A Appendix A – Configuration Record Forms

This Appendix contains photocopy-ready forms for recording the configuration and setting of the M-3520 Intertie Protection Relay. The forms can be supplied to field service personnel for relay configuration, and kept on file for future reference. Examples of the suggested use of these forms are illustrated in Chapter 2, **Application** and Chapter 3, **Operation**.

A copy of the **Relay Configuration Table** (page A-2), discussed in Section 2.2, Configuration, Functions is provided to define and record the blocking inputs and output configuration for the relay. For each function; check if **DISABLED** or check the output contacts *to be operated by the function*, and check the inputs designated *to block the function operation.*

The Communication Data & Unit Setup Record Form reproduces the Communication and Setup unit menus. This form records definition of the parameters necessary for communication with the relay, as well as access codes, user logo (identifying) lines, date & time setting, and front panel display operation.

The Functional Configuration Record Form reproduces the Configure Relay menus (including the Setup Relay submenu) accessible via M-3822 IPScom® Communication Software or the optional M-3931 HMI front panel module. For each function or setpoint, refer to the configuration you have defined using the Relay Configuration Table, and circle whether it should be enabled or disabled, the output contacts it will activate, and the inputs that will block its operation.

The Setpoint & Timing Record Form allows recording of the specific values entered for each enabled setpoint or function. The form follows the main menu selections of the relay.

The "AS SHIPPED" data forms illustrate the factory settings of the relay.

EXAMPLES:

```
59 #1 PHASE OVERVOLTAGE
disable  enable
```

```
59 #1 BLOCK INPUT
f1 i6 i5 i4 i3 i2 i1
```

```
59 #1 RELAY OUTPUT
o8 o7 o6 o5 o4 o3 o2 o1
```

```
59 #1  PICKUP
_______ VOLTS
```

```
59 #1  DELAY
_____CYCLES
```

FUNCTION	D	OUTPUTS								INPUTS						
		8	7	6	5	4	3	2	1	FL	6	5	4	3	2	1
21 #1																
21 #2																
25																
27 #1																
27 #2																
27G																
32 #1																
32 #2																
46DT																
46IT																
47 #1																
47 #2																
50																
50G																
51G																
51V																
59 #1																
59 #2																
59I																
59G																
60FL																
67DT																
67IT																
67NDT																
67NIT																
79																
81 #1																
81 #2																
81 #3																
81 #4																
81R #1																
81R #2																

Check each box applicable : ✓ (See page A-1 for information on using this table.)

D Column = Function Disabled. FL Column = Function blocked by fuse loss.

INPUTS Columns =Designated function blocking input(s) OUTPUTS Columns =Designated function output(s)

Table A-1 Relay Configuration Table

KEY TO INPUT DATA RECORD FORMS

A. All unshaded [ ] screens shown on forms require data inputs. Whatever is in that screen when **ENTER** button is pushed (see Figure A-1) will be installed in the M -3520 relay.

B. All shaded [ ] screens are either menu screens which have horizontal choices (made with right - left arrows) or screens displaying a result of a choice previously made. Lightly shaded screens indicate separate functions.

C. **Dotted** boxes ┌ ─ ─ ─ ┐ enclose screens which bound areas that the **ENTER** button will move within. In order to move out of one of the **dotted** boxes it is necessary to either push **EXIT** or make a menu choice change using the Right/Left arrow.

D. The Up/Down arrows *only* adjust value or letter (lower/upper case) inputs – they do not move around within the menus.

E. The Right/Left arrows are used *only* to make horizontally displayed choices. These can be either menu choices or input value digit choices. The previous choice or location in a menu is highlighted immediately.

F. The **ENTER** button records the setting change and moves down *within* a menu. The operator will notice that after the last menu item, **ENTER** moves to the top of the same menu but does not change menu positions.

G. Pushing **EXIT** at any time will exit the display screen to the last screen containing a horizontal choice. (Return to the preceding menu).

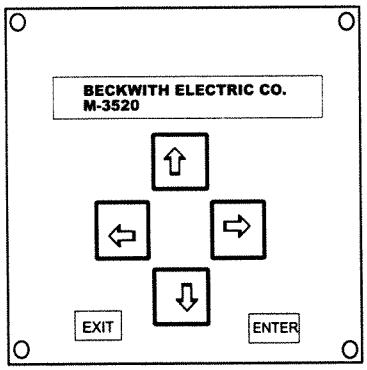


Figure A-1 Human-Machine Interface Module

H. The symbol "←"or "→" in a screen indicates additional horizontal menu choices are available in the indicated direction. As previously described, the Right/Left arrows will move the operator to those additional choices.

■ **NOTE**: If a function is disabled, the input screens for that function will not be displayed.

