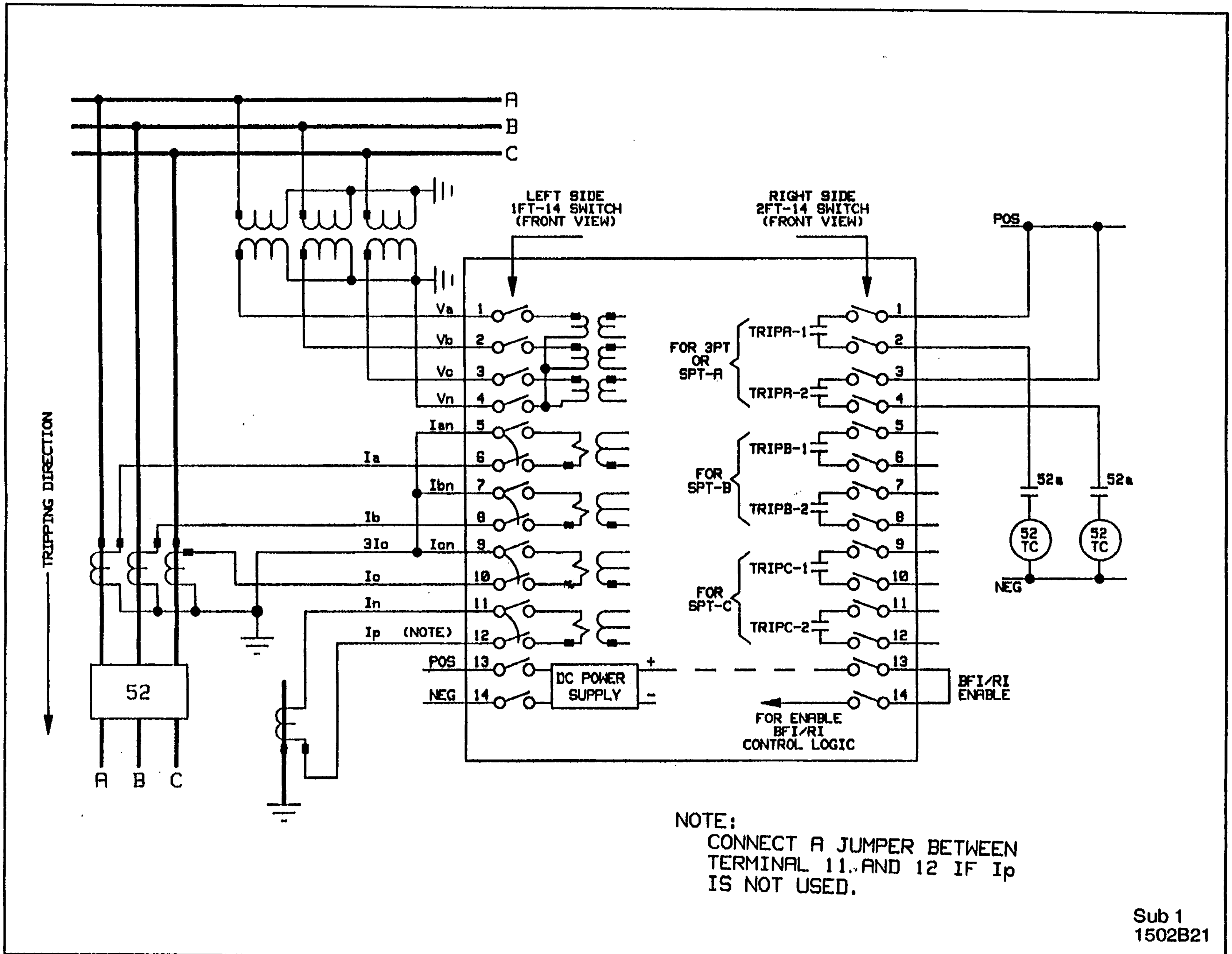


Figure 4-3. MDAR Systems External Connection.

TABLE 4-1. SETTING DISPLAY (SHEET 1 OF 3)

Information/Settings	Displayed at Function Field	Value Field (using 5 A ct and 60 Hz) (SEE NOTE ON SHEET 3)
Software version	VERS	numerical (0,1)
Oscillographic data initiation	OSC *	TRIP/Z2TR/Z2Z3/ΔVΔI
Fault data initiation	FDAT	TRIP/Z2TR/Z2Z3
ct ratio	CTR	30-5000 (5)
PT ratio	VTR	300-7000 (10)
Rated freq.	FREQ	60, 50
ct secondary rating	CTYP	5 or 1
Enable/disable readouts in primary I & V values	RP	YES/NO
Reactance for fault location (ohms per unit distance)	XPUD	0.300-1.500, in 0.001/DTYP
Fault location, displayed in km or miles	DTYP	KM or MI (miles)
Reclosing mode	TTYP	
1. 3PT on all faults, no RI		OFF
2. 3PT on all faults, with 3RI on ϕGF		1PR
3. 3PT on all faults, with 3RI on ϕGF/2ϕF		2PR
4. 3PT on all faults, w/3RI		3PR
5. SPT on ϕGF with SRI 3PT on MϕF without RI		SPR
6. SPT on ϕGF with SRI 3PT on MϕF with 3RI		SR3R
Single phasing limit timer	62T *	0.300-5000, in 0.050 sec. steps
RI on Z1T	Z1RI	YES/NO
RI on Z2T	Z2RI	YES/NO
RI ON Z3T	Z3RI	YES/NO
Breaker Failure Reclose block	BFRB *	YES/NO
Pilot logic control	PLT *	YES/NO
Pilot system selection:	STYP	
1. Non-Pilot, 3-zone distance		3ZNP
2. Zone-1 extension		Z1E
3. Permissive overreach transfer trip or unblocking		POTT
4. Permissive underreach transfer trip		PUTT
5. Blocking		BLK
Forward Direction Ground Timer	FDGT *	BLK, 0 to 15 cycles in 1cycle steps
Weakfeed Enable	WFEN *	YES/NO
3-Terminal Line Application	3TRM *	YES/NO
Blocking system channel coordination timer	BLKT *	0-98, in 2 ms steps
Reverse block sw.	RBSW *	Omitted
Pilot phase setting	PLTP *	OUT, 0.01-50.00 in 0.01 Ω steps
Pilot ground setting	PLTG *	OUT, 0.01-50.00 in 0.01 Ω steps

*Optional

TABLE 4-1. SETTING DISPLAY (SHEET 2 OF 3)

Information/Settings	Displayed at Function Field	Value Field (using 5 A ct and 60 Hz) (SEE NOTE ON SHEET 3)
Zone 1 phase unit	Z1P	OUT, 0.01-50.00 in 0.01 Ω steps
Zone 1 ground unit	Z1G	OUT, 0.01-50.00 in 0.01 Ω steps
Zone 1 delay trip timer	T1	YES/NO, 2 cycles if YES
Zone 2 phase unit	Z2P	OUT, 0.01-50.00 in 0.01 Ω steps
Zone 2 phase timer	T2P	BLK, 0.10-2.99, in 0.01 sec. steps
Zone 2 ground unit	Z2G	OUT, 0.01-50.00 in 0.01 Ω steps
Zone 2 ground timer	T2G	BLK, 0.10-2.99, in 0.01 sec. steps
Zone 3 phase unit	Z3P	OUT, 0.10-50.00 in 0.01 Ω steps
Zone 3 phase timer	T3P	BLK, 0.10-9.99 in 0.01 sec. steps
Zone 3 ground unit	Z3G	BLK, 0.01-50, 0.01 Ω steps
Zone 3 ground timer	T3G	BLK, 0.10-9.99 in 0.01 sec. steps
Zone 3 direction	Z3FR	FWD/REV
Pos. Seq. line impedance angle	PANG	40-90, in 1.0 degree steps
Zero Seq. line impedance angle	GANG	40-90, in 1.0 degree steps
ZOL/Z1L	ZR	0.1-7.0, in 0.1 steps
Low Voltage unit	LV	40-60 in 1.0V (rms) steps
Overcurrent units		
Low set phase	IL	0.5-10, in 0.1 A steps
Low set ground	IOS	0.5-10, in 0.1 A steps
Med. set ground	IOM	0.5-10, in 0.1 A steps
High set phase	ITP	OUT, 2-150.0, 0.5 A steps
High set ground	ITG	OUT, 2-150.0, 0.5 A steps
Out-of-step block	OSB*	YES/NO
OSB override timer	OSOT*	400-4000 in 16 ms steps
OSB inner blinder	RT	1.00-15.00, in 0.10 Ω steps
OSB outer blinder	RU*	3.00-15.00, in 0.10 Ω steps
Directional overcurrent, zero or negative sequence	DIRU	ZSEQ/NSEQ/DUAL
Directional overcurrent ground backup time curve family	GBCV	OUT, CO2,5,6,7,8,9,11
Ground backup pick-up	GBPU	0.5-4.0, in 0.1 A steps
Ground backup time curves within family	GTC	1-63, in 1.0 steps
Choice of directional or non-directional ground backup	GDIR	YES/NO

* Optional

TABLE 4-1. SETTING DISPLAY (SHEET 3 OF 3)

Information/Settings	Displayed at Function Field	Displayed at Value Field (using 5 A ct and 60 Hz) (SEE NOTE)
CIF trip/stub bus protection	CIF	CIFT/STUB/BOTH/NO
LLT trip	LLT	YES/FDOG/NO
LOP block	LOPB	YES/NO
LOI Block	LOIB	YES/NO
Alarm 2 (Trip) Seal-In	AL2S	YES/NO
Remote Setting	SETR	YES/NO
Real Time Clock	TIME	YES/NO
1. Set Year	YEAR	1980-2079, in 1 year steps
2. Set Month	MNTH	1-12, in 1 month steps
3. Set Day	DAY	1-31 in 1 day steps
4. Set Weekday	WDAY	Sun, Mon, Tues, Wed, Thur, Fri, Sat
5. Set Hour	HOUR	0-24, in 1 hour steps
6. Set Minute	MIN	0-60, in 1 minute steps

NOTE: WHEN THE CTYP FUNCTION IS SET AT 1 AMPERE, THE RANGE OF THE FOLLOWING FUNCTIONS ARE AS SHOWN BELOW:

- ZIP/ZIG/Z2P/Z2G Z3P/Z3G/PLTP/PLTG 0.05-250.00, in 0.05 Ω steps
- ITP/ITG 0.4-30.0, in 0.1 A steps
- IL/IOS/IOM 0.1-2.0, in 0.02 A steps

NOTE: SEE ALSO SECTION 5.2.4, SELECTIONS OF CTYP SETTINGS.

NOTE: SEE PREFACE FOR INFORMATION ON SETTING NOMENCLATURE APPLIQUES.

NOTE: The increments of timers are based on the line frequency, e.g., 16 msec for 60 Hz and 20 msec for 50 Hz (to the nearest msec)

TABLE 4-2. METERING DISPLAY

Information	Displayed at Function Field	Displayed at Value Field
Phase A current (mag.)	IA	numerical, A (X.X)
Phase A current (ang.)	IA	deg. (X.X)
Phase A voltage (mag.)	∠ VAG	numerical, v (XX.X)
Phase A voltage (ang.)	∠ VAG	deg. (XX)
Phase B current (mag.)	IB	(0.0)
Phase B current (ang.)	∠ IB	(0)
Phase B voltage (mag.)	VBG	(0.0)
Phase B voltage (deg.)	∠ VBG	(0)
Phase C current (mag.)	IC	(0.0)
Phase C current (ang.)	∠ IC	(0)
Phase C voltage (mag.)	VCG	(0.0)
Phase C voltage (ang.)	∠ VCG	(0)
Month / Day	DATE	numerical (00.00)
Hour / Minute	TIME	numerical (00.00)
Local/Remote Setting	SET	LOC/REM/BOTH
Carrier Receive -1	RX1*	YES/NO
Carrier Receive -2	RX2*	YES/NO
LOP indication	LOP	YES/NO
LOI indication	LOI	YES/NO
Out-of-Step Block	OSB*	YES/NO

* Optional

TABLE 4-3. TARGET (FAULT DATA) DISPLAY (SHEET 1 OF 2)

Information	Displayed at Function Field	Displayed at Value Field
Month / Day	DATE	XX.XX
Year	YEAR	XXXX
Hour / Minute	TIME	XX.XX
Second	SEC	XX.XX
Fault type	FTYP	AG/BG/CG/AB/BC/CA/ ABG/BCG/CAG/ABC
BKR.#1 ϕA tripped	BK1A	YES/NO
BKR.#1 ϕB tripped	BK1B	YES/NO
BKR.#1 ϕC tripped	BK1C	YES/NO
BKR.#2 ϕA tripped	BK2A	YES/NO
BKR.#2 ϕB tripped	BK2B	YES/NO
BKR.#2 ϕC tripped	BK2C	YES/NO
Zone 1 phase tripped	Z1P	YES/NO
Zone 1 ground tripped	Z1G	YES/NO
Zone 2 phase tripped	Z2P	YES/NO
Zone 2 ground tripped	Z2G	YES/NO
Zone 3 phase tripped	Z3P	YES/NO
Zone 3 ground tripped	Z3G	YES/NO
Pilot phase tripped	PLTP*	YES/NO
Pilot ground tripped	PLTG*	YES/NO
High set phase tripped	ITP	YES/NO
High set ground tripped	ITG	YES/NO
Close-into fault trip	CIF	YES/NO
Load-loss tripped	LLT	YES/NO
Ground backup tripped	GB	YES/NO
SPF tripped (SPF)	SPT*	YES/NO
62T tripped (SPT)	62T*	YES/NO
Fault location	Z	(In ohms)
Fault Z angle	FANG	(numerical)
Fault distance	DMI or DKM	(in miles or KM)
Prefault load current	PFLC	numerical, A
Prefault phase voltage	PFLV	numerical V
Prefault load angle	LP	numerical deg.
Carrier send	SEND*	YES/NO
Receiver #1	RX1*	YES/NO
Receiver #2	RX2*	YES/NO
Weakfeed tripped	WFT*	YES/NO

TABLE 4-3. TARGET (FAULT DATA) DISPLAY (SHEET 2 OF 2)

	Displayed at	
Information	Function Field	Value Field
Fault type	FTYP	AG/BG/CB/AB/BC/CA ABG/BCG/CAG/ABC
Fault voltage VA (mag.)	VPA	numerical, V
(ang.)	∠ VPA	numerical deg.
Fault voltage VB(mag.)	VPB	numerical V
(ang.)	∠ VPB	numerical deg.
Fault voltage VC(mag.)	VPC	numerical V
(ang.)	∠ VPC	numerical deg.
Fault voltage 3V0(mag.)	3VO	numerical V
(ang.)	∠ 3VO	numerical deg.
Fault voltage IA(mag.)	IPA	numerical A
(deg.)	∠ IPA	numerical deg.
Fault voltage IB(mag.)	IPB	numerical A
(deg.)	∠ IPB	numerical deg.
Fault voltage IC(mag.)	IPC	numerical A
(deg.)	∠ IPC	numerical deg.
Fault current IN(mag.)	IN	numerical A
(deg.)	∠ IN	numerical deg.
Month/Day	DATE	XX.XX
Year	YEAR	1980-2079
Hour/Minute	TIME	XX.XX
Second	SEC	XX.XX

TABLE 4-4. RECOMMENDED JUMPER POSITIONS (V2.XX)

INTERCONNECT Module

JMP 1 to 6, & 13	For the rated input dc voltage
JMP 7 & 9	For Stub Bus Protection
JMP 8 & 10	For the trip alarm (AL2-2)
JMP 11 & 12	For MDAR with FT switches only

MICROPROCESSOR Module

JUMPER	POSITION	FUNCTION
JMP 1	1-2	EEPROM (8kx8)
JMP 2	2-3	Standard
JMP 3	IN	Spare jumper
JMP 4	OUT	No dropout time delay for trip contacts
JMP 5	OUT	Disable output contact test
JMP 6	OUT	Normal operation
JMP 8 & 9	1-2	RAM (32kx8)
JMP 10	IN	Spare jumper
JMP 11 & 12	OUT	Spare positions

Section 5. SETTING CALCULATIONS

5.1 CALCULATION OF MDAR SETTINGS

The following MDAR setting calculations correspond to the setting categories in the Installation Section (4). Assume that the protected line has the following data:

- 18.27 miles
- Line reactance 0.8 ohms/mile
- 69 kV, 60 cycles
- Positive and negative sequence impedances:
  ZIL(Pri) = Z2L(Pri) = $15\angle 77°$ ohms
- Zero sequence impedance: /
  Z_{0L}(pri) = $50\angle 73°$ ohms
- Current Transformer Ratio (CTR):
  RC = 1200/5 = 240 (Set CTR = 240)
- Voltage Transformer Ratio (VTR):
  RV = 600/1 = 600 (Set VTR = 600)
- Relay secondary ohmic impedances are:

  $Z = Z_{pri} \times R_C/R_V$

  $Z_{1L} = Z_{2L} = 15\angle 77° \times 240/600 = 6\angle 77°$ ohms

  $Z_{0L} = 50\angle 73° \times 240/600 = 20\angle 73°$ ohms

5.1.1 Ratio of Zero and Positive Sequence Impedances

$ZR = Z_{0L}/Z_{1L} = 20/6 = 3.33$

then MDAR will automatically calculate the zero sequence current compensation factor (k_0) by using the value of ZR, i.e.,

$$k_0 = (Z_{0L} - Z_{1L})/3Z_{1L} = [ZR\angle(GANG - PANG)\ \text{-}1]/3$$

5.1.2 Zone 1 Distance Unit Settings

A setting of 80% of the line impedance for zone-1 reach is recommended, thus the Zone-1 phase and ground reach should be:

Z1P = 6 x 0.8 = 4.8 and

Z1G = 6 x 0.8 = 4.8

NOTE: Z1P and Z1G can be set for different values if the application is required. Refer to Section H, Step 10 for calculation and example.