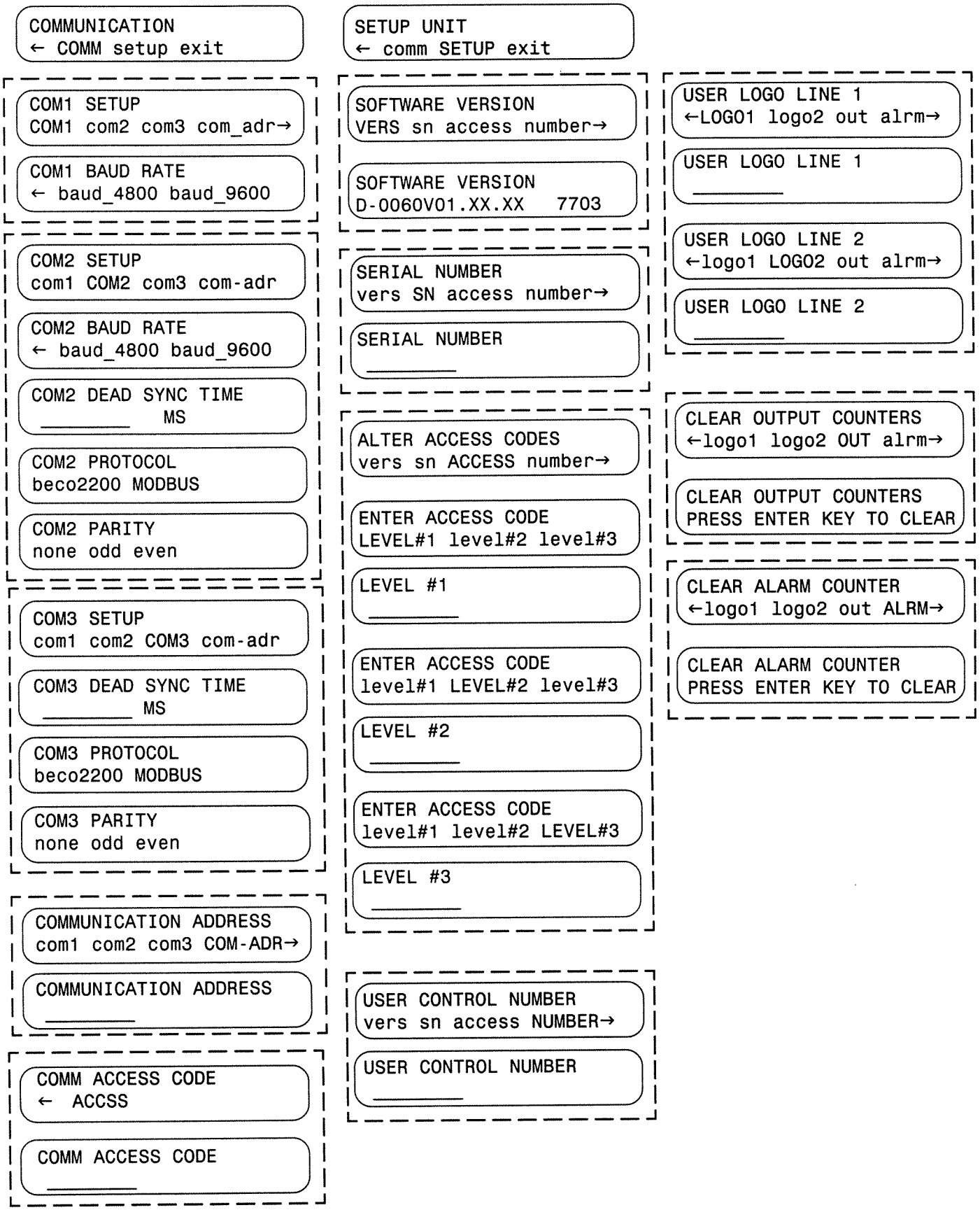
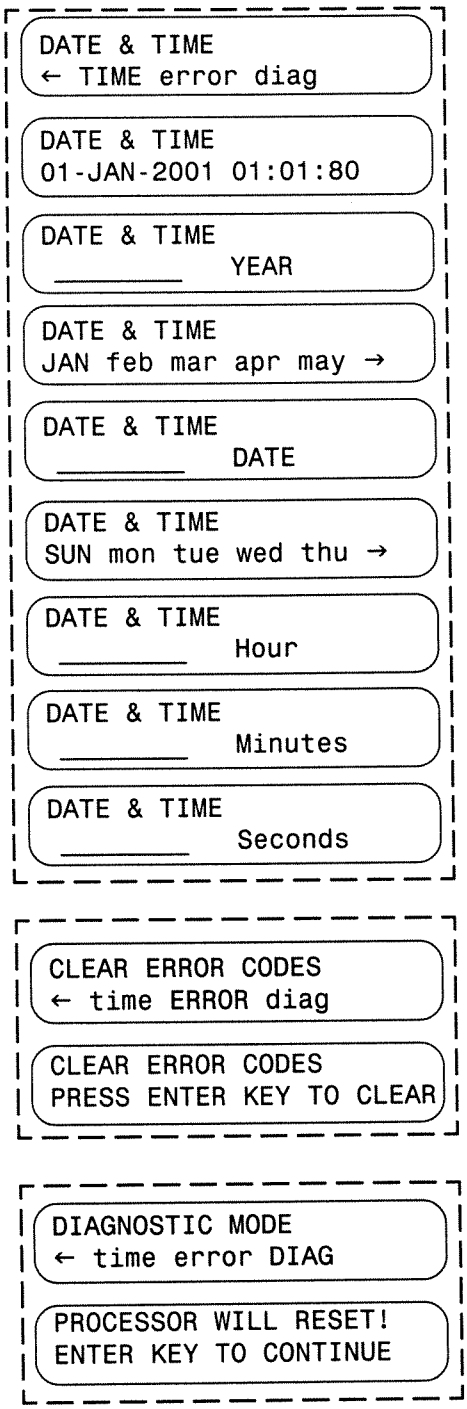


Figure A-2 Communication Data & Unit Setup Record Form (1 of 2)



■ **NOTE**: See Section 6.2, Diagnostic Test Procedures

Figure A-2 Communication Data & Unit Setup Record Form (2 of 2)

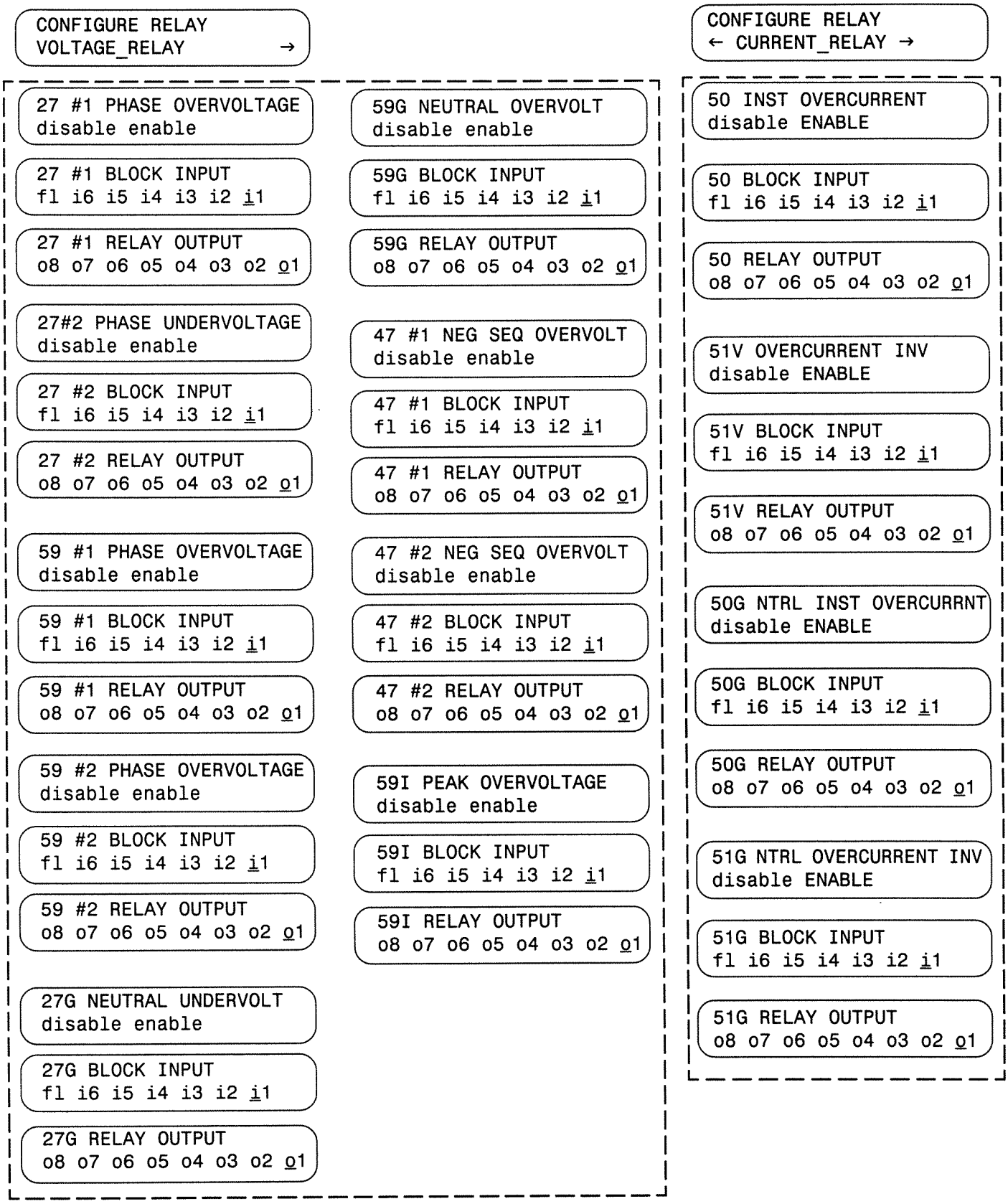


Figure A-3 Functional Configuration Record Form (1 of 3)