5.1.3 Zone 2 Distance Unit Settings

Generally, Zone-2 reach is set for 100% of the protected line plus 50% of the shortest adjacent line. If the shortest (or only) adjacent line primary impedance is 20 ohms, then the Zone-2 reach setting would be:

Z2P = 6 + (20 x 0.5) x 240/600 = 10 and

Z2G = 10

NOTE: Z2P and Z2G can be set for different values if the application is required.

5.1.4 Zone 3 Distance Unit Settings

Generally, Zone-3 reach is set for 100% of the protected line plus 100% of the longest adjacent line emanating from the remote bus, while accounting for the infeed from the same remote bus.

If the longest (or only) adjacent line from the remote bus is 25 ohms primary, and the infeed effect may increase its impedance by 30%, then the Zone-3 reach setting should be:

Z3P = 6 + (25 x 1.3) x 240/600 = 19 and

Z3G = 19

NOTE: Z3P and Z3G can be set for different values if the application is required.

5.1.5 Overcurrent Unit Setting

a. The low set phase overcurrent unit is used for supervising the OSB, the load-loss-trip and CIF functions. It should be set higher than the line charging current and below the minimum load current.

NOTE: It should be set above the maximum tapped load current if applicable.

Assume that the line charging current is negligible for this line section, and the minimum load current is 2.0 A secondary, then the low set phase overcurrent unit setting should be:

IL = 1

b. The low-set ground overcurrent unit is used for supervising the reverse directional overcurrent ground unit (RDOG). It should be set as sensitive as possible. A setting of 0.5 amperes is recommended:

IOS = 0.5

c. The medium set ground overcurrent unit is used for supervising the Zone 1, Zone 2 and Zone 3 ground distance units (Z1G, Z2G and Z3G), the forward directional overcurrent ground unit (FDOG). Generally, it is recommended to be set 2 times the IOS setting.

IOM = 2 x IOS = 1.0

d. The directional high set overcurrent phase and ground units (ITP and ITG) are used for direct trip function. The general setting criterion for the instantaneous direct trip unit is:

The unit should be set higher than 1.15 times the maximum fault on the remote bus, where the factor of 1.15 is to allow for the transient overreach. For this example, assume that the maximum load is not higher than the maximum forward end zone fault current, and the maximum phase and ground fault currents on the remote bus are 20 and 24 amperes, respectively, then the settings of the high-set phase (ITP) and the high-set ground (ITG) should be:

ITP = 20 x 1.15 = 23

ITG = 24 x 1.15 = 27.6

5.1.6 OSB Blinder Settings (RT and RU)

The requirements for setting the blinder units are:

- Inner blinder must be set to accommodate maximum fault resistance for internal 3-phase fault
- Inner blinder should not operate on severe stable swings
- Outer blinder must have adequate separation from inner blinder for fastest out-of-step swing to be acknowledged as an out-of-step condition
- Outer blinder must not operate on load

a. Setting the Inner Blinder

If the OSB is used to supervise tripping of the 3ϕ unit on heavy load current, the inner blinder 21BI must be set sufficiently far apart to accommodate the maximum fault arc resistance. A reasonable approximation of arc resistance at fault inception is 400 volts per foot. If a maximum ratio of "line voltage per spacing" is 10,000 volts/ft. for a high voltage transmission line, and if a minimum internal 3-phase fault current is calculated as:

$$I_{min.} = [E / 1.73(Z_A+Z_L)]$$

where Z_A is maximum equivalent source impedance, Z_L is line impedance and E is line-to-line voltage.

then $R_{max.} = 400 \times FT / I_{min.}$

$$= 400 \times 1.73(Z_A+Z_L)/10000$$

$$= 0.0693\ (Z_A+Z_L)$$

Adding a 50% margin to cover the inaccuracies of this expression:

$$R_{max.} = 0.104(Z_A+Z_L) \text{ primary ohms}$$

$$R_S = 0.104(Z_A+Z_L)R_C/R_V \text{ secondary ohms}$$

Set inner blinder to:

$$R_T = R_S \times \cos(90° - \text{PANG}) \qquad (1)$$

This is the minimum permissible inner blinder setting when it is used to provide a restricted trip area for a distance relay.

Another criterion that may be considered is based upon the rule of thumb that stable swings will not involve an angular separation between generator voltages in excess of 120°. This would give an approximate maximum of:

$$Z_{inner} = (Z_A+Z_L+Z_B)/\ (2 \times 1.73) \qquad (2)$$

$$= 0.288(Z_A+Z_L+Z_B) \text{ primary ohms}$$

$$Z_{inner} = 0.288(Z_A+Z_L+Z_B)R_C/R_V \text{ secondary ohm}$$

where Z_B is the equivalent maximum source impedance at the end of the line away from Z_A.

An inner blinder setting between the extremes of equations (1) and (2) may be used. This provides operation for any 3-phase fault with arc resistance, and restraint for any stable swing. Except in those cases where very fast out-of-step swings are expected, the larger setting can be used.

It will usually be possible to use the minimum inner blinder setting of 1.5 ohms.

b. Setting the Outer Blinder

For slow out-of-step swings, a reasonably close placement of outer to inner blinder characteristic is possible. The separation must, however, be based on the fastest out-of-step swing expected. A 50 ms interval is inherent in the out-of-step sensing logic, and the outer blinder must operate 50 ms or more ahead of the inner blinder.

Since the rate of change of the ohmic value manifested to the blinder elements is dependent upon accelerating power and system WR^2, it is impossible to generalize. However, based on an inertia constant (H) equal to 3, and the severe assumption of full load rejection, a machine will experience (assuming a uniform acceleration) an angular change in position of no more than 20° per cycle on the first half slip cycle.

If the inner blinder were set for ($0.104Z_T$), and the very severe 20° per cycle swing rate were used, the outer blinder should be set for approximately:

$Z_{outer} = 0.5\ Z_T$ primary ohms (3)

where $Z_T = Z_A + Z_B + Z_L$

This is the minimum setting of the outer blinder for a 20° per cycle swing rate.

5.1.7 Overcurrent Ground Backup Unit (GB)

The overcurrent ground backup unit GB provides seven sets of curves, which are similar to the CO and MCO curves, for backing up the distance ground on high resistance ground faults. Four settings (GBCV, GBPU, GTC and GDIR) should be determined for applying this unit.

a. GBCV is the ground backup curve selection. Seven sets of familiar CO curves are provided (C02,5,6,7,8,9 and 11), and are shown in Figures 2-1 thru 2-7. The selection is based on the application and coordination time. A selection of “OUT” disables the ground backup function.

b. GBPU is the current level setting. Its range is 0.5 to 4.0 amperes in 0.5 steps. In general, the current level setting criterion is:

$(I_{Fmin}/2)$ > Setting level > 2 x (Max. residual load, $3I_0$)

where I_{Fmin} = Minimum ground fault current for a fault two buses away

For better sensitivity, GBPU should be set at 0.5 amperes, this would be adequate for most of the application.

c. GTC is the time delay setting of the GB unit. As shown in Figures 2-1 thru 2-7, it has 63 setting selections, from 1 to 63 in 1.0 steps. In general, the time delay setting should be coordinated with any protective device downstream of the line section.

d.GDIR is the setting for directional control selection. The GB unit will become a directional torque control overcurrent ground unit if GDIR is set at YES. The following equation can be used to calculate the trip time for all CO curves from CO-2 thru CO-11 :

$$T\ (\text{sec}) = \left[T_0 + \frac{K}{(3I_0 - C)^P}\right] \times \frac{GTC}{24,000} \qquad (\text{for } 3I_0 \geq 1.5)$$

$$T\ (\text{sec}) = \frac{R}{(3I_0 - 1)} \times \frac{GTC}{24,000} \qquad (\text{for } 1 < 3I_0 < 1.5)$$

Where $3I_0 = \frac{I_F}{GBPU}$

GBPU = Pickup current setting (0.5 to 4.0A).

GTC = Time curve dial setting (1 to 63).

T_0, K, C, P and R are constants, and are shown in Table 5-3. (Refer also to the example in Appendix H, Section 1.1.9.)

Taking the CO-8 curve set as an example (see Figure 2-5), assuming that the maximum 3Io of unbalanced load is 0.2A, the minimum ground fault current for a fault two buses away is 10A, and 0.7 seconds is required for coordination with current of 20 times the GBPU setting, then the settings of the GB function should be as shown below:

10/2 > GB > 2 x 0.2 set GBPU = 0.5

Using the curve in Figure 2-1, for 0.7 seconds at 20 times the GBPU setting, GTC should be set to 24.

- Set GBCV = C0-8 and
- Set GDIR = YES if directional control is required.

5.1.8 Timer Settings

a. Zone-2 timer (T2) setting should be coordinated with the Zone-1 and other high-speed trip units on the adjacent line terminal. Coordination Time Interval (CTI) of 0.3 to 0.5 seconds is recommended. For example, if T2 of 0.4 seconds is used, then the phase and ground Zone-2 timers should be set as follows:

T2P = 0.4 and T2G = 0.4

NOTE: T2P and T2G are separate timers; they can be set at different time settings.

b. Zone-3 timer (T3) settings would be similar to the above. For example, if T3 of 0.8 seconds is required, then the phase and ground Zone-3 timer should be set as follows:

T3P = 0.8 and T3G = 0.8

NOTE: T3P and T3G are separate timers; they can be set at a different time settings.

c. For out-of-step block (OSB), if applied, the OSB override timer setting (OSOT) is determined by the power system operation. Its range is 400 to 4000 ms, in 16 ms steps. For example, set MDAR OSOT = 500 if OSB override time of 500 ms is required.

d. For single-pole trip application only, the single phasing limit timer setting (62T) is for preventing thermal damage to rotating machines, due to the I_2 component during single phasing. Its range is 300 to 5000 ms. in 50 ms steps. The setting should be based on the poorest $(I_2)^2t$ constant of the machines in service. For example, set MDAR 62T = 1550, if 3PT is required before 1.55 seconds and after one pole has been open and the breaker does not or cannot reclose.

e. For the blocking system only, the channel coordination timer setting (BLKT) is based on the following application criteria:

BLKT > (Slowest remote carrier start time + channel time + margin) - (the fastest local 21P/21NP pickup time)

Where channel time includes the transmitter and receiver times, and the times which occur between these devices, e.g., wave propagation, interfacing relays, etc.

For MDAR:

fastest 21P/21NP pickup time	=	14 ms
slowest carrier start time	=	4 ms
suggested margin time	=	2 ms

For example, the MDAR channel coordination timer should be determined as shown below, if the channel time is 3 ms.

BLKT = (4 + 3 + 2) - 14= -5

i.e., set BLKT = 0

5.2 SELECTION OF MDAR SETTINGS

The following settings are determined by the application. They do not require calculation.

5.2.1 The OSC setting is for selecting one of the 4 ways (TRIP/Z2TR/Z2Z3/ΔIΔV) to initiate the oscillographic data taken, where:

TRIP --- start data taken only if trip action occurs.

Z2TR --- start data taken if Zone 2 units pick up, or any trip action occurs.

Z2Z3 --- start data taken if Zone 2 or Zone 3 units pick up, or any trip action occurs.

ΔIΔV --- start data taken if ΔI, ΔV, Zone 2 or Zone 3 units pick up, or any trip action occurs.

NOTE: The setting of ΔI, ΔV, for OSC is not recommended.

5.2.2 The FDAT setting is for selecting one of the 3 ways (TRIP/Z2TR/Z2Z3) to initiate the fault data taken, where:

TRIP --- start to store fault data only if trip action occurs.

Z2TR --- start to store fault data if Zone 2 units pick up or any trip action occurs.

Z2Z3 --- start to store fault data if Zone 2 or Zone 3 units pick up or any trip action occurs.

5.2.3 The current transformer ratio setting (CTR) is used for the load current monitoring, if it is selected to be displayed in primary amperes. It has no effect on the protective relaying system. For this example, set CTR = 240.

5.2.4 The voltage transformer ratio setting (VTR) is used for the system voltage monitoring, if it is selected to be displayed in primary volts. It has no effect on the protective relaying system. For this example, set VTR = 600.

5.2.5 The frequency setting (FREQ) should be selected to match the power system operating frequency. For example, select FREQ = 60 if the power system operating frequency is 60 Hertz.

5.2.6 The current transformer type setting (CTYP) provides the flexibility for 5 Amp or 1 Amp rated current transformer selection. For example, select and set CTYP = 5 if a 5 Amp current transformer is used.

The setting of CTYP affects all the distance unit and overcurrent unit setting ranges. The ranges will be automatically changed as listed in Table 5-1.

5.2.7 The read primary setting (RP) should be set at YES if all the monitoring ac voltages and currents are selected to be displayed in primary KV and KA values, respectively.

5.2.8 The ohms per unit distance of the line reactance setting (XPUD) is the multiplier for fault distance display. It has a range of 0.3 to 1.5 in 0.001

steps. In this example, the line reactance is 0.8 ohms/mile; set XPUD = 0.8.

The fault distance calculation is as follows:

$$DMI = \frac{VTR}{CTR} \times \frac{Z_S \times \sin\angle FANG}{XPUD}$$

Where Z_S is the secondary impedance magnitude, and FANG is the fault angle.

5.2.9 The setting of DTYP (distance type) has a selection of MILE and KM. It should be selected to match with the setting of XPUD. For this example, select DTYP = MILE.

5.2.10 The setting of TTYP is for selecting the reclosing mode in single pole trip applications (if applicable). It has six selecting positions (OFF, 1PR, 2PR, 3PR, SPR, and SR3R). Refer to the guidelines for reclosing mode programming for the TTYP setting selection.

5.2.11 For an SPT application, set the 62T single phasing limit timer from 300 to 5000 ms in 50 ms steps. The setting is based on the generator's $(I_2)^2t$ performance. LV should be set between 85% and 90% of the rated line-to-neutral voltage.

5.2.12 The settings of Z1RI, Z2RI and Z3RI provide the selectivity for Zone 1 RI (reclosing initiation), Zone 2 RI and Zone 3 RI, respectively. For the non-pilot system application, set Z1RI, Z2RI and/or Z3RI to YES, if RI is required when the particular distance zone operates. For the pilot reclosing, Z1RI should be set to "YES".

5.2.13 For a pilot system, set BFRB to YES if RB on the breaker failure squelch feature is required.

5.2.14 The setting of PLT (pilot) combines with the signal of Pilot Enable (on the backplane panel) and controls the operation of pilot and reclosing initiation. The absence of either signal will:

- disable the pilot system
- block the RI2 output, and
- allow an RI1 output for a non-pilot system.

The PLT can be set either locally from the front panel or, remotely, via the communication channel.

5.2.15 The STYP (system type) selects the desired relaying system for the application. It has two selections: 3ZNP (3 zone non-pilot) and Z1E (Zone 1 extension) in the non-pilot MDAR. There are five selections: 3ZNP, Z1E, POTT (permissive overreach transfer trip or unblocking), PUTT (permissive underreach transfer trip) and BLK (blocking) in the pilot MDAR. It should be set to the desired selection.

5.2.16 For the pilot MDAR only, the WFEN (weakfeed enable) selection should be set to YES for the weakfeed terminal, if applicable.

5.2.17 For pilot MDAR only, the 3TRM (3 terminals) setting should be selected to YES for all of the three terminals that apply.

5.2.18 For application of POTT/BLK systems, the transient block logic is always in the POTT/BLK system, but it is initiated by the reverse looking units. The Z3FR setting should be set to "YES" and Z3P, Z3G should be set to 100% of the line impedance.

5.2.19 The FDGT (FDOG trip delay timer) can be set from 0 to 15 cycles or block (BLK) as desired. It is recommended to set to 3 cycles or longer. Refer to Section 3.9 for the detailed FDGT information.

5.2.20 Distance/overcurrent units can be disabled if required by the application. The following distance/overcurrent units can be disabled by setting the unit to OUT:

a. List of units which can be disabled:

PLTP, PLTG, Z1P, Z2P, Z2G, Z3P, Z3G, ITP, ITG and GB.

b. Procedure to disable the unit:

Switch MDAR to the setting mode, scrolling the function field to the proper function Then set the unit to OUT via the value field.

5.2.21 Set T1 to YES if Zone 1 delay trip is required.

5.2.22 The T2P, T2G, T3P and/or T3G timer functions can be disabled, if desired, by setting the timer to BLK.

5.2.23 The Zone 3 distance units (Z3P and Z3G) can be selected to reach forward-looking or reverse-looking by setting the Z3FR (Zone 3 forward or reverse) to FWD or REV.

5.2.24 Set the positive sequence impedance angle (PANG) value based on the positive sequence line impedance angle. This setting affects the performance of the distance units.

5.2.25 Set the zero sequence impedance angle (GANG) value based on the zero sequence line impedance angle. This setting affects the performance of the distance units.

5.2.26 Set the ZR value based on the absolute value of the ratio of the line impedances (Z_{OL}/Z_{1L}).

5.2.27 The LV units are used in CIFT, SPT and weakfeed logic in the MDAR. They should normally be set to 40 volts unless a higher setting is required for more sensitive applications. Refer to Section 5.2.11 for the SPT application.

5.2.28 The polarizing approach for the directional ground overcurrent unit is controlled by the setting of DIRU. It has 3 selections:

ZSEQ --- Voltage polarization only.

DUAL --- Both voltage and current polarization.

NSEQ --- Negative sequence voltage and current polarization.

5.2.29 Set GDIR to YES if directional control is required for the GB function.

5.2.30 Based on the requirements, set Close-Into-Fault (CIF) and stub-bus protection functions, by selecting the value field (CIFT/STUB/BOTH/NO) of CIF, where:

CIFT --- CIF trip but not stub-bus protection has been selected.

STUB --- Stub-bus protection but not CIF trip has been selected.

BOTH --- Both CIF trip and stub-bus protection have been selected.

NO --- Neither CIF nor stub-bus protection has been selected.

Set LLT (loss-of-load trip) to YES, FDOG or NO, where:

YES --- LLT trip with Z2 supervision.

FDOG --- LLT trip with both Z2 and FDOG supervision.

NO --- LLT trip function is not used.

5.2.31 Set LOPB to YES, if loss-of-potential block trip function is required.

5.2.32 Set LOIB to YES, if loss-of-current block trip function is required.

5.2.33 Set AL2S to YES, if trip alarm seal-in is required. The Reset pushbutton can be used to reset the sealed AL2.

5.2.34 Set the SETR to YES if remote setting is required.

5.2.35 Procedure to set the real-time clock:

5.2.36 With MDAR in the "setting" mode, scroll the function field to TIME, and set the value to YES. Depress function pushbutton RAISE to display YEAR, MNTH (month, DAY, WDAY (week day), HOUR, and MIN (minute), and set the corresponding number via the value field. The MDAR clock will start at the time when the minute value is entered.

5.3 GUIDANCE FOR RECLOSING INITIATION MODE PROGRAMMING

5.3.1 For non-pilot without SPT system:

a. Select TTYP = OFF or 1PR, or 2PR or 3PR, and

b. Select PLT = NO, and

c. Use the RI2 output contact for the reclosing circuit, and

d. Select one or all of the Z1RI, Z2RI and Z3RI to YES, depending on the application.

5.4 5.3.2 For non-pilot with SPT system:

a. Select TTYP = OFF or 1PR, or 2PR, or 3PR, or SPR or SR3R and

b. Select one or all of the Z1RI, Z2RI and Z3RI to YES, depending on the application.

c. Use the RI1 output contact for the SRI reclosing timing circuit, and the RI2 output contact for the 3RI timing circuit.

The Reclosing Initiation mode will be based on the TTYP setting, as shown in Table 5-2.

TABLE 5-1. CURRENT TRANSFORMER SETTINGS

MDAR UNITS	At CTYP = 5	At CTYP = 1
Z1P/Z1G/Z2P/Z2G Z3P/Z3G/PLTP/PLTG	0.01-50.00, in 0.01 Ω steps	0.05-250, in 0.05 Ω steps
ITP/ITG	2.0-150.00, in 0.5 A steps	0.4-30.0. in 0.1 A steps
IL/IOS/IOM	0.5-10.0, in 0.1A steps	0.1-2.0, in 0.02 A steps

TABLE 5-2. RECLOSING INITIATION MODE PROGRAMMING

TTYP	TYPE OF FAULT	RECLOSING MODE
OFF	all	no reclosing
1PR	ϕG Other Faults	RI2 contact closes; no reclosing
2PR	ϕG, $\phi\phi$ 3ϕ	RI2 contact closes; no reclosing
3PR	all	RI2 contact closes
SPR	Phase-to-ground Other Faults	RI1 contact closes; no reclosing
SR3R	Phase-to-ground Other Faults	RI1 contact closes; RI2 contact closes

TABLE 5-3. TRIP TIME CONSTANTS FOR CURVES

CURVE #	T_0	K	C	P	R
C02	111.99	735.00	0.675	1	501
C05	8196.67	13768.94	1.13	1	22705
C06	784.52	671.01	1.19	1	1475
C07	524.84	3120.56	0.8	1	2491
C08	477.84	4122.08	1.27	1	9200
C09	310.01	2756.06	1.35	1	9342
C011	110	17640.00	0.5	2	8875

Section 6. ACCEPTANCE TESTS (V2.02)

The following kinds and quantities of test equipment are used for the MDAR Acceptance Tests:

- Voltmeter (1)
- Ammeter (1)
- Phase Angle Meter (1)
- Load Bank (2)
- Variac (3)
- Phase Shifter (1)
- Optional Doble or Multi-Amp Test System

NOTE: Before turning on the dc power supply, check jumper positions on the Interconnect and Microprocessor modules as shown in Table 4-4. Also, refer to this table for relay system operation.

Refer to the NOTE under Tables 6-1 and 6-3 for 1 amp ct application.

1. FULL PERFORMANCE TESTS

Full performance tests explore MDAR responses and characteristics for engineering evaluation. They are in two parts: Non-Pilot and Pilot Acceptance Tests.

NOTE: Customers who are familiar with the MDAR performance and characteristics should disregard this section and proceed directly to Section 2 “Maintenance Tests”.

1.1 Non-Pilot Performance Tests

To prepare the MDAR relay assembly for Non-Pilot Acceptance Tests, connect the MDAR per Figure 6-1, Configuration 1.

1.1.1 Front Panel Check

Step 1. Turn on rated battery voltage. Check the FREQ setting to match the line frequency and ct type CTYP. Apply a balanced 3-phase voltage (70 Vac); the Alarm-1 relay should be energized. (Terminals TB4-7 and -8 should be zero ohms.)

Step 2. Check “RELAY-IN-SERVICE” LED; it should be “ON”.

Step 3. Press “RESET TARGETS” push-button; the green LED (Volts/Amps/Angle) should be “ON”.

Step 4. Using a dc voltmeter, measure the dc voltages on the front panel display with respect to common (± 5 %).

Step 5. Press the DISPLAY SELECT pushbutton, and note that the mode LED cycles thru the five display modes. Release the pushbutton so that the SETTINGS mode LED is “ON”.

Step 6. Refer to the Installation Section, Table 4-1, for all possible MDAR SETTINGS, and set the values in accordance with Table 6-1. For Negative Sequence Directional Unit, change DIRU from ZSEQ to NSEQ. For dual polarizing directional ground unit, change DIRU to DUAL.

Step 7. Press the DISPLAY SELECT pushbutton to obtain the METERING mode (VOLTS/ AMPS/ ANGLE). (Refer to Installation Section, Table 4-2.)

1.1.2 Angle Current and Voltage Input Check

Step 8. Using Figure 6-1, Configuration 1, apply three ac voltages of 70 V_{LN} and an ac current of 1A. Adjust phase A current to lag phase A voltage (V_{AN}) by 75°.

Step 9. Press FUNCTION RAISE or FUNCTION LOWER pushbutton. Read input current (IA), input voltage (V_{AG}), and angle (ANG). All values within 5%.

NOTE: Be sure that the RP setting is “NO”. If the RP setting is “YES”, the readings will be the primary side values.

The angle measurement is for reference only. For I<0.5A, the display of angle will be blocked and show zero degrees.

1.1.3 Zone 1 Test/Single-Phase-To-Ground

Step 10. Using Figure 6-1, Configuration 1, adjust:

V_{1N} = 30V

V_{2N} = 70V

V_{3N} = 70V

MDAR goes into fault mode processing only after the current detector is enabled. MDAR performs the test:

- Phase current (ΔI_A, ΔI_B, or ΔI_C) >1.0A peak and 12.5% change
- Ground current (ΔI_0)>0.5 A peak
- Voltage (ΔVan, ΔVbn, or ΔVcn) >7V and 12.5% change with a current change of ΔI>0.5 A

When one of the above is true, MDAR starts fault processing. In order to perform the above, apply a certain value of current *suddenly.* If MDAR does not trip, turn the current off, readjust to a higher value, and then *suddenly* reapply current.

The current required to trip can be calculated using the following:

$$I = \frac{V_{LN}}{Z_{1G}COS(PANG - X)\left[1 + \frac{(Z_R - 1)}{3}\right]}$$

From Table 6-1:

- Z1G = 4.5 Ω
- PANG = 75°
- ZR = 3.0

using an X = 75° (lagging)

The current required to trip = 4.00A $\pm 5\,\%$ for fault current lagging fault voltage by 75°. This is the maximum torque angle test. For other points on the MHO circle, change X to a value between 0° and 150°, and calculate the value of I.

See Table 4-3, for a description of the following displayed fault data for:

- Fault Type (FTYP)
- Targets (BK1, Z1G)
- Fault Voltages (V_A, V_B, V_C, $3V_0$) and Currents (I_A, I_B, I_C, $3I_0$)

With the external jumper connected between TB1-13 and TB1-14, the BFIA-1, BFIA-2 should be closed. The GS contact will be ON for approximately 50 ms. when the fault is applied. Alarm 2 relay will be picked-up, which can be reset by the RESET button after the fault is removed. Change TTYP to 1PR; the RI2-1 and RI2-2 should be CLOSED. Change TTYP to 2PR (or 3PR). Repeat test; RI2-1 and RI2-2 should be closed. Change TTYP to “OFF”. Repeat test. RI2-1, RI2-2 should not be picked-up.

Repeat AG fault and measure the trip time, which should be < 2 cycles. Change the setting of T1 from No to Yes. Repeat the test; the trip time should extend for an additional 2 cycles. Reset T1 to zero.

The following formula can be used when PANG ≠ GANG:

$$Vxg = (I_X + K_0 I_0)\, Zcg$$

$$\text{or}\quad Vxg = \left(I_x + \frac{K_0 I_x}{3}\right) Zcg$$

$$\text{or}\quad I_X = \frac{V_{xg}}{Z_{cg}\left(1 + \frac{K_o}{3}\right)}$$

where

$$K_0 = \frac{(Z_{oL} - Z_{1L})}{Z_{1L}}$$

$$= |Z_R|\angle(GANG - PANG)\ \text{-}1$$

$$I_X = \frac{V_{xg}}{|Z_{cg}|e^{jPANG}\left[1 + \frac{|Zr|e^{j(GANG - PANG)} - 1}{3}\right]}$$

$$\text{or}\quad I_X = \frac{V_{xg}}{\frac{2}{3}|Z_{cg}|e^{jPANG} + \frac{1}{3}|Z_{cg}||Zr\ |e^{jGANG}}$$

Example:

Vag = 30 Z1g = 4.5 PANG = 85
GANG = 40 Zr = 3

$$Ia = \frac{30}{\frac{2}{3}(4.5)e^{j85} + \frac{1}{3}(4.5)(3)e^{j40}}$$

$$= \frac{30}{3\cos(85) + j\,3\sin(85) + 4.5\cos(40) + j4.5\sin(40)}$$

$$= 4.31\angle(-57.76)$$

This is the trip current (4.3A) at the maximum torque angle of -57.76° (current lags voltage by 57.76°).

The following equation should be used for the angle of x on the MHO circle:

$$Iax = \frac{30}{6.96\cos(57.76 - x)}$$

Step 11. Using Figure 6-1, Configurations 2 and 3, repeat (preceding) Step 10 for BG and CG faults. Note Targets**.**

1.1.4 Zone 1 Test/Three-Phase

Step 12. Using Figure 6-2, connect current and voltage circuits and apply:

- V_{AN} = 30V ∠0° IA = 6.67 ∠–75°
- V_{BN} = 30V ∠–120° IB = 6.67 ∠–195°
- V_{CN} = 30V ∠120° IC = 6.67 ∠+45°

Using a value of x = 75° (lagging), the current required to trip is calculated as follows (Note Targets):

$$I = \frac{V_{LN}}{Z_{1P}\cos(PANG - X)} = 6.67A \quad \pm 5\%$$

Since V2.00 uses $I_A + I_B + I_C$ to calculate $3I_0$, a balanced 3-phase current source is recommended to be used for this test ($3I_0 = 0$). Figure 6-2 gives a concept of the test. If a Doble or Multi-Amp test set is used, be sure to synchronize the 3-phase currents. If possible, use a multi-trace storage scope to verify the waveforms of I_A, I_B and I_C.

In order to plot the MHO circle for different input angle (X), the setting of RT (and RU, if OSB option is included) should be at maximum (15 ohms). The RT setting is used for load restriction. (Refer to OSB test for detailed information.) Set TTYP = 3PR. Repeat test; RI2-1 and RI2-2 should be closed. For TTYP = OFF, or 1PR, or 2PR repeat the test. RI2-1 and RI2-2 should be open.

1.1.5 Zone 1 Test/Phase-To-Phase

Step 13. Two methods can be used for this test.

a. Using T-connection (with Doble or Multi-Amp Test Unit; refer to Figure 6-3 for external terminal connection and configuration 1.

- V_A = 1/2 V_F @ 0°
- V_B = 1/2 V_F @ 180°
- V_C = 3/2 (70) = 105V @ 90° lead

Using $V_F = V_A - V_B$ = 30V

- V_A = 15V @ 0°
- V_B = 15V @ 180°

NOTE: Current (I_A) required to trip = 3.33A ± 5%, with an angle of -75 degrees.

The following table is for BC and CA fault tests when the T-connection is used:

BC		CA	
V_{AN}	= 105 ∠90°	V_{AN}	= 15 ∠180°
V_{BN}	= 15 ∠0°	V_{BN}	= 105 ∠90°
V_{CN}	= 15 ∠180°	V_{CN}	= 15 ∠0°
I_F	= 3.33 ∠-75°	I_F	= 3.33 ∠–75°

b. Using Y-connection

NOTE: This test is actually for ϕϕG testing (see Figure 6-3, configuration 1).

$$V_{AN} = \frac{1}{2} V_F \left(\frac{2}{\sqrt{3}} \angle 0°\right)$$

$$V_{BN} = \frac{1}{2} V_F \left(\frac{2}{\sqrt{3}} \angle -120°\right)$$

$$V_{CN} = \left(\frac{3}{2} \times 70 - \sqrt{|V_{AN}|^2 - \left|\frac{1}{2} V_F\right|^2}\right) \angle 120°$$

or

V_{AN} = 17.3 ∠0°

V_{BN} = 17.3 ∠–120°

V_{CN} = 96.4 ∠120°

For either T or Y connection, using a value of x = 75° (lagging), current required to trip:

$$I = \frac{V_F}{2Z_{1P}\cos(\text{PANG} - X)}$$

From Table 6-1:

- Z_{1P} = 4.5 Ω
- PANG = 75°

For Y-connection only, current (IA) required to trip = 3.33A ±5%, with an angle of -45°, because Ian has already lagged V_F (V_{ab}) by 30°. Review all targets.