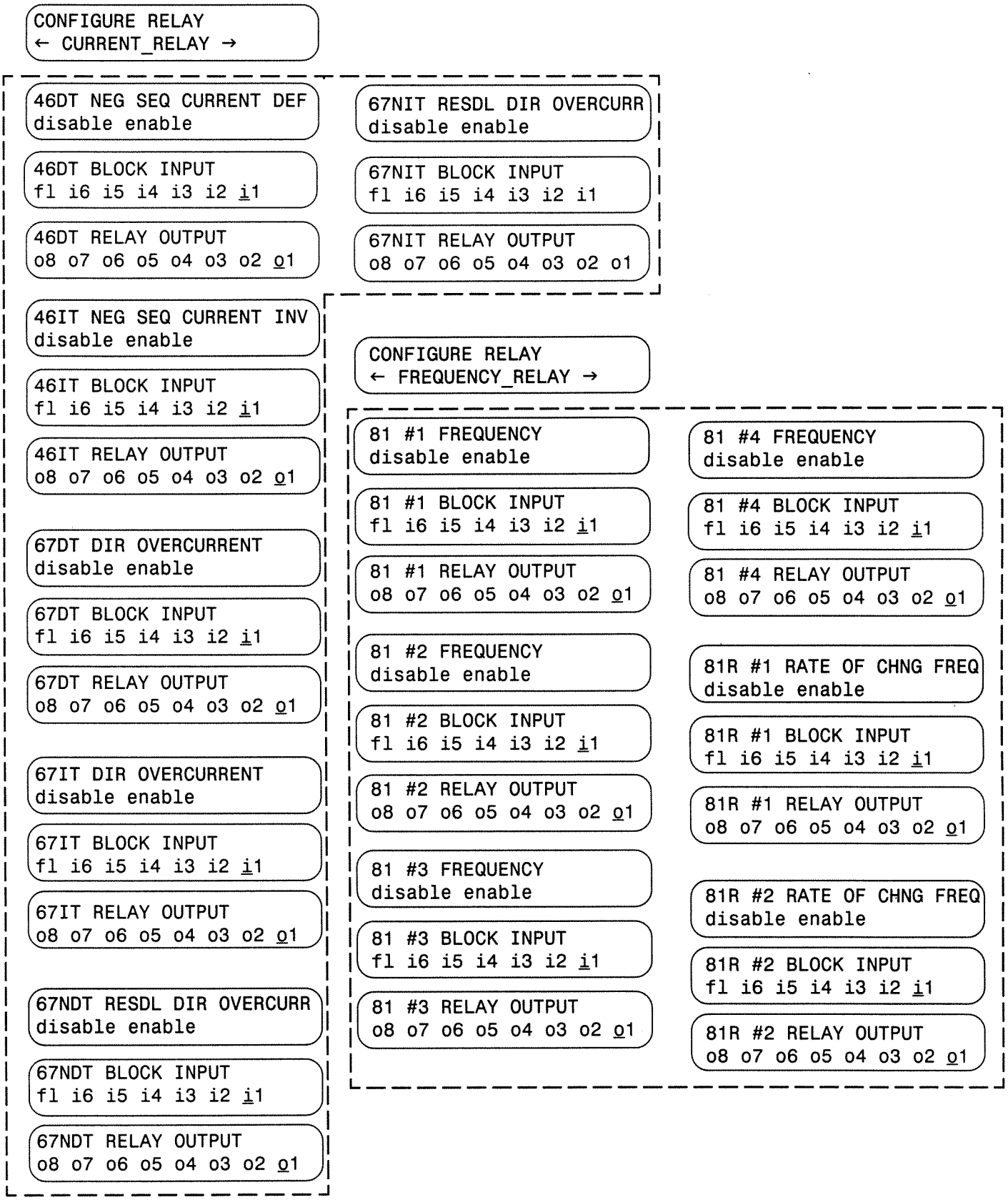


Figure A-3 Functional Configuration Record Form (2 of 3)

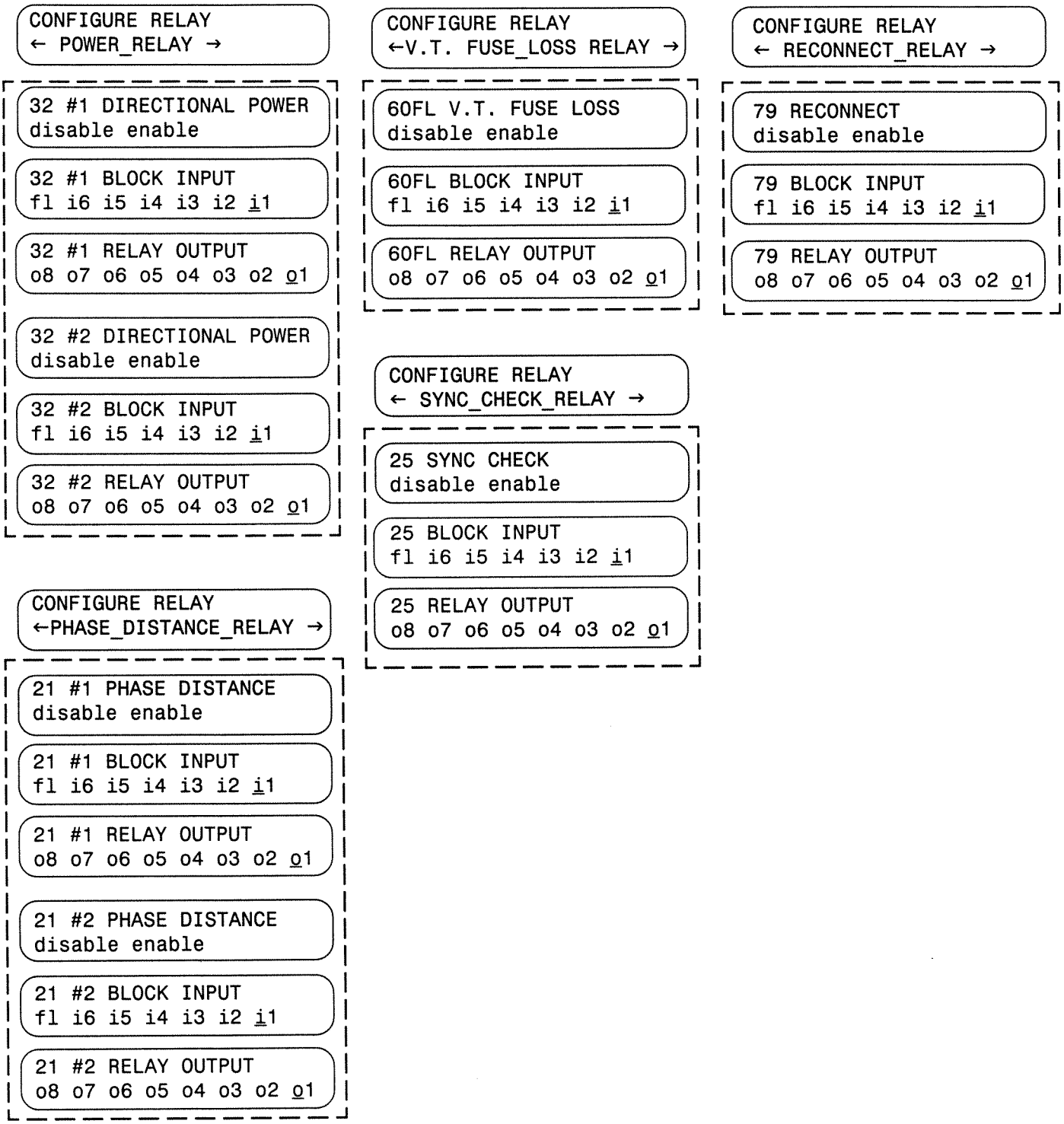


Figure A-3 Functional Configuration Record Form (3 of 3)

VOLTAGE RELAY
VOLT curr freq pwr →

27 PHASE UNDERVOLTAGE
PHASE_UNDER phase_over→

27 #1 PICKUP
_____ Volts

27 #1 DELAY
_____ Cycles

27 #2 PICKUP
_____ Volts

27 #2 DELAY
_____ Cycles

59 PHASE OVERVOLTAGE
phase_under PHASE_OVER→

59 #1 PICKUP
_____ Volts

59 #1 DELAY
_____ Cycles

59 #2 PICKUP
_____ Volts

59 #2 DELAY
_____ Cycles

27G NEUTRAL UNDERVOLTAGE
←NUTRL_UNDER nutrl_over→

27G PICKUP
_____ Volts

27G DELAY
_____ Cycles

59G NEUTRAL OVERVOLTAGE
←nutrl_under NUTRL_OVER→

59G PICKUP
_____ Volts

59G DELAY
_____ Cycles

47 NEG SEQ OVERVOLTAGE
← NEG_SEQ peak_over

47 #1 PICKUP
_____ Volts

47 #1 DELAY
_____ Cycles

47 #2 PICKUP
_____ Volts

47 #2 DELAY
_____ Cycles

59I PEAK OVERVOLTAGE
← neg_seq PEAK_OVER

59I PICKUP
_____ PU

59I DELAY
_____ Cycles

Figure A-4 Setpoint & Timing Record Form (1 of 4)

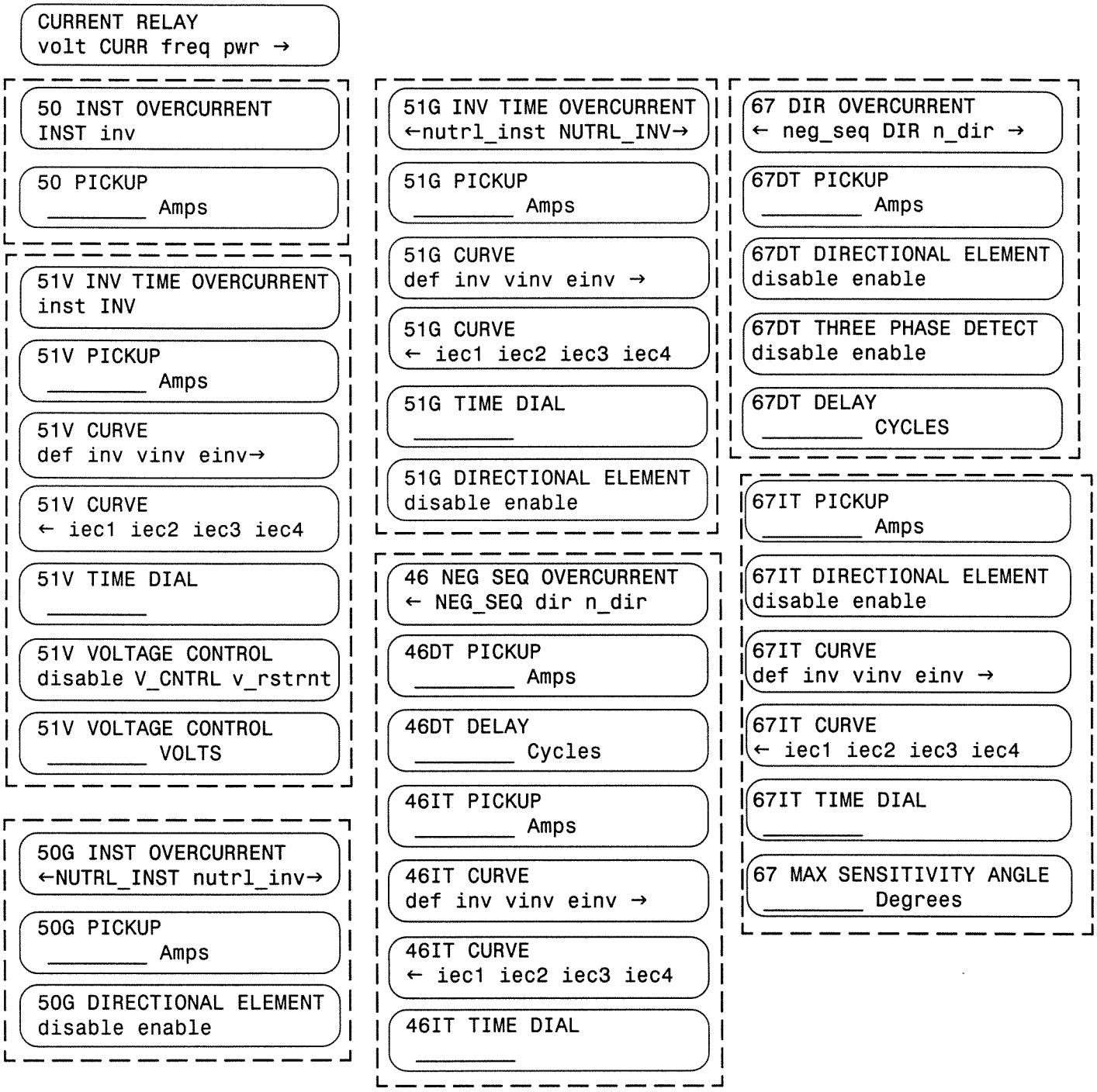


Figure A-4 Setpoint & Timing Record Form (2 of 4)