NOTE: The accuracy of the voltage reading in the metering mode is between 1 and 77 Vrms. The inaccurate reading on V_{CN} will not affect the results of the test.

The reclose contacts (RI2-1 and RI2-2) should be closed for setting of TTYP = 2PR or 3PR, and should be open for TTYP = OFF or 1PR.

Step 14. Repeat Step 13 for both BC and CA faults. Use the following voltages for each fault type:

BC	CA
$V_{AN} = 96.4\angle 120°$ V	$V_{AN} = 17.3\angle -120°$ V
$V_{BN} = 17.3\angle 0°$ V	$V_{BN} = 96.4\angle 120°$ V
$V_{CN} = 17.3\angle -120°$ V	$V_{CN} = 17.3\angle 0°$ V
$I_F = 3.33\angle -45°$	$I_F = 3.33\angle -45°$

1.1.6 Zone 2 Tests

Step 15. Press the DISPLAY SELECT pushbutton until the SETTINGS mode LED is displayed. Change the setting values to:

- Z1P = "OUT" (Zone 1 phase value)
- Z1G = "OUT" (Zone 1 ground distance)
- Z2P = 4.5 Ω (Zone 2 phase value)
- T2P = 1.0 sec (Zone 2 phase timer)
- Z2G = 4.5 Ω (Zone 2 ground value)
- T2G = 1.5 sec (Zone 2 ground timer)
- Z2RI = "YES" (Zone 2 reclosing)
- TTYP = "3PR" (Reclosing mode)

Step 16. Perform Steps 10 thru 14 (above) for Zone 2 only, using delayed trip times according to the zone 2 phase timer (T2P), and the Zone 2 ground timer (T2G). Tolerances for T2P and T2G are 5% for an input current that is 10% above the calculated value.

Repeat Step 10.The RI2 contacts 1 and 2 should be closed, and the RB contacts 1 and 2 should be open. Reset Z2RI to "NO".

Repeat Step 10 again. The RI2 contacts 1 and 2 should be open and the RB contacts 1 and 2 should be closed.

Change the settings of T2G and T2P to BLK. Zone 2 should not be tripped for any type of fault.

1.1.7 Zone 3 Tests

Step 17. Press the DISPLAY SELECT pushbutton until the SETTINGS mode LED is displayed. Change the setting values to:

- Z2P = "OUT" (Zone 2 phase value)
- Z2G = "OUT" (Zone 2 ground distance)
- Z3P = 4.5 Ω (Zone 3 phase value)
- T3P = 2.0 sec (Zone 3 phase timer)
- Z3G = 4.5 Ω (Zone 3 ground value)
- T3G = 2.5 sec (Zone 3 ground timer)
- Z3FR = "FWD" (Zone 3 direction)
- Z3RI = "YES" (RI = Z3T)
- TTYP = "3PR" (Reclosing Mode)

Step 18. Perform preceding steps 10 thru 14 for Zone 3 only, using delayed trip times according to the Zone 3 phase timer (T3P), and the Zone 3 ground timer (T3G). Tolerances for T3P and T3G are ±5% for an input current that is 10% above the calculated value.

Repeat Step 10. The RI2 contacts 1 and 2 should be closed, and the RB contacts 1 and 2 should be open. Reset Z3RI to "NO".

Repeat Step 10 again. The RI2 contacts 1 and 2 should be open and the RB contacts 1 and 2 should be closed.

Step 19. Set Z3FR = REV, then repeat Step 10, except apply AG reversed fault (i.e., I_a leads Van by 105°). The relay should trip, at I_a = 4.2A, in 2.5 seconds. Reset Z3FR to "FWD".

NOTE: For customers who use a computer to test the relays, or use their own settings for maintenance, refer to the following example to calculate and determine trip currents; set the relay as follows:

Z1P = ZIG = 4.5 T1 = 0

Z2P = Z2G = 6.0 T2P= T2G = 0.2

Z3P = Z3G = 9.0 T3P= T3G = 0.3

PANG = GANG = 75° ZR = 3

a. Single-Phase-to-Ground Fault

Use the equation in Step 10, and the following input voltages:

$$V_{AN} = 45\angle 0° = V_{LN}$$

$$V_{BN} = 70\angle -120°$$

$$V_{CN} = 70\angle 120°$$

The single-phase trip currents for Zone 1, Zone 2, and Zone 3 at the maximum torque angle $(I_A \angle 75°)$ are 6.0A, 4.5A and 3.0A, respectively.

b. Phase-to-Phase Fault

Use the T-connection and the equation in step 13. Apply the following input voltages:

$$V_{AN} = 18\angle 0° = \frac{1}{2}V_F$$

$$V_{BN} = 18\angle -180° = \frac{1}{2}V_F$$

$$V_{CN} = 105\angle 90°$$

The single-phase trip currents for Zone 1, Zone 2 and Zone 3 at the maximum torque angle $(I_{AB}\angle -75°)$ are 4A, 3A and 2A, respectively.

c. Three-Phase Fault

Use the equation in Step 12 with the following input voltages:

$$V_{AN} = 27\angle 0° = V_{LN}$$

$$V_{BN} = 27\angle -120°$$

$$V_{CN} = 27\angle 120°$$

The three-phase trip currents for Zone 1, Zone 2 and Zone 3 at the maximum torque angles

$$(I_A\angle -75°, I_B\angle -195°, I_C\angle +45°)$$

should be 6.0A, 4.5A and 3.0A, respectively.

1.1.8 Instantaneous Overcurrent (High-Set Trip)

Step 20. Using the SETTINGS mode, change the following settings:

ITP = 10A	LOPB	= "NO"
ITG = 5A	Z3G	= "OUT"
	Z3P	= "OUT"

NOTE: The High-Set ground overcurrent (ITG) and phase overcurrent (ITP) are supervised by Forward Directional Ground unit (FDOG) and Forward Directional Phase unit (FDOP), respectively. In order to test the High-Set trip, the 3ϕ voltages are necessary as directional reference. The ITG and ITP will automatically become non-directional overcurrent units if the setting of LOPB is YES and at least one input voltage is zero volts (e.g., LOPB = YES in the metering mode).

Step 21. Using Figure 6-1, configuration #1, to connect currents and voltages, apply AG fault as shown in Step 1.1.3. The MDAR should trip at I_a = 5 Amps ± 5 % with a target of ITG-AG. For reversed fault, apply 10A reversed fault current (i.e., I_a leads Van by 135° for Y-connection, or 105° for T-connection). The relay should not trip.

Step 22. Using Figure 6-3, to connect currents and voltages, apply AB fault as shown in Step 1.1.5. The MDAR should trip at Iab = 10 Amps ±5%, with a target of ITP - AB. Apply a 15A reversed fault current (i.e., I_a leads V_{ab} by 135° for Y-connection or 105° for T-connection). The relay should not trip.

1.1.9 Ground Backup (GB) Test

Step 23. Use the SETTINGS mode and change the following settings:

- ITP = "OUT"
- ITG = "OUT"
- GBCV = CO-8
- GBPU = .5
- GDIR = "NO"
- GTC = 24

NOTE: The note in Step 20 applies to the GB test. The GB can be set to directional ground overcurrent. For loss-of-potential condition, GB will be converted to non-directional, automatically, regardless of the GDIR=YES setting.

Using Figure 6-1, apply A-G fault of 4.1A to MDAR. Trip time is determined as follows:

$$(T_{MSEC}) = \left[478 + \frac{4122}{3I_0 - 1.27}\right]\frac{GTC}{24}$$

where $3I_0 = \dfrac{3I_{OF}}{GBPU}$

($3I_{OF}$ is zero sequence fault current.)

$$(T_{MSEC}) = \left[478 + \frac{4122}{4.1/0.5 - 1.27}\right]\frac{24}{24}$$

T_{MSEC} = 1073 msec

= 1.073 sec $\pm 5\%$ to trip

For values of $3I_0$ between 1.0 and 1.5, the following equation would apply:

$$(T_{MSEC}) = \frac{(9200)}{3I_0 - 1} \times \frac{GTC}{24}(CO-8 \ \text{only})$$

The following equation can be used to calculate the trip time for all CO curves from CO-2 to CO-11:

T(sec) =

$$\left[T_0 + \frac{K}{(3I_0 - C)^P}\right] \times \frac{GTC}{24,000} \quad (for \quad 3I_0 \geq 1.5)$$

$$T(sec) = \frac{R}{(3I_0 - 1)} \times \frac{GTC}{24,000} \quad (for \quad 1 < 3I_0 < 1.5)$$

where $3I_0 = \dfrac{3I_{OF}}{GBPU}$

GBPU = Pickup current setting (0.5 to 4.0A).

GTC = Time curve dial setting (1 to 63).

T_o, K, C, P and R are constants, and are shown in Table 6-2.

Step 24. For a Zero Sequence Directional unit (DIRU = ZSEQ), the tripping direction of MDAR is: the angle of $3I_0$ leads $3V_0$ between +30° and +210°. Change the setting of GDIR to "YES". Apply AG fault as shown in preceding Step 10, Figure 6-1. The relay should trip at the following angles:

- +28°
- -60° (± 88°)
- -148°

The relay should *not* trip at the angles of:

- +32°
- +120° (± 88°)
- -152°

For a Negative Sequence Directional Unit (DIRU = NSEQ), the tripping direction of MDAR is: I_2 leads V_2 by a value between +8° and +188°. The relay should trip at the following angles:

- +3°
- -82° (± 85°)
- -167°

The relay should not trip at the angles of:

- +13°
- +98° (± 85°)
- +183°

Step 25. For a dual polarizing ground directional unit (DIRU = DUAL) test, connect the test circuit shown in Figure 6-4;apply Ip 1.0A$\angle -90°$ to terminals 12 (+) and 11(-), and apply a balanced 3-phase voltage (70V) to Va, Vb, Vc, and Vn. Apply Ia = 4A to terminals 6(+) and 5(-).

NOTE: In order to eliminate the voltage polarizing effect, make sure the voltages are finely balanced so that 3V0 is less than 1.0 volt.

The relay should trip at the following angles:

- -3°
- -90° (± 87°)
- -177°

The relay should <u>not</u> trip at the following angles:

- +3°
- +90° (±87°)
- +177°

1.1.10 CIF, STUB, Iom, IL and LV Tests

Step 26. Set the relay per Table 6-1. Change the following settings: Iom = 3, IL = 2, CIF = CIFT, and connect a rated dc voltage to 52b, between TB5/3 (+) and TB5/4 (-). Apply an AG fault as shown in Step 10 (Figure 6-1). The relay should trip at I_a = 2A (IL) with CIF target. Change IL setting from 2 to 3.5A and repeat the test shown in Step 26. The relay should trip at I_a = 3A (I_{om}) with CIF target.

Step 27. LV setting test. Set LV = 60 and with I_{AN} = 4A, apply AG fault as shown in Step 10. The CIF trip should be for V_{AN} <60 Vrms ± 5%.

Step 28. For STUB Bus Protection (SBP), check the blue jumpers on the Interconnect module.

JMP7 and 9 should be IN; JMP13 should be at the rated voltage position. Select CIF = STUB. Disconnect the voltage from 52b and connect it to terminals TB5/13(+) and TB5/14(-).

NOTE: Make sure the jumpers (JMP8 and JMP10) are not IN before applying the voltage to TB5/13(+) and TB5/14(-).

Apply I_A = 4A. The STUB bus trips for any V_{AN} voltage with a target of CIF. Disconnect the voltage from SBP and reset $I_{om} = I_L$ = 0.5 and CIF = NO.

1.1.11 Loss-of-Potential (LOP) Test

Step 29. For Load Loss Trip (LLT), set:

LLT = Yes

Z2P = Z2G = 4.5 ohms

T2P = T2G = 2.99 sec (or BLK)

Apply:

Va = $30\angle 0°$

Vb = $70\angle -120°$

Vc = $70\angle 120°$

Ia = $3.5\angle -75°$

Ib = $1\angle -120°$

Ic = $1\angle +120°$

Suddenly increase Ia from 3.5 to 4.5A and then turn I_b OFF immediately. The relay should trip with LLT target. The trip is accelerated due to the pickup of Zone 2 and the setting of LLT = YES.

Change the setting of LLT = FDOG and the input current Ia from 0.5 to 1.5A; then turn I_b OFF immediately. The relay should trip with a target of LLT. The trip is due to the pickup of FDOG and setting of LLT = FDOG.

Reset: LLT = NO

Z2P = Z2G = OUT

T2P = T2G = BLK

Step 30. Disconnect all current inputs. Connect 3 balanced voltages of 70 Vac to V_{an}, V_{bn}, and V_{cn}. Using the SETTINGS mode, change the setting: LOPB = YES.

NOTE: The "RELAY IN SERVICE" LED will not be turned "OFF" for the condition of setting LOPB = Yes, but Zone 1, 2, 3 and pilot distance units will be blocked and all overcurrent units (GB, ITP, and ITG) will be converted to non-directional operation.

LOPB will be set if the following logic is satisfied:

- one (or more) input voltages (V_{AN}, V_{BN} or V_{CN}) are detected (as <7 Vrms) without ΔI change, **or**
- a 3Vo (> 7Vrms) is detected with 3Io <Ios

Apply VAN, VBN and VCN rated voltage to MDAR. Scroll the LED to metering mode; the display shows LOPB = NO. Reduce VAN to 62 Vrms (e.g., $3V_0$ = 8V). After approximately 0.5 seconds, the display shows LOPB = YES and the form C failure alarm (AL1) contact is also deenergized.

Step 31. Set the relay as follows:

Z1P	=	4.5	GBCV	=	CO-8
Z1G	=	4.5	GBPU	=	0.5
ITP	=	10	GDIR	=	YES
ITG	=	5	GTC	=	24

Repeat Step 10 (AG Fault) with I_{AN} = 4.5A. While in the metering mode, be sure that LOPB = YES before the fault current is applied. The relay should be tripped with a target of GB. Apply 5.5A; the relay should be tripped with a target of ITG. Repeat the test with a reversed AG Fault; the relay will trip. Reset LOPB = NO; the relay should not trip for the reversed fault. Set LOPB = YES.

Step 32. Apply a balanced three-phase voltage (70 Vrms) and current (3A). Turn off Va; the relay should not trip. Reset LOPB to NO.

1.1.12 Loss-Of-Current (LOI) Test

Step 33. Set LOIB to YES and I_{OM} = 1.0A. Apply a balanced three-phase voltage (70 Vrms). Connect the current inputs per Figure 6-1, and apply a single phase current of 1.1A to I_A. After approximately 0.5 seconds, the "Relay In Service" LED will be turned off, and the Form C failure alarm (AL1) contact will be dropped out (deenergized) indicating a failure condition.

Step 34. Increase I_A to 1.5A. Depress the DISPLAY SELECT pushbutton and change to the metering (VOLTS/AMPS/ANGLE) mode. Press FUNCTION RAISE pushbutton until the LOI display is shown. The value should indicate "YES". Suddenly turn OFF V_A voltage; the relay should not be tripped within 500 ms. It may operate after 500 ms if a delta I is detected by the relay. Change the setting of LOIB from YES to NO.

1.1.13 Output Contact Test

Step 35. The purpose of this test is to check the hardware connections and relay contacts. It is designed for a bench test only. Remove JMP3 (spare on the Microprocessor PC Board) and place it in the JMP5 position. Open the red-handled FT switch (Trip and Breaker Failure Initiate) in order to avoid the undesired trip.

NOTE: The red-handled FT switch (#13) controls the dc supply of BFI, RI2 and the optional RI1 relays. In order to test these relays in the system, the external wiring should be disconnected to avoid undesired reclosing or trip. For relays without FT switches, *do not* **perform the Output Contact tests using the relay system.**

Change the LED mode to "TEST" and select the tripping function field and the desired contact in the value field. Push the ENTER button; the ENTER LED should be "ON". The corresponding relay should operate when the ENTER button is pressed. The following contacts can be tested:

- TRIP
- BFI
- RI1 (optional)
- RI2
- RB
- AL1 (with three balanced voltages applied)
- AL2
- GS
- SEND (optional)
- STOP (optional)

Remove JMP5 and replace it on JMP3.