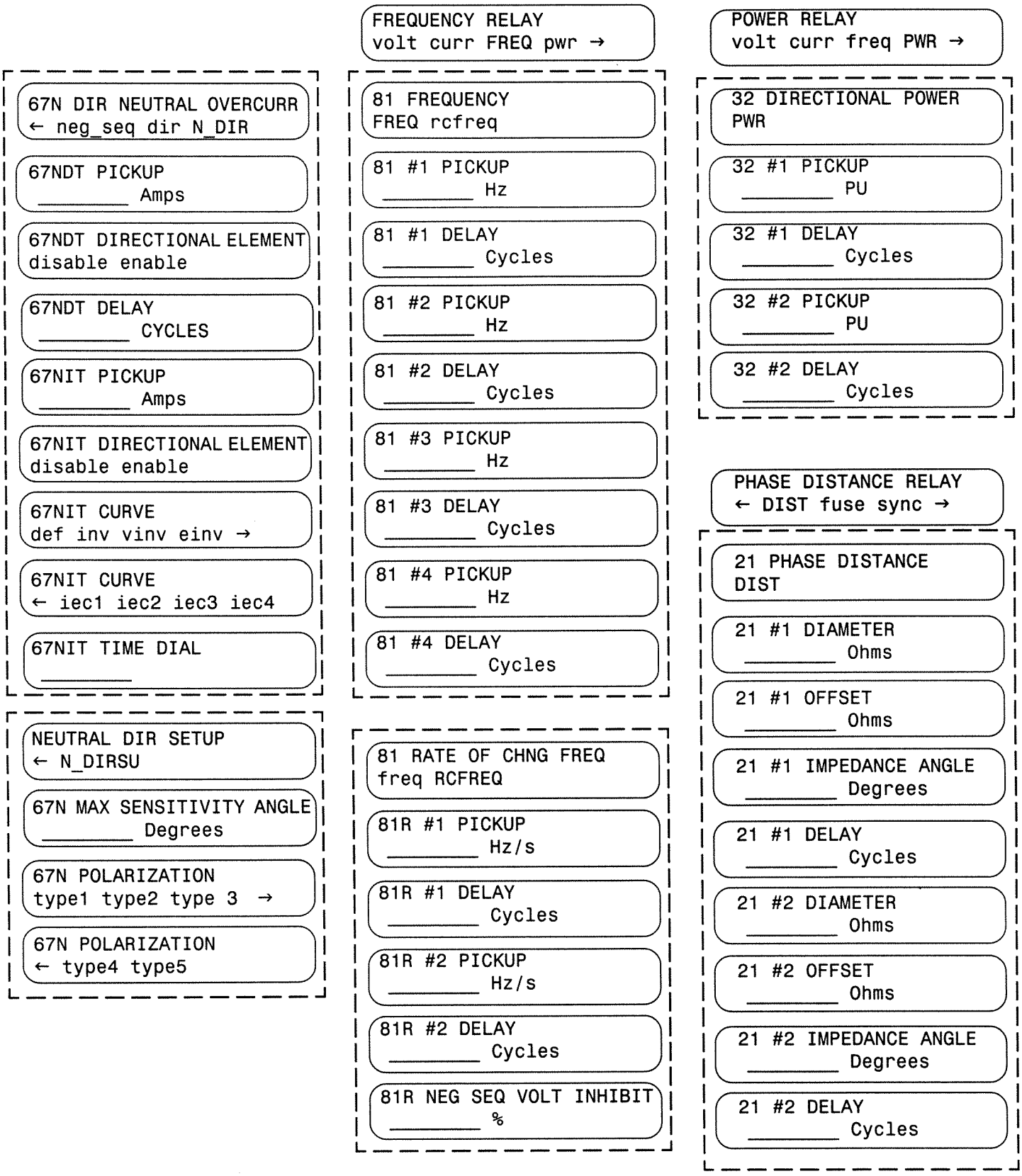


Figure A-4 Setpoint & Timing Record Form (3 of 4)

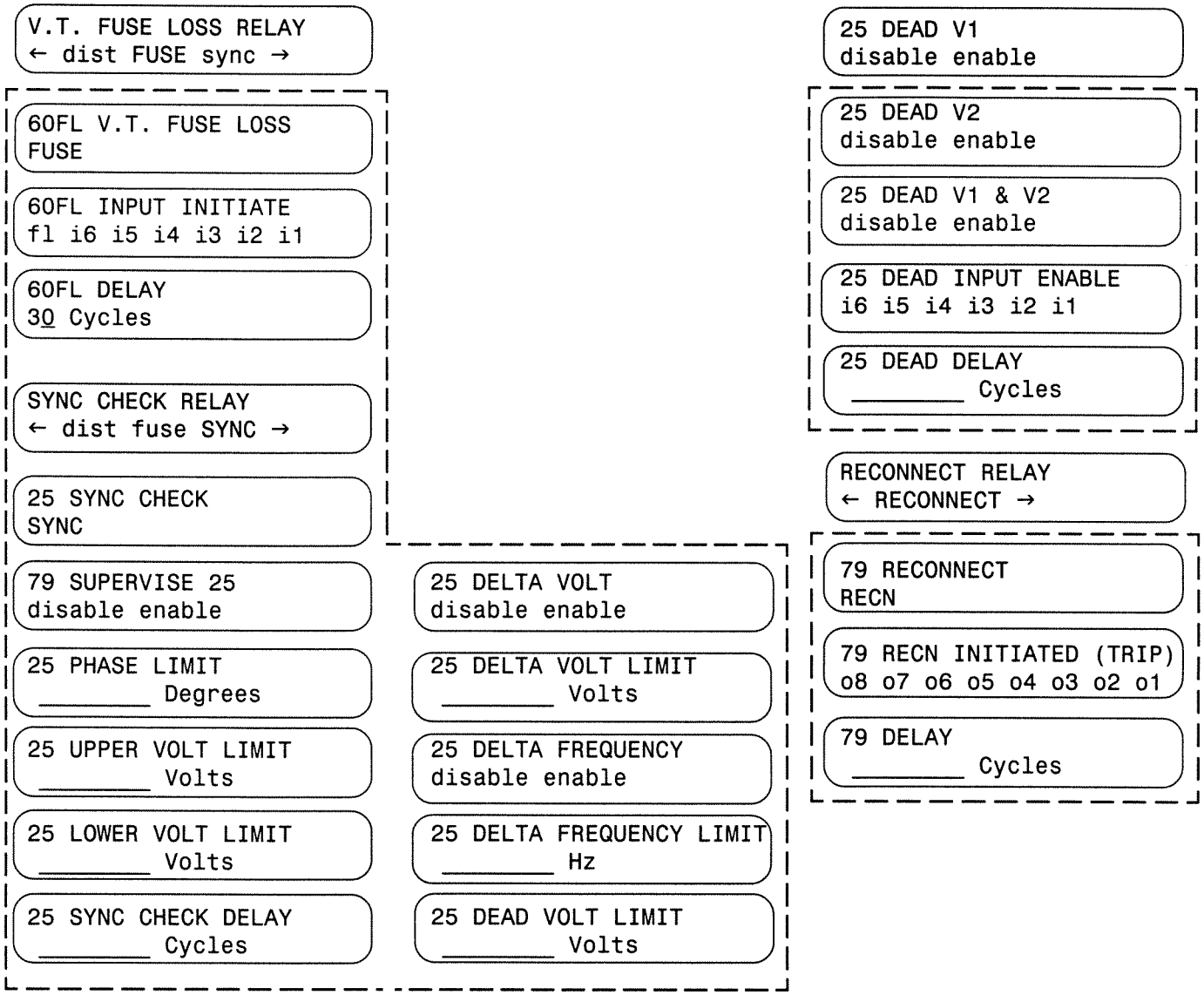


Figure A-4 Setpoint & Timing Record Form (4 of 4)

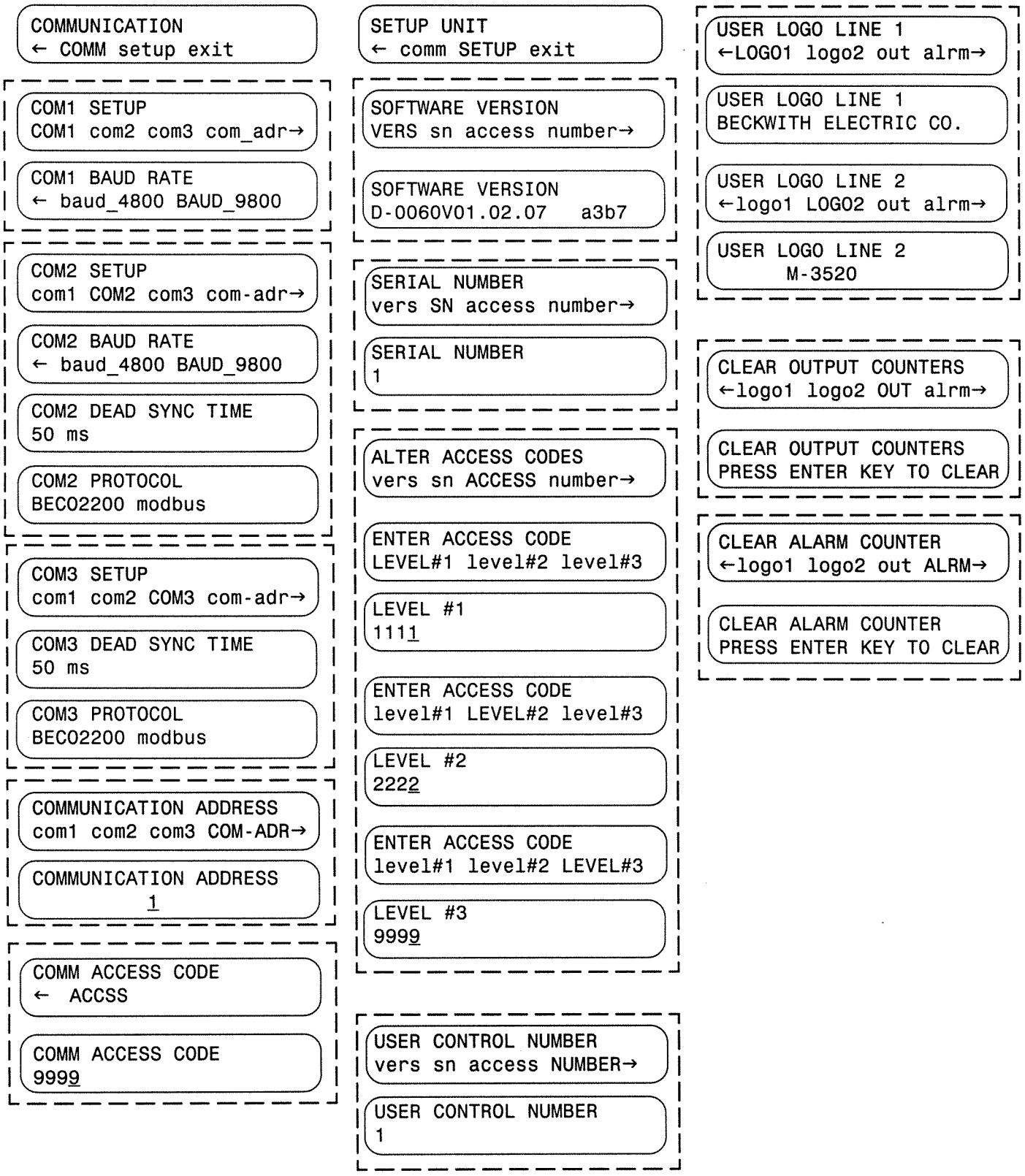
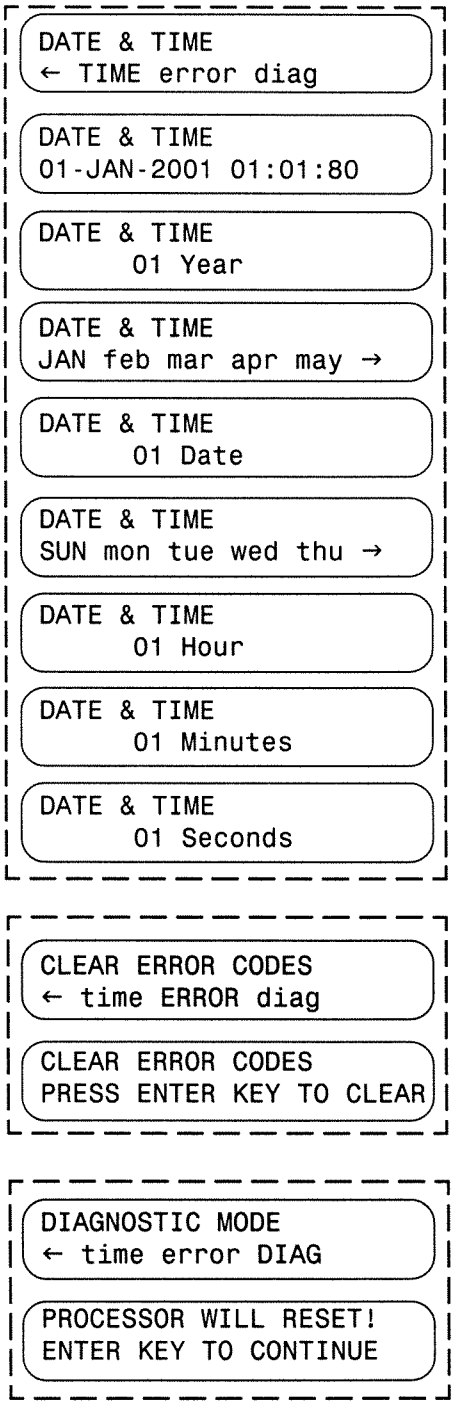


Figure A-2 Communication Data & Unit Setup – As Shipped (1 of 2)



■ **NOTE**: See Section 6.2, Diagnostic Test Procedures

Figure A-2 Communication Data & Unit Setup – As Shipped (2 of 2)