Step 36. This completes the basic Acceptance Test for the MDAR Non-Pilot system. (See subsequent segment for optional Single Pole Trip and Out-of-Step Block tests.)

1.2 PILOT PERFORMANCE TESTS

To prepare the MDAR relay assembly for Pilot Acceptance Tests, connect the MDAR per Figure 6-1, Configuration 1.

1.2.1 Front Panel Check

Step 1. Repeat steps 1 thru 6 in Non-Pilot Acceptance Tests, except that in step 6, set values are in accordance with Table 6-3.

Step 2. Change the value settings, in Table 6-3, as follows:

• PLT	YES	• PLTP	6.0
• Z3FR	REV	• Z3P	6.0
• ZIP	OUT	• Z3G	6.0
• ZIG	OUT	• T3P	BLK
• PLTG	6.0	• T3G	BLK

The RBSW is always set at "YES" internally, regardless of the display shown by the remote WRELCOM software.

NOTE: When the dc voltage is applied to TB5 terminals, check jumper position on Interconnect module for the appropriate selection.

Connect a rated dc voltage to PLT/ENA terminals TB5/9(+) and TB5/10(-).

1.2.2 Blocking (BLK) Scheme

Step 3. Change the STYP setting to BLK. Apply a rated dc voltage to RCVR #1 terminals TB5/7(+) and TB5/8(-). Check the metering mode for RX1 = YES. Apply an AG fault as shown in Step 10 of the Non-Pilot Acceptance Test (i.e., V_a = 30 volts and I_a = 4 Amps). The trip A contacts should not be closed. The CARRY SEND should be "open" and the CARRY STOP should be "closed".

Step 4. Remove the dc voltage from RCVR #1 and apply AG fault. Trip A contacts should be "closed" and the target should show "PLTG AG".

Change the LED mode to "TEST" and select the "RS1" function. Push the ENTER button; the ENTER LED should be "ON". Repeat Step 4 with the ENTER button depressed. The relay should not trip.

Step 5. Apply AG reversed fault (i.e., I_a leads V_a by 105 degrees). The CARRY SEND contacts should be "closed" and the CARRY STOP contacts should be "open". (I_a should be > 3 A for the Zone 3 setting of 6 ohms.)

Step 6. Change the LED mode to TEST and select the function "TK". Push the ENTER button; the ENTER LED should be "ON" and the CARRY SEND contacts should be closed.

Step 7. In order to determine setting accuracy (6 ohms), the forward directional ground unit must be disabled. Set FDGT = BLK. Repeat preceding Step 4 of the Pilot Acceptance Test, with a trip input current (I_a) of 3 Amps (±5%).

Step 8. Set the Forward Directional Ground Timer (FDGT) from 0 to 15 cycles. Repeat Step 4 with I_a = 1.5 A. The relay should be tripped after the delay time of FDGT.

NOTE: The FDOG trip is determined by the IOM setting. It trips if $3I_0 > I_{om}$ and the forward ground directional unit picks up.

Step 9. In order to perform the Breaker Failure Reclose Block Test, change the setting of FDGT = 0 and BFRB = NO. Repeat test Step 4; RB contacts (TB3/1 and TB3/2) should not close. Change BFRB to YES and repeat the test. The RB contacts should be closed with a time delay between 150 ms and 200 ms.

NOTE: For Va = Vb = Vc = 0, Ia = Ib = Ic = 0, the setting of OSB = YES, WFEN = NO, and the input of 52b = OV, the carrier SEND contacts will be closed. This is not desirable, but occurs only on the test bench. If tested with the relay system, V = 0 and I = 0 mean that the 52b input is at a rated voltage which will stop the SEND signal.

1.2.3 PUTT or POTT Schemes

Step 10. Change the setting to STYP = PUTT (for underreach scheme) or STYP = POTT (for overreach scheme). In order to determine setting accuracy (6 ohms), the forward directional ground unit must be disabled. Set FDGT = BLK. Apply a rated voltage to RCVR #1 terminals TB5/7(+) and TB5/8(-), and apply an AG fault as shown in Step 10 of the Non-Pilot Acceptance Test. The trip contact A should be closed at the input I_a = 3A (± 5%); the target should show "PLTG AG", and the CARRY SEND contact should be "closed" for POTT setting. Do not test carry STOP for POTT and PUTT schemes.

Step 11. Apply a reversed AG fault (I_a leads V_a by 105°). The relay should not trip, and the CARRY SEND contact should stay "open".

Step 12. Remove the voltage on RCVR #1. Apply a forward AG fault as shown in Step 10. The trip contacts should remain "open" for I_a = 5A.

Step 13. Change the LED mode to TEST and select the function "RS1". Push the ENTER button; the ENTER LED should be "ON". Repeat Step 12 with the ENTER button depressed. The relay should trip.

Step 14. Repeat steps 8 and 9 for FDGT and BFRB tests, by using Step 10 with Ia = 1.5 A.

1.2.4 Weakfeed Scheme

Step 15. This function is for POTT only. In addition to the setting changes in Step 2, change the following settings:

- STYP POTT
- WFEN YES
- Z3G 4.5
- Z3P 4.5
- Z3FR REV

Apply a rated voltage to PLT/ENA terminals TB5/9(+) and TB5/10(-), also RCVR #1 terminals TB5/7(+) and TB5/8(-).

With $V_{an} = V_{bn} = V_{cn}$ = 70 Vrms applied (as shown in Figure 6-1), the relay should operate normally.

NOTE: Do not apply fault current.

Turn V_{an} "OFF"; the relay should trip with a target of WFT, and the Carrier Send contact (TB4-1 and TB4-2) should close momentarily.

Reduce Van from 70 Vrms to 69Vrms and apply a reverse AG fault current of 5A (i.e., I_a leads V_{an} by 105 degrees). Turn V_{an} "OFF"; the relay should not trip, and the Carrier Send contact (TB4-1 and TB4-2) should stay open.

Step 16. This completes the basic Acceptance Test for the MDAR Pilot System. (See subsequent segments for optional Single Pole Trip test.)

1.3 SINGLE POLE TRIP (OPTION) ACCEPTANCE TESTS

Step 1. Set relay for Non-Pilot (per Table 6-1), or for Pilot Systems (per Table 6-3). Check the 62T setting; it should be 5.000. For a Pilot System, change the setting to PLT = YES, and apply a rated dc voltage to Pilot Enable terminals TB5/9(+) and TB5/10(-). Also apply a rated voltage to RCVR #1 terminals TB5/7(+) and TB5/8(-) if the STYP = POTT or PUTT; set TTYP = SPR.

Apply AG fault as shown in this Appendix Section 1.1.3, Step 10. The Trip A contacts (2FT-14/1-2 and 3-4) should be closed. Repeat BG fault (for Trip B contact closures) and repeat CG-Fault (for Trip C contact closures).

1.3.1 Sound Phase Fault (SPF) and 62T Trip

Step 2. Apply a rated dc voltage to 52a terminals TB5/1(+) and TB5/2(-) and to 52b terminals TB5/3(+) and TB5/4(-). Connect a Westinghouse Lockout (WL) switch to the trip circuit.

Step 3. Apply a phase-to-phase fault (as shown in this Appendix, segment 1.1.5, Step 13). Turn the fault current “ON” and “OFF”. The WL switch trips with a target of SPF.

Step 4. Set the WL switch, immediately; it will trip again with a target of 62T. Remove the voltages from 52a and 52b.

1.3.2 Reclose (RI) Trip and Breaker Failure (BFI) Contacts

Step 5. Refer to the Non-Pilot Acceptance Test for the single-phase-to-ground faults (Steps 10 and 11), and to the three-phase fault (Step 12). The fault current should be 20% greater than the calculated values for the tests in these steps. The “fault types” applied to the MDAR relay are shown in Table 6-4 (column 2). TTYP settings are shown in column 1, whereas the results of RI, Trip, and BFI contacts are shown in columns 3, 4, and 5, respectively.

1.4 MDAR WITH OUT-OF-STEP BLOCK OPTION

Refer to Figure 6-5. The RT setting (21BI) is for the inner blinder and it is also used for three-phase fault load restriction. The RU setting (21BO) is for the outer blinder. If the setting of OSB is “YES”, and the power swing stays inside the two parallel lines (RT and RU) for more than 50 ms, the three-phase fault trip will be blocked until the timer (OSOT) times out.

Connect the test circuit as shown in Figure 6-2.

1.4.1 Condition OSB = NO

Step 1. Set the relay per Table 6-1, except for the following settings:

Z1P = 10	
Z1G = 10	T2P = 0.1
Z2P = 20	T2G = 0.1
Z2G = 20	

(Check: PANG = GANG = 75; RT = RU = 15; OSOT = 4000)

Step 2. Adjust the inputs as follows:

$$V_a = 40\angle 0° \qquad I_a = I_F\angle -45°$$

$$V_b = 40\angle -120° \qquad I_b = I_F\angle -165°$$

$$V_c = 40\angle 120° \qquad I_c = I_F\angle 75°$$

Step 3. Apply current I_F of 2.35A ±5% suddenly. The relay should trip with a display of Z2P = ABC.

Step 4. Apply I_F of 4.7A ±5% suddenly. The relay should trip with a display of Z1P = ABC.

Step 5. Change the RT setting from 15 to 4. Repeat Steps 3 and 4 (above). The relay should not trip because the RT restricts the 3-phase fault current.

NOTE: The trip current (IF) can be obtained from the equation in test Step 12 (1.1.4 Zone 1 Test/Three-Phase), with the parameters:

VLN = 40 PANG = 75

Z1P = 10 (or Z2P = 20) X = 45

1.4.2 Condition OSB = YES

Change the OSB setting from NO to YES and RT = 4, RU = 8.

Step 1. Change the LED to metering mode with the display of OSB = NO.

Step 2. Apply a current I_F of 2.7A ± 5% suddenly. The display should show OSB = YES for 4 seconds. This means the input power swing is inside the outer blinder (2IBO). Repeat this test for I_F = 4A and 4.75A. The display should show OSB = YES because the power swing is within two blinders (2IBO and 2IBI).

Step 3. Apply a current of 4.5A and increase the IF to 5.5A immediately. The relay should trip with a display of Z2P = ABC (or Z1P = ABC). This means the power swing stays inside the blinders for more than 50 ms and then crosses over 21BI. For the current of 4.5A, Z1P or Z2P may pick up, but the relay trips after the OSOT timer times out.

Step 4. Apply I_F of 5.25A suddenly (5% above the calculated value). The relay should trip with a display Z1P = ABC. The trip time should be <2 cycles.

2. MAINTENANCE QUALIFICATION TESTS

Maintenance qualification tests will determine if a particular MDAR unit is working correctly.

2.1 Non-Pilot Maintenance Tests

It is recommended that either Doble or Multi-Amp test equipment should be used for this test. Refer to Figure 6-1 for the input voltage and current terminal connection per configuration 1. Check all jumper positions on the Interconnect module for rated dc voltage.

2.1.1 Front Panel and Metering Check

Step 1. Turn on rated dc voltage. Check the FREQ setting; it should match the line frequency and ct type (CTYP). Apply a balanced 3-phase voltage (70 Vac); the Alarm 1 relay should be energized. (Terminal TB4/7 and TB4/8 should be zero ohms.) The "Relay-in-Service" LED should be "ON".

Step 2. Press RESET pushbutton; the green LED (Volts/Amps/Angle) should be "ON". Press the FUNCTION RAISE or FUNCTION LOWER pushbutton. Read the input voltages and their angles:

VAG = 70 $\angle 0°$
VBG = 70 $\angle -120°$
VCG = 70 $\angle 120°$
with an error of ± 1 volt and ± 2°.

Step 3. Press the DISPLAY SELECT pushbutton, and note that the mode LED cycles thru the five display modes. Release the pushbutton so that the SETTINGS mode LED is "ON". Press the RAISE button to scroll thru the FUNCTION FIELD to check the settings per Table 6-1 (non-pilot) or Table 6-3 (pilot). Change the setting, if necessary, by depressing the RAISE button in the VALUE FIELD to the desired value and then pressing the ENTER button.

Step 4. Press the RESET pushbutton (LED jumps to Metering mode). Apply 3.0 A to I_A with an angle of -75°. Read I_A from the front display; it should be 3.0 $\angle -75°$ with an error of 5% and ± 2°. Move the input current from IA to IB or IC terminal. Read I_B or I_C to verify the transformer's accuracy.

2.1.2 Impedance Accuracy Check

Step 5. Apply voltages to MDAR as follows:

V_A = 30 $\angle 0°$
V_B = 70 $\angle -120°$
V_C = 70 $\angle 120°$

Apply forward fault current I_A $\angle -75°$ suddenly. The relay should trip for I_A = 4A ± 5%. The display should show "Z1G AG".

Repeat for B and C phases per the following table:

Phase B	**Phase C**
V_A = 70 $\angle 120°$	V_A = 70 $\angle -120°$
V_B = 30 $\angle 0°$	V_B = 70 $\angle 120°$
V_C = 70 $\angle -120°$	V_C = 30 $\angle 0°$
I_B = 4 $\angle -75°$	I_C = 4 $\angle -75°$

2.1.3 Input Opto-Coupler Check

Step 6. External Reset
Apply an AG fault as shown in Step 5. The LAST FAULT LED should be flashing. Press the front RESET pushbutton. The green LED (Volts/Amps/Angle) should be "ON". Press the DISPLAY SELECT pushbutton and move the LED back to LAST FAULT. The fault information "Z1G AG" should be displayed again. Apply a rated dc voltage to terminals TB5/5 (+) and TB5/6(-). The target data should be erased and the display should show "FTYP". Remove the external reset voltage.

Step 7. 52b Terminals
Change the CIF setting from "NO" to "CIFT".

Apply an AG fault as shown in Step 5, with I_A = 2 ∠–75°. The relay should not trip. Apply a rated dc voltage to terminals TB5/3 (+) and TB5/4 (-). Repeat the test. The relay should trip with a target of CIF. Remove the 52b voltage and set CIF to STUB for the next test.

Step 8. Stub Bus Protection (SBP)
Check the blue jumpers on the Interconnect module. Jumpers (JMP 7 and JMP 9) should be “IN”. JMP 13 should be at the rated voltage position. Apply a balanced 3-phase voltage (70 Vac and I_A = 2A) using any angle. The relay should not trip. Apply a rated voltage to the SBP terminals: TB5/13(+) and TB5/14(-). The relay should trip with a target of CIF. Change jumpers from JMP 7 and 9 back to JMP 8 and 10; if the Stub Bus Protection is not used. Reset CIF to “NO”.

2.1.4 Input Transformer (I_P) Check

Step 9. Change the settings from Table 6-1 (or Table 6-3) as follows:

ZIP	=	OUT
ZIG	=	OUT
DIRU	=	DUAL
GBCV	=	CO-8
GBPU	=	0.5
GDIR	=	YES
GTC	=	24

For a dual polarizing ground directional unit (DIRU = DUAL) test, connect the test circuit shown in Figure 6-4. Apply I_P = 1.0A ∠–90° to terminals 12(+) and 11(-), and apply a balanced 3-phase voltage (70 Vac) to Va, Vb, Vc, and Vn. Apply Ia = 4A to terminals 6 (+) and 5 (-). The relay should trip at the following angles:

- -3°
- -90° (± 87°)
- -177°

The relay should *not* trip at the following angles:

- +3°
- +90° (± 87°)
- +177°

Change the settings back to Table 6-1 or 6-3.

2.1.5 Output Contact Test

Step 10. The purpose of this test is to check the hardware connections and relay contacts. It is designed for a bench test only. Remove JMP 3 (spare on the Microprocessor PC Board) and place it in the JMP 5 position.

Change the LED mode to “TEST” and select the tripping function field and the desired contact in the value field. Push the ENTER button; the ENTER LED should be “ON”. The corresponding relay should operate when the ENTER button is pressed. The following contacts can be tested:

- TRIP
- BFI
- RI1 (optional)
- RI2
- RB
- AL1 (with 3 balanced voltages)
- AL2
- GS
- SEND (optional)
- STOP (optional)

Remove JMP 5 and place it on JMP3.

2.2 Pilot Maintenance Test

Connect the MDAR per Figure 6-1, Configuration 1.

2.2.1 Basic Function Test

Step 1. Repeat Step 1 thru 10 in the Non-Pilot Maintenance Test (2.1.1 thru 2.1.5).

2.2.2 Input Opto-Coupler Check

Step 2. PLT ENA Terminals
Change the following settings from Table 6-3:

- PLT YES
- Z1P 0UT
- Z1G OUT
- PLTP OUT
- PLTG 6.0
- Z3P OUT
- Z3G 6.0
- T3P BLK
- T3G BLK
- Z3FR REV

a. Block Systems Only

Change the STYP setting to BLK. Apply a forward fault, as shown in the Non-Pilot Maintenance Test, step 5. The relay should not trip.

Apply a rated dc voltage to PLT ENA terminals TB 5/9(+) and TB 5/10(-). Repeat the test. The relay should trip.

b. POTT/PUTT Systems Only

Change the STYP setting to POTT. Change the LED mode to TEST and select the function “RS1”. Push the ENTER button; the LED should be “ON”. Apply a forward fault as shown in Non-Pilot Maintenance test, Step 5. With the ENTER button depressed, the relay should not trip. Apply a rated dc voltage to terminals TB 5/9(+) and TB 5/10(-). Repeat the test. The relay should trip.

Step 3. Receivers 1 and 2

Apply a dc voltage to PLT ENA terminals TB 5/9(+) and TB5/10(-).

a. Block Systems Only

Change the STYP setting to BLK. Apply a forward fault as shown in the Non-Pilot Maintenance test, Step 5. The relay should trip.

Apply a rated dc voltage to RCVR #1 terminals TB 5/7 (+) and TB 5/8(-). Repeat the test. The relay should not trip. Move the dc voltage from RCVR #1 to RCVR #2 terminals TB 5/11(+) and TB 5/12(-), and repeat this test for RCVR #2.

b. POTT/PUTT Systems Only

Change the STYP setting to POTT. Apply a forward fault as shown in the Non-Pilot Maintenance test, Step 5. The relay should not trip. Apply a rated dc voltage to RCVR #1 terminals TB 5/7(+) and TB 5/8(-). Repeat the test. The relay should trip.

Move the dc voltage from RCVR #1 to RCVR #2 terminals TB 5/11(+) and TB 5/12(-), and repeat this test for RCVR #2.

2.3 Single-Pole Trip Test

2.3.1 Output Contact Test (Phases B and C)

Step 1. Set relay for Non-Pilot systems (Table 6-1) or for Pilot systems (Table 6-3). Check the 62T setting; it should be 5.000.

For a Pilot system, change the PLT setting to YES, and apply rated dc voltage to Pilot enable terminals TB 5/9(+) and TB 5/10(-). Also, apply a rated voltage to RCVR #1 terminals TB 5/7(+) and TB 5/8(-) if the STYP = POTT or PUTT; set TTYP = SPR.

Step 2. Repeat Non-Pilot Maintenance test, step 5 for trip and BFI. Check the contact closures for Trip A, Trip B, Trip C and BFIA, BFIB, BFIC.

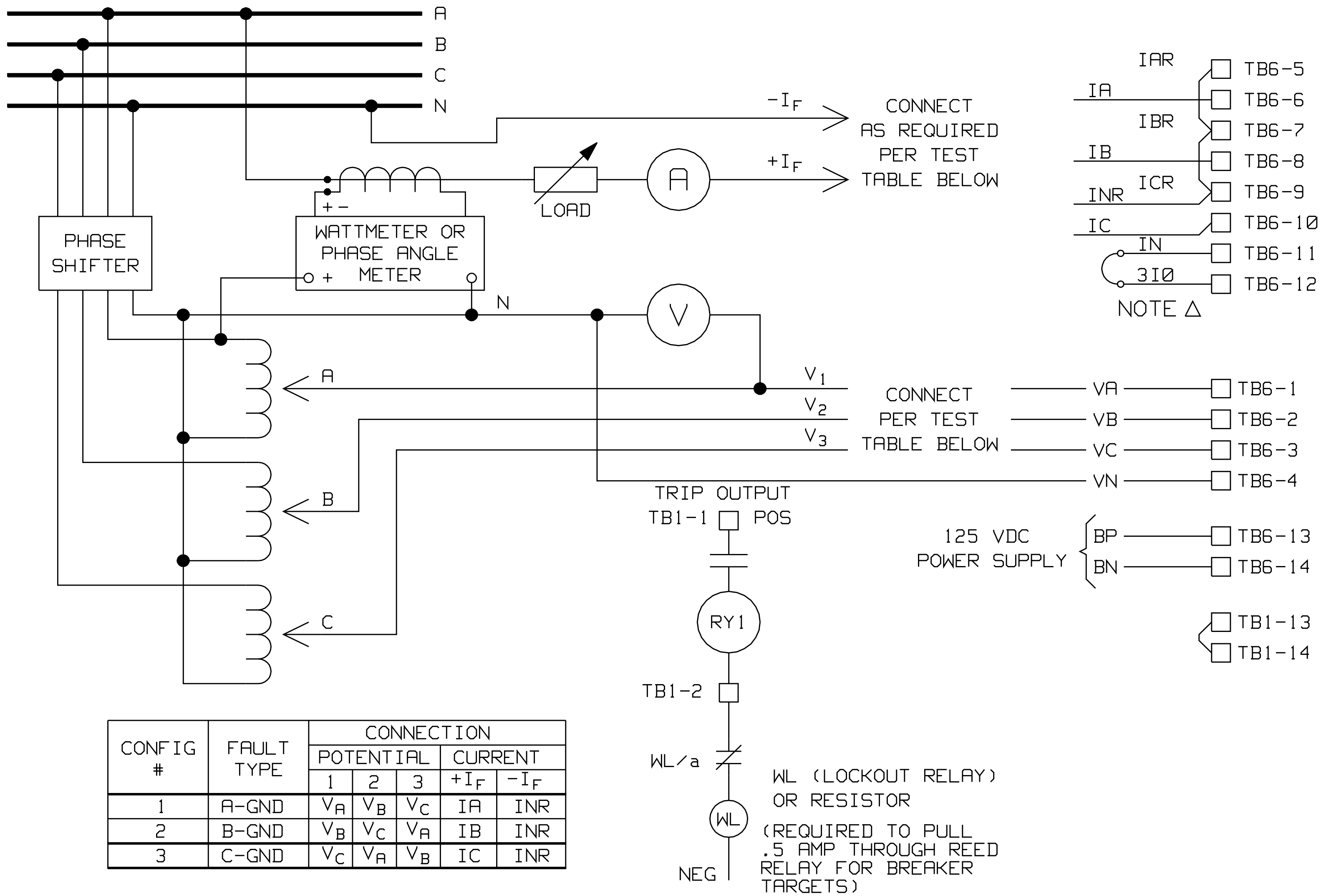
2.3.2 Input Opto-Coupler Check

Step 3. 52a Terminals

Apply a rated voltage to 52b terminals TB 5/3(+) and TB 5/4(-) and then apply a rated voltage to 52a terminals TB 5/1(+) and TB 5/2(-). The relay should trip in 5 seconds with a display of 62T.

NOTE: When using sophisticated automated test equipment, to test MDAR, it should be noted that some conditions can be simulated that are not realistic. For instance, the equipment has the ability to remove three-phase voltage instantaneously. This can cause erroneous test results.

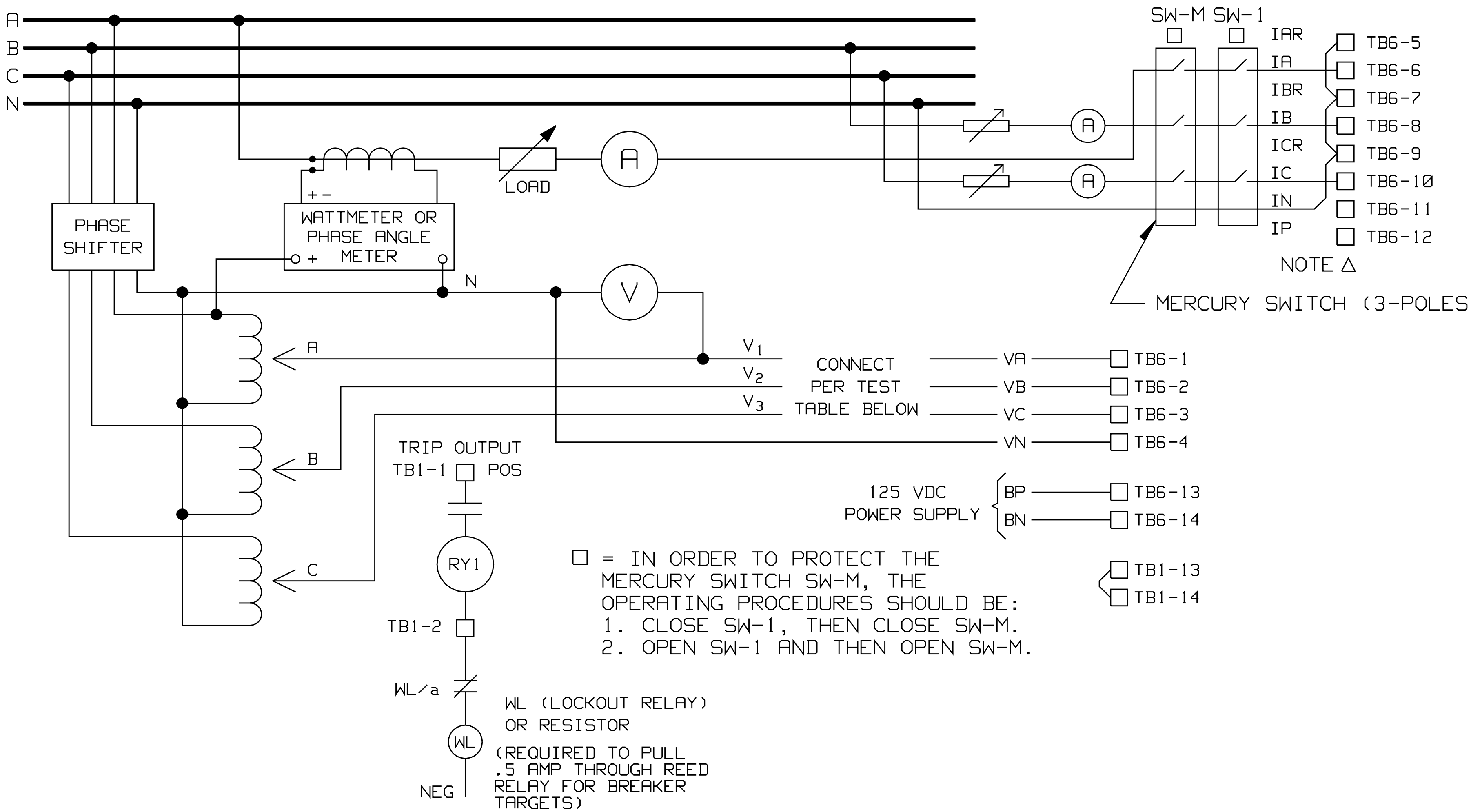
For example, if a Zone 2 fault is applied to MDAR but removed, before the Zone 2 trip decision, by instantaneous removal of voltage and current, MDA may trip. This is due to the total voltage collapse occurring while MDA is in the fault mode. This does not represent a true power system condition since the voltage and current cannot become zero instantaneously.



CONFIG #	FAULT TYPE	CONNECTION				
		POTENTIAL			CURRENT	
		1	2	3	$+I_F$	$-I_F$
1	A-GND	V_A	V_B	V_C	IA	INR
2	B-GND	V_B	V_C	V_A	IB	INR
3	C-GND	V_C	V_A	V_B	IC	INR

△ = CONNECT A JUMPER BETWEEN TERMINALS 11 & 12 IF IP (DUAL POLARIZING DIRECTIONAL GROUND UNIT) IS NOT USED.

Figure 6-1. Test Connection for Single-Phase-to-Ground Faults (Sheet 1 of 4)



△ = CONNECT A JUMPER BETWEEN TERMINALS 11 & 12 IF IP (DUAL POLARIZING DIRECTIONAL GROUND UNIT IS NOT USED.

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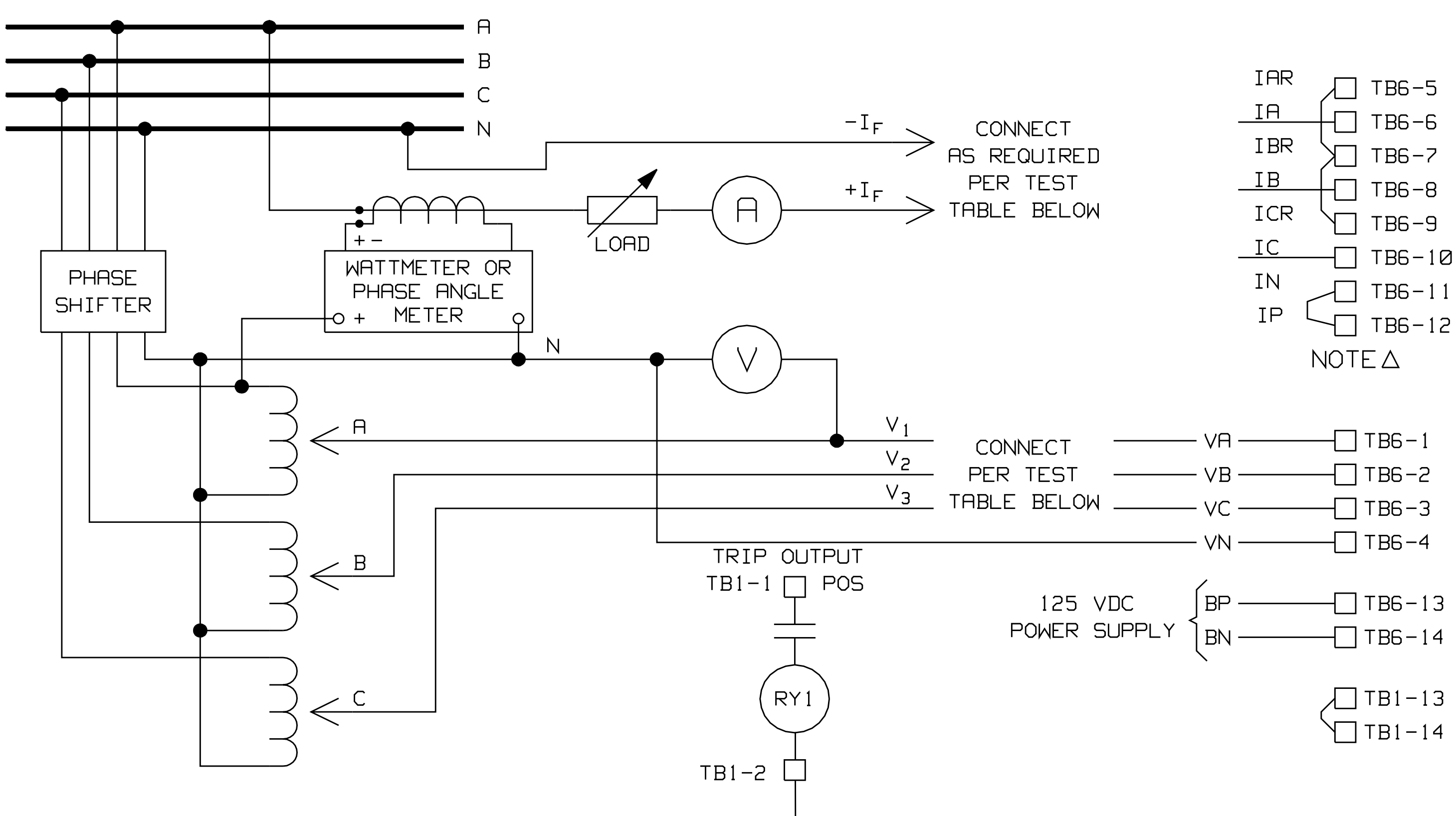
Figure 6-2. Test Connection for Three-Phase Faults *(Sheet 2 of 4)*



CONFIG #	FAULT TYPE	CONNECTION				
		POTENTIAL			CURRENT	
		1	2	3	$+I_F$	$-I_F$
1	AB	V_A	V_B	V_C	IA	IB
2	BC	V_B	V_C	V_A	IB	IC
3	CA	V_C	V_A	V_B	IC	IA

NOTE △ : CONNECT A JUMPER BETWEEN TERMINALS 11 & 12 IF IP (DUAL POLARIZING DIRECTIONAL GROUND UNIT IS NOT USED.