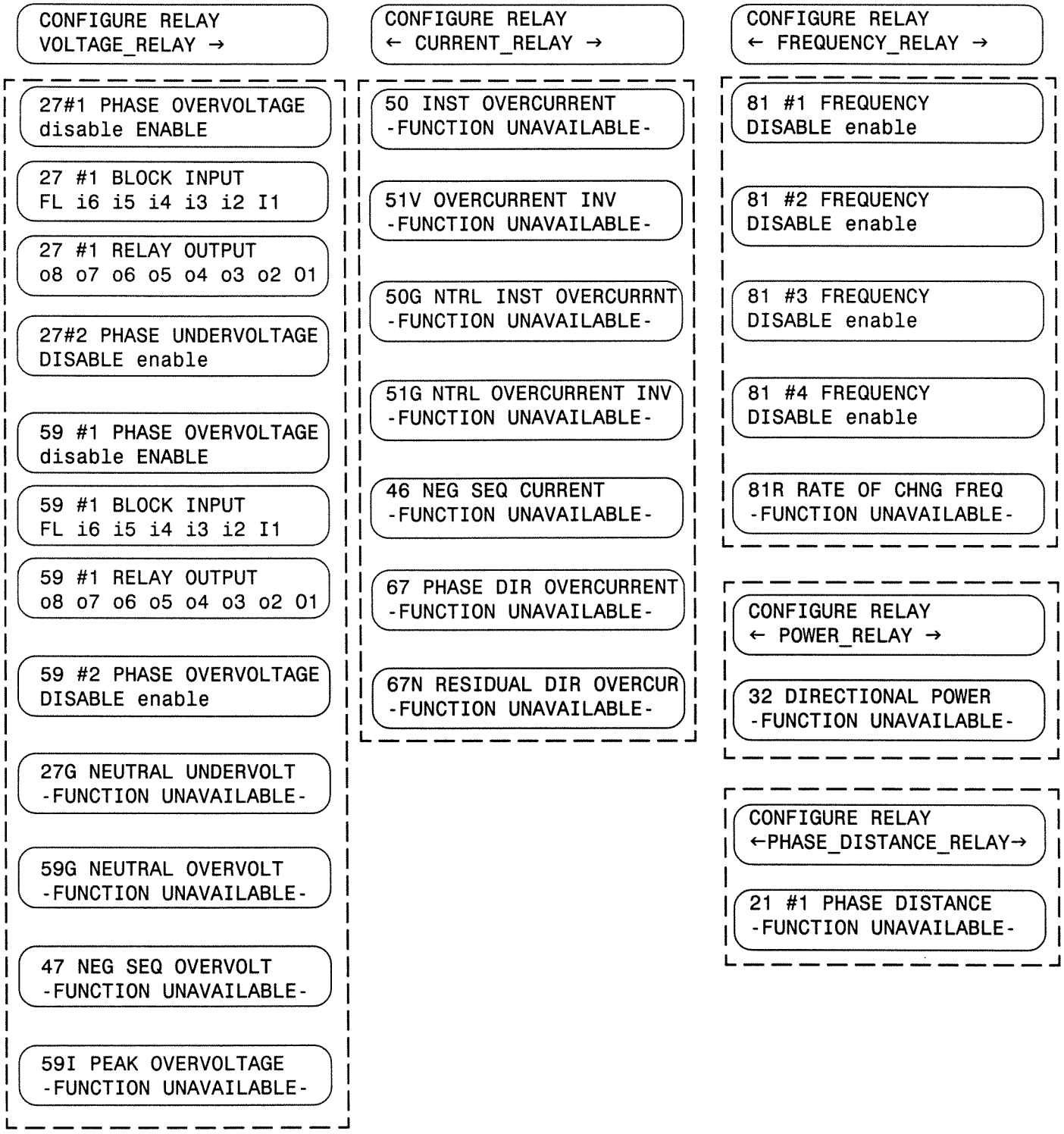


Figure A-3 Functional Configuration – As Shipped (1 of 2)

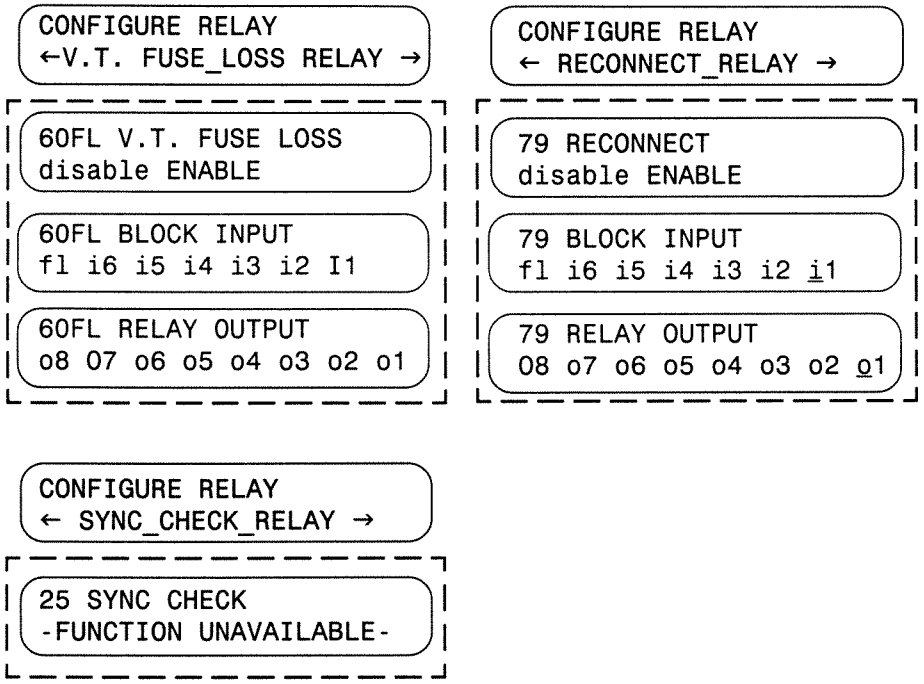


Figure A-3 Functional Configuration Record Form – As Shipped (2 of 2)

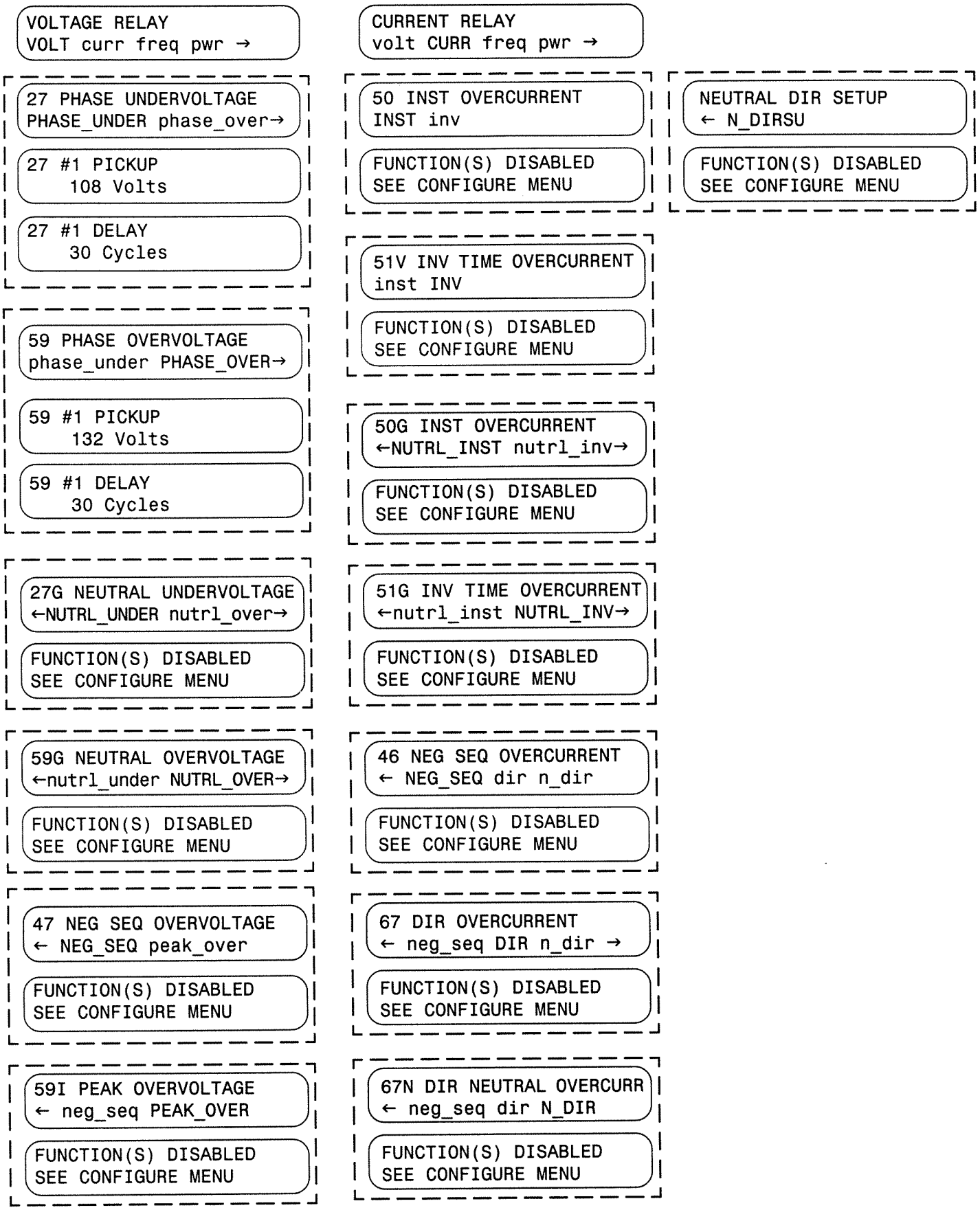


Figure A-4 Setpoint & Timing – As Shipped (1 of 2)