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Figure 6-3.Test Connection for Phase-to-Phase Faults (Sheet 3 of 4)

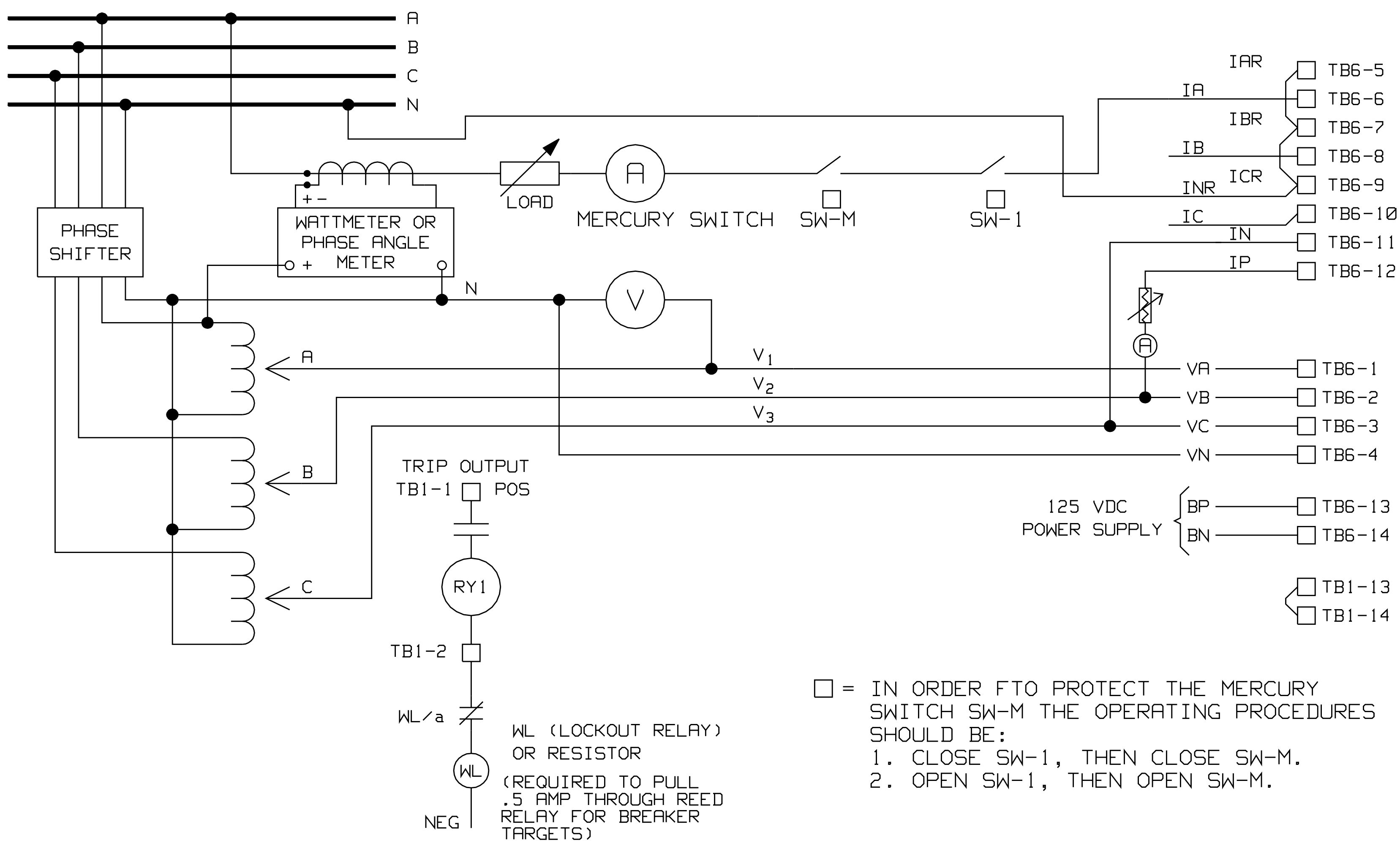

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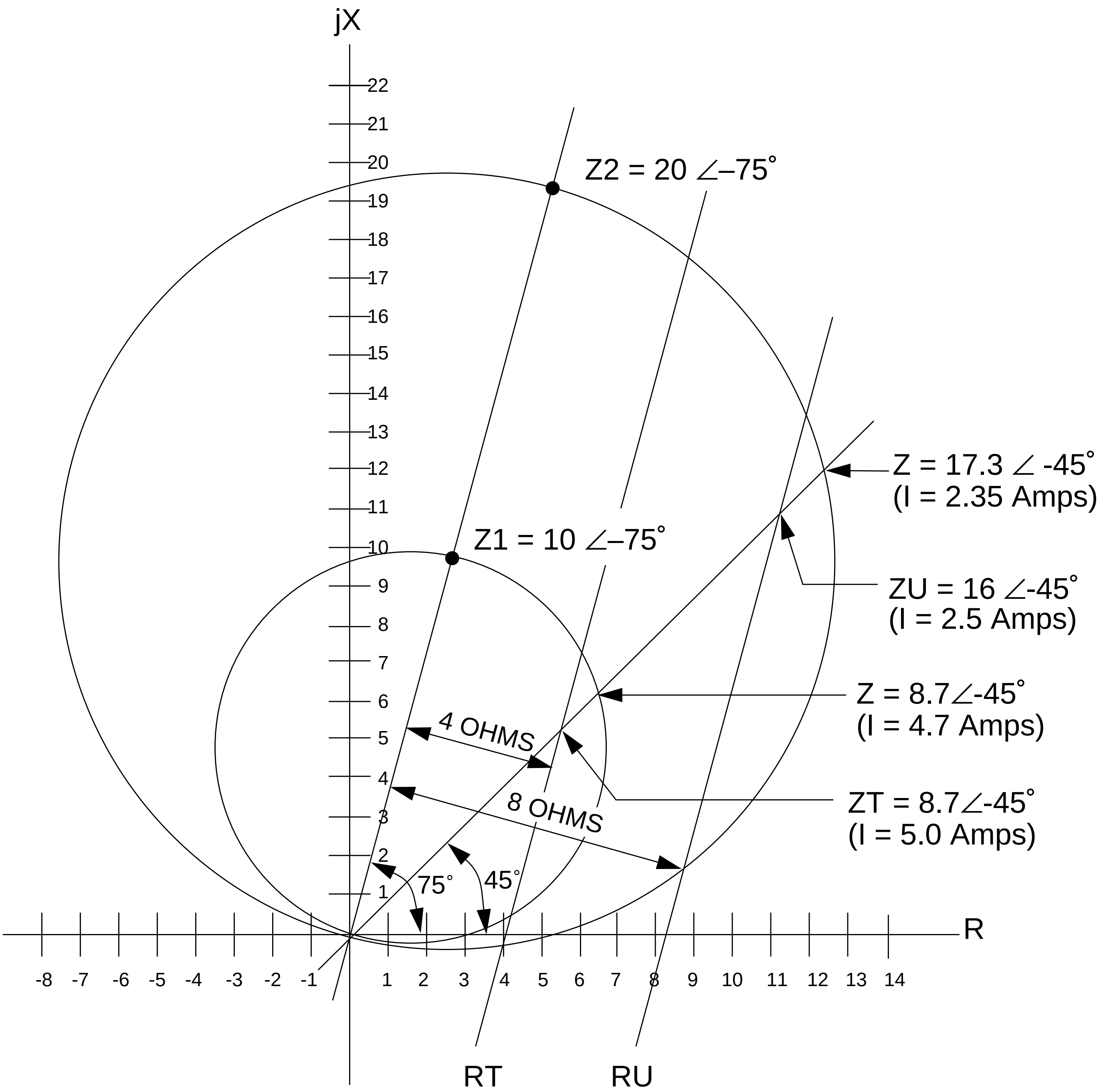
Figure 6-4. Test Connection for Dual Polarizing Ground Directional Unit *(Sheet 4 of 4)*



INPUTS: Va = 40 ∠0°, Vb = 40 ∠-120°, Vc = 40 ∠120°

SETTINGS: PANG = 75°, GANG = 75°, ZR = 3

ABC FAULT WITH FAULT ANGLE OF 45°

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Figure 6-5. MDAR with Out-of-Step Block Option

TABLE 6-1. MDAR SETTINGS (NON-PILOT SYSTEM)

VERS	0	Z3FR	FWD
OSC	TRIP	PANG	75
FDAT	TRIP	GANG	75
CTR	1000	ZR	3.0
VTR	2000	LV	60
FREQ	60	IL	.5
CTYP	5	IOS	.5
RP	NO	IOM	.5
XPUD	.5	ITP	OUT
DTYP	KM	ITG	OUT
TTYP	OFF	OSB	NO **
62T	5.000 *	OSOT	4000 **
Z1RI	YES	RT	15.00
Z2RI	NO	RU	15.00 **
Z3RI	NO	DIRU	ZSEQ
STYP	3ZNP	GBCV	OUT
Z1P	4.5	GTC	24
Z1G	4.5	GDIR	YES
T1	NO	CIF	NO
Z2P	OUT	LOI	NO
T2P	1.00	AL2S	NO
Z2G	OUT	LLT	NO
T2G	1.50	LOPB	NO
Z3P	OUT	SETR	NO
T3P	2.00	TIME	NO
GBPU	0.5		
T3G	2.50		

* For Single-Pole trip option only.
** For Out-of-Step Block option only.

NOTE: This MDAR settings table is for 60 Hz and 5A ct systems. For 1A ct, change Z1P, Z1G, Z2P, Z2G, Z3P, Z3G, RT, RU by multiplying a factor of 5, and all current values mentioned in the text should be multiplied by a factor of 0.02.

TABLE 6-2. TRIP TIME CONSTANTS FOR CO CURVES

Curve #	T_o	K	C	P	R
CO2	111.99	735.00	0.675	1	501
CO5	8196.67	13768.94	1.13	1	22705
CO6	784.52	671.01	1.19	1	1475
CO7	524.84	3120.56	0.8	1	2491
CO8	477.84	4122.08	1.27	1	9200
CO9	310.01	2756.06	1.35	1	9342
CO11	110.	17640.00	0.5	2	8875

TABLE 6-3. PRESENT MDAR SETTINGS (PILOT SYSTEM)

VERS	0	T3P	2.00
OSC	TRIP	Z3G	OUT
FDAT	TRIP	T3G	2.50
CTR	1000	Z3FR	FWD
VTR	2000	PANG	75
FREQ	60	GANG	75
CTYP	5	ZR	3.0
RP	NO	LV	60
XPUD	.5	IL	.5
DTYP	KM	IOS	.5
TTYP	OFF	IOM	.5
62T	5.000*	ITP	OUT
Z1RI	YES	ITG	OUT
Z2RI	NO	OSB	NO**
Z3RI	NO	OSOT	4000**
PLT	NO	RT	15.00
STYP	3ZNP	RU	15.00**
FDGT	0	DIRU	ZSEQ
WFEN	NO	GBCV	OUT
3TRM	NO	GBPU	.5
BLKT	0	GTC	24
RBSW	NO	GDIR	YES
PLTP	OUT	CIF	NO
PLTG	6.00	LLT	NO
Z1P	4.5	LOPB	NO
Z1G	4.5	LOIB	NO
T1	NO	AL2S	NO
Z2P	OUT	SETR	NO
T2P	1.00	TIME	NO
Z2G	OUT		
T2G	1.50		
Z3P	OUT		

*   For Single Pole Trip option only.
** For Out-of-Step Block option only.

NOTE: This MDAR settings table is for 60 Hz and 5A ct systems. For 1A ct, change PLT, PLG, Z1P, Z1G, Z2P, Z2G, Z3P, Z3G, RT, RU by multiplying a factor of 5, and all current values mentioned in the text should be multiplied by a factor of 0.02.

TABLE 6-4. FAULT TYPES APPLIED TO MDAR

SETTING TTYP	FAULT TYPE APPLIED	OUT CONTACTS RI	TRIP	BFI
OFF	AG	NO	A,B,C	A,B,C
	BG	NO	A,B,C	A,B,C
	CG	NO	A,B,C	A,B,C
	ABC	NO	A,B,C	A,B,C
1PR	AG	RI2	A,B,C	A,B,C
	AB	NO	A,B,C	A,B,C
	ABC	NO	A,B,C	A,B,C
2PR	AG	RI2	A,B,C	A,B,C
	AB	RI2	A,B,C	A,B,C
	ABC	NO	A,B,C	A,B,C
3PR	AG	RI2	A,B,C	A,B,C
	BG	RI2	A,B,C	A,B,C
	CG	RI2	A,B,C	A,B,C
	AB	RI2	A,B,C	A,B,C
	ABC	RI2	A,B,C	A,B,C
SPR	AG	RI1	A	A
	BG	RI1	B	B
	CG	RI1	C	C
	ABC	NO	A,B,C	A,B,C
SR3R	AG	RI1	A	A
	BG	RI1	B	B
	CG	RI1	C	C
	ABC	RI2	A,B,C	A,B,C

Section 7. INDEX TO NOMENCLATURE

Numerics

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System Diagrams

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MDAR System Logic Diagram	(sheet 3 of 4)	SD-4
MDAR System Logic Diagram	(sheet 4 of 4)	SD-5
MDAR Block Diagram	(sheet 1 of 1)	SD-6

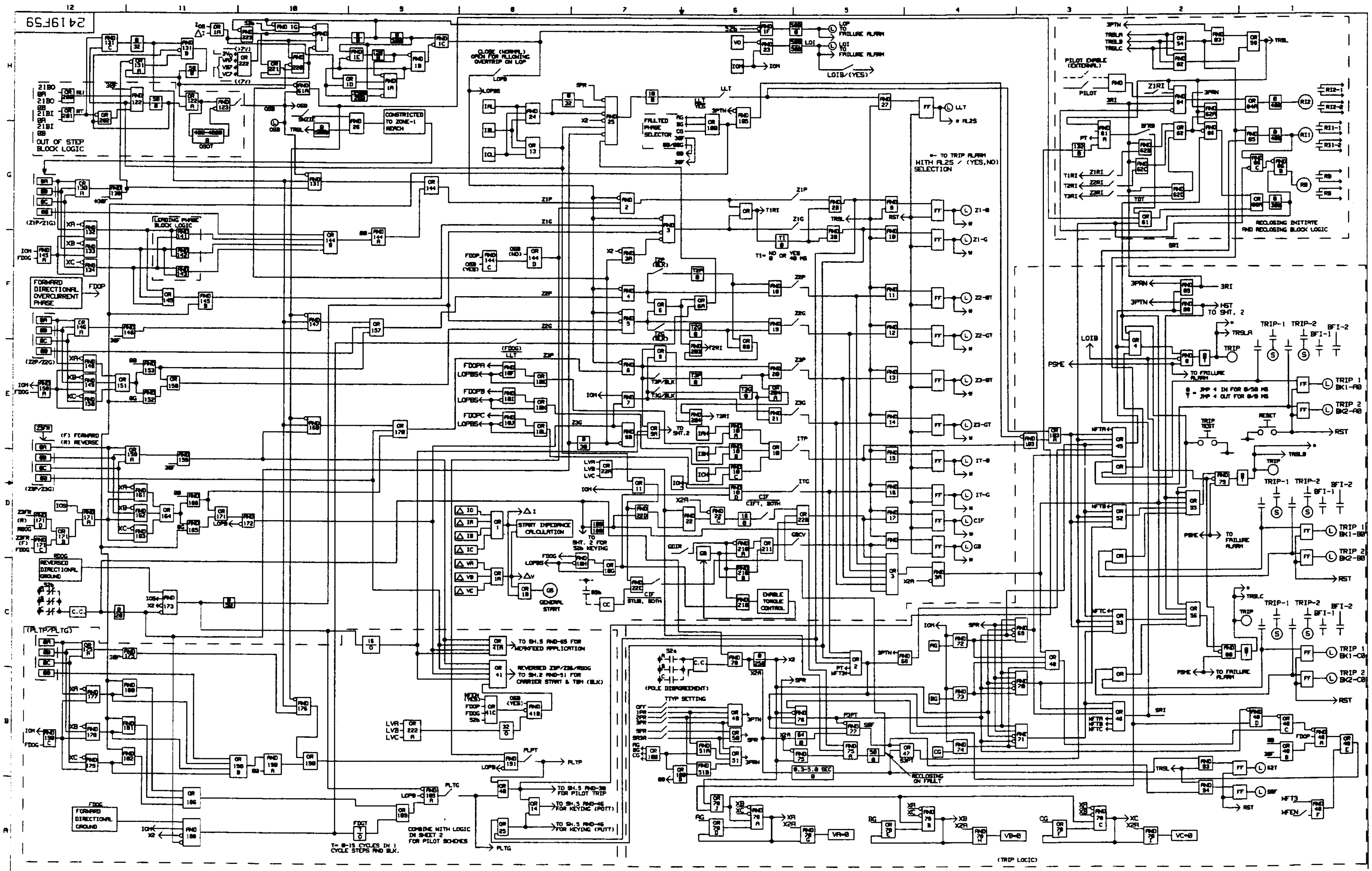

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Figure J-1. MDAR System Logic Diagram – V2.02

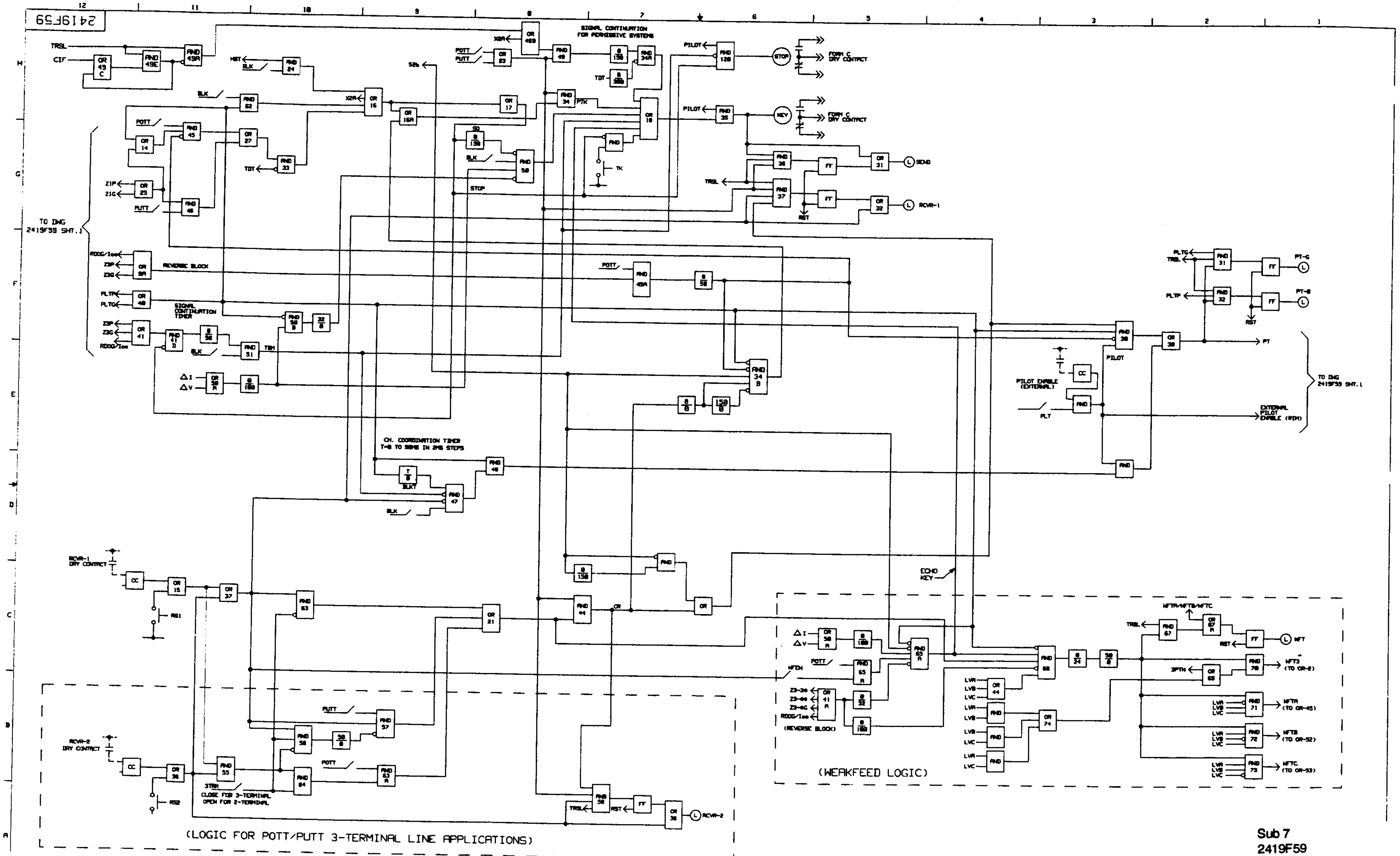

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Figure J-2. MDAR System Logic Diagram – V2.02

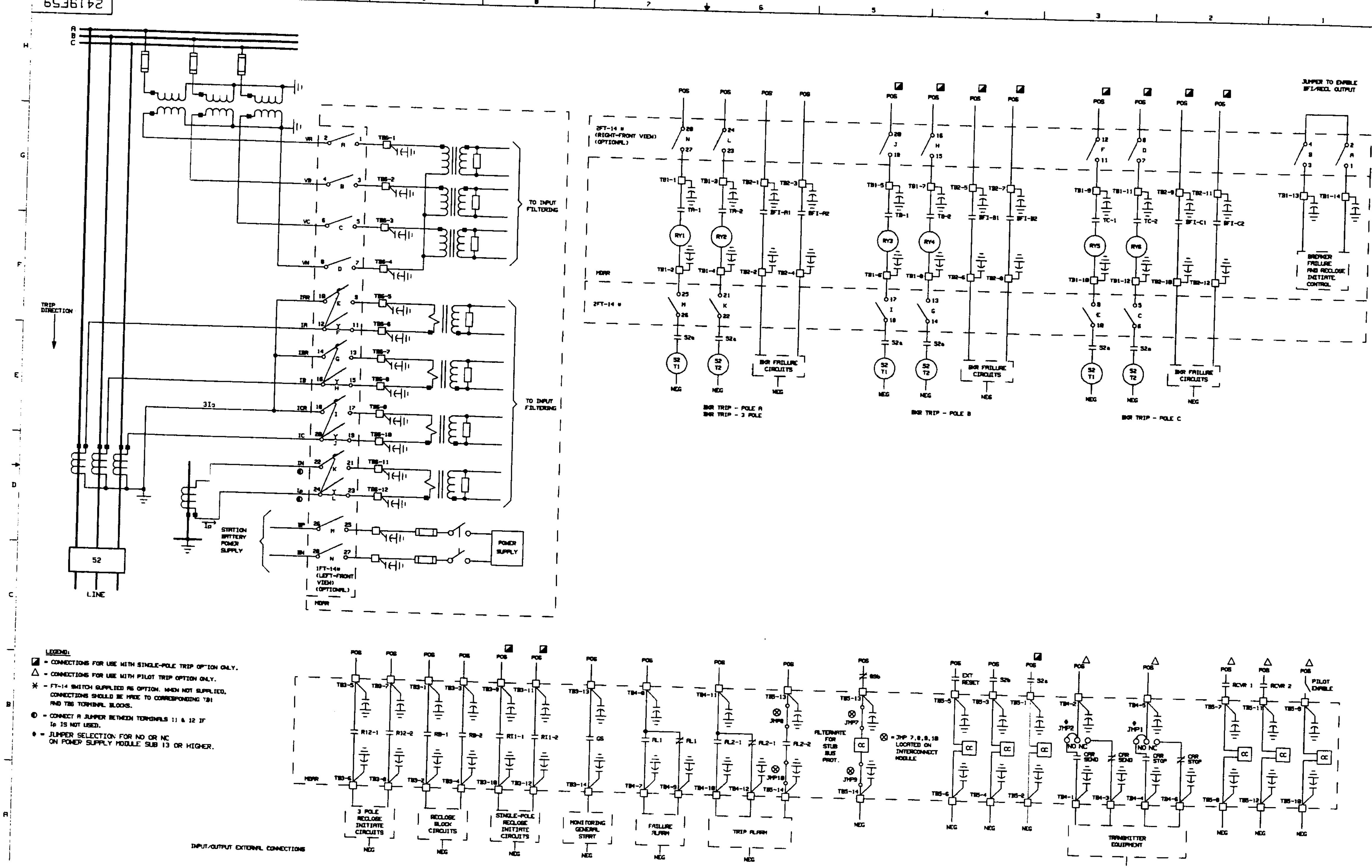

Figure J-3. MDAR System Logic Diagram – V2.02

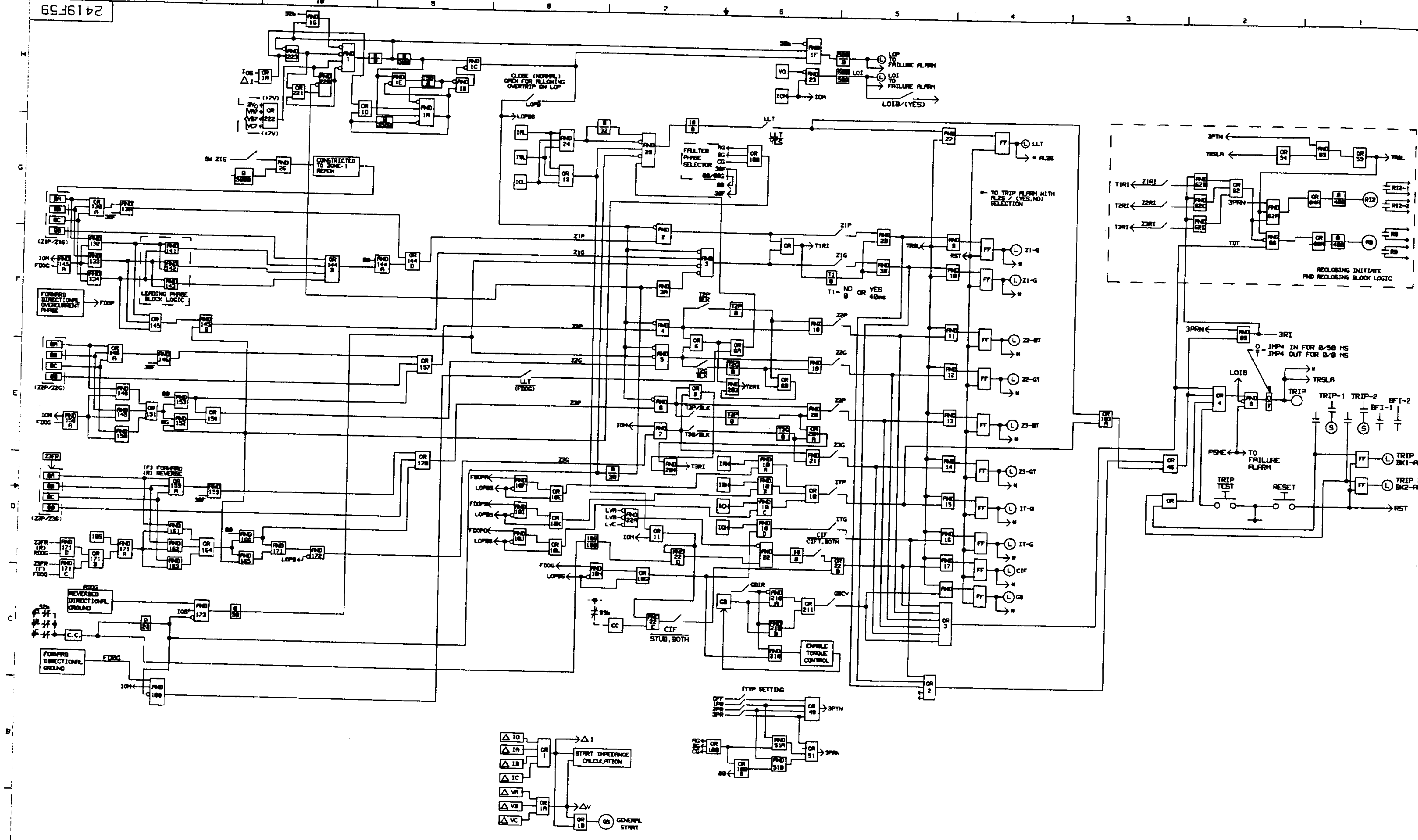

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Figure J-4. MDAR System Logic Diagram – V2.02

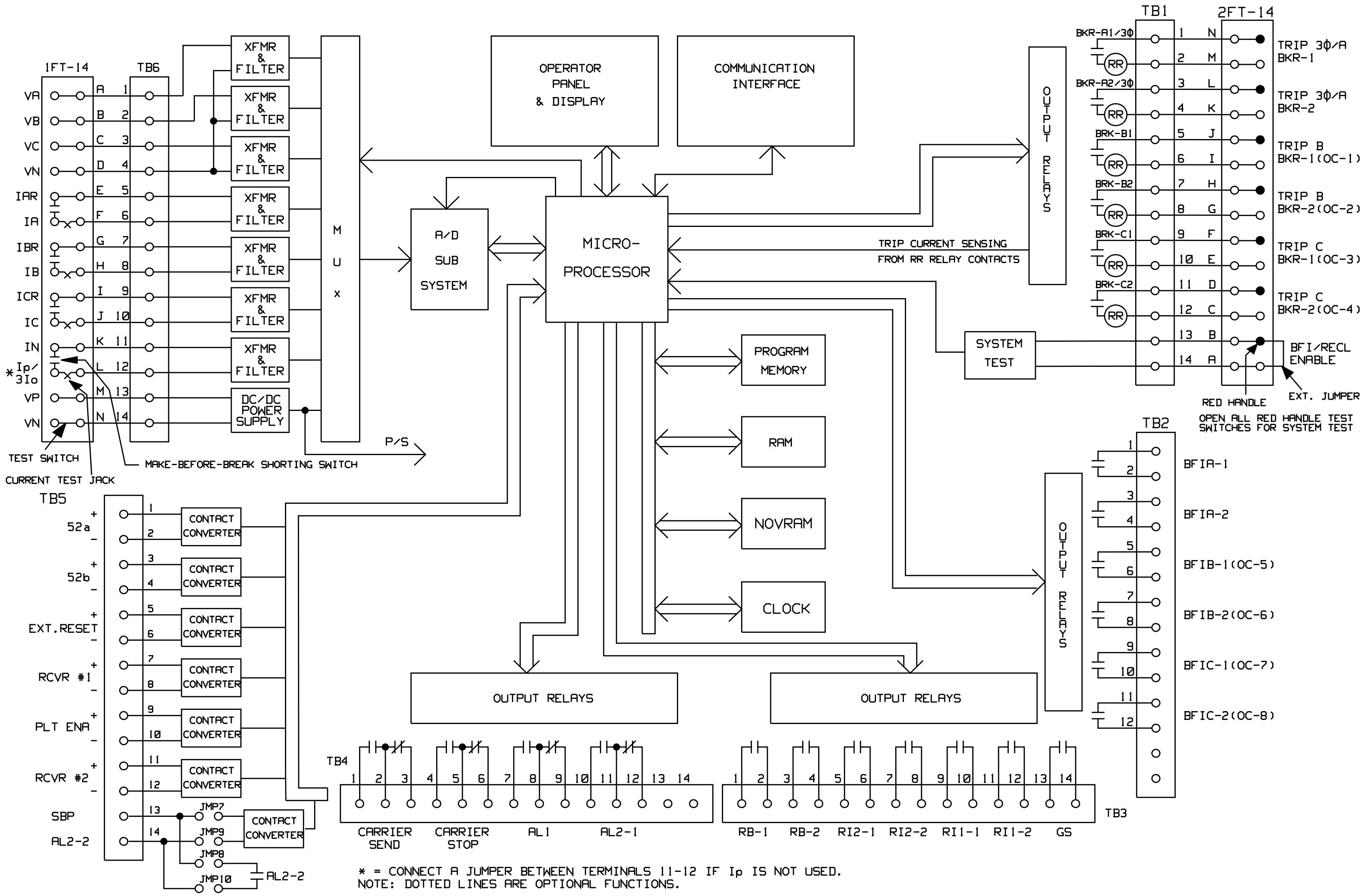

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Figure SD-2. MDAR Block Diagram (sheet 1 of 1)