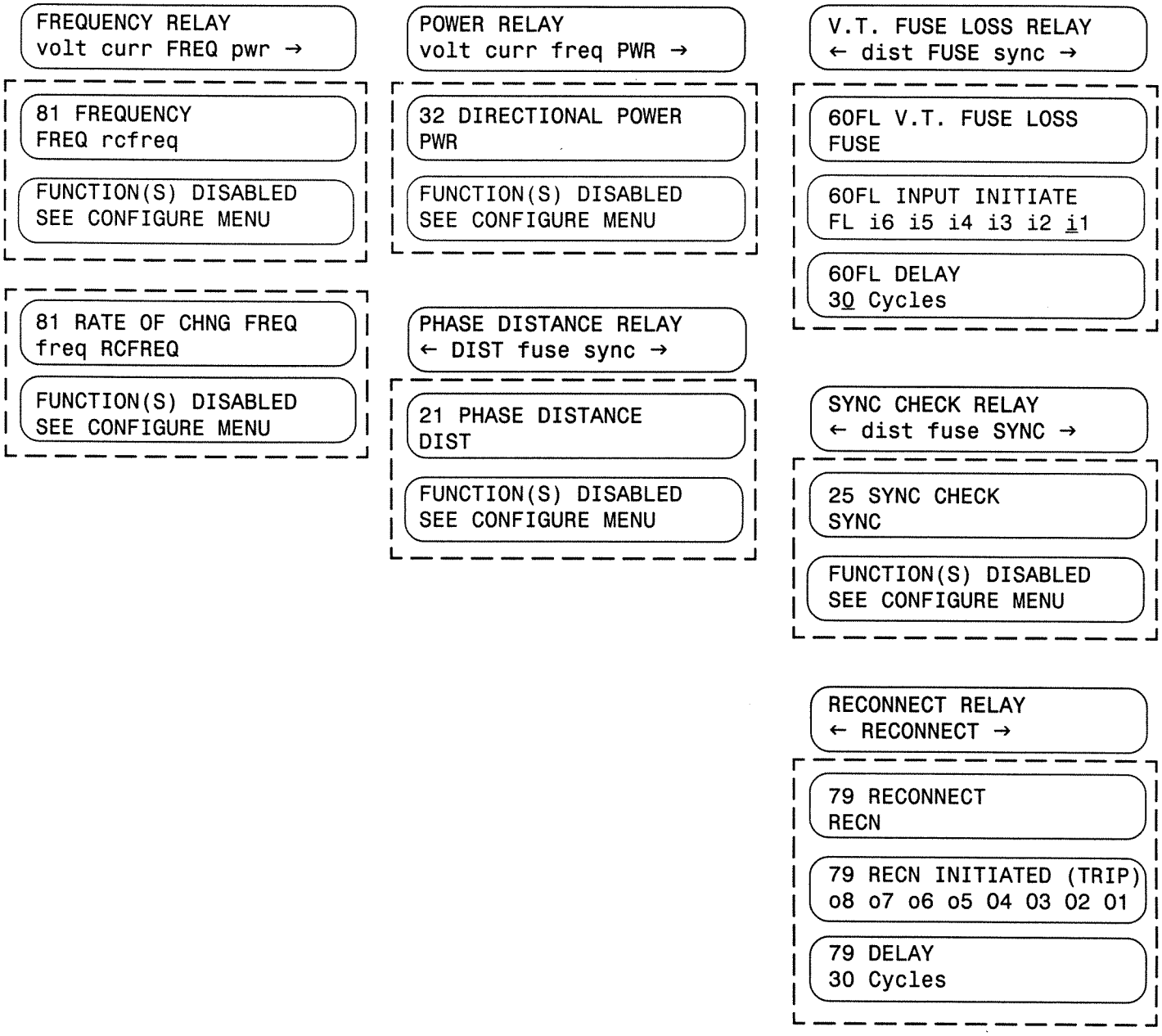


Figure A-4 Setpoint & Timing – As Shipped (2 of 2)

FUNCTION	D	OUTPUTS									INPUTS					
		8	7	6	5	4	3	2	1	FL	6	5	4	3	2	1
21 #1	✓															
21 #2	✓															
25	✓															
27 #1									✓	✓						✓
27 #2	✓															
27G	✓															
32 #1	✓															
32 #2	✓															
46DT	✓															
46IT	✓															
47 #1	✓															
47 #2	✓															
50	✓															
50G	✓															
51G	✓															
51V	✓															
59 #1									✓							✓
59 #2	✓															
59I	✓															
59G	✓															
60FL			✓													✓
67DT	✓															
67IT	✓															
67NDT	✓															
67NIT	✓															
79		✓														
81 #1	✓															
81 #2	✓															
81 #3	✓															
81 #4	✓															
81R #1	✓															
81R #2	✓															

Check each box applicable : ✓ (See page A-1 for information on using this table.)

D Column = Function Disabled.

FL Column = Function blocked by fuse loss.

INPUTS Columns =Designated function blocking input(s)

OUTPUTS Columns =Designated function output(s)

Table A-2 M-3520 Configuration As Shipped

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B Appendix B – Communications

The M-3520 Intertie Protection Relay incorporates three serial ports for intelligent, digital communication with external devices. Equipment such as RTUs, data concentrators, modem, or computers can be interfaced for direct, on-line real time data acquisition and control.

Generally, all data available to the operator through the front panel of the relay, with the optional M-3931 HMI module is accessible remotely through the BECO 2200 data exchange protocol. This protocol document and the BECO 2200 M-3520 database-specified protocol document are available from the factory or our website at www.beckwithelectric.com.

The M-3822 IPScom® Communication Software package has been supplied for communication to any IBM compatible computer running under Microsoft® Windows 95 or higher.

The protocol implements serial, byte oriented, asynchronous communication, and can be used to fulfill the following communications functions:

- Real time monitoring of line status.
- Interrogation and modification of setpoints.
- Downloading of recorded oscillograph data.
- Reconfiguration of functions.

■ **NOTE:** The following restrictions apply for MODBUS protocol use:

1. MODBUS protocol is not supported on COM1
2. Parity is supported on COM2 and COM3 only, valid selections are 8,N,2; 8,0,1 or 8,E,1. ASCII mode is not supported (RTU only)
3. Standard baud rates from 300 to 9600 are supported
4. Only the following MODBUS commands are supported:
   a. Read holding register (function 03)
   b. read input register (function 04)
   c. Force single coil (function 05)
   d. Preset single register (function 06)
6. MODBUS does not support oscillograph record downloading.

For detailed information on communications, refer to Chapter 4, **IPScom Computer Operation.**

Communication Ports

The M-3520 has both front and rear panel RS-232 ports, and a rear RS-485 port. The front and rear panel RS-232 ports are 9-pin (DB9S) connector configured as DTE (Data Terminal Equipment) per the RS-232C standard. Signals are defined in Table B-1.

The RS-485 port is assigned to the rear panel terminal block pins 1 through 4 (see Figure B-2). This can be configured for isolated RS-485 two-wire or non-isolated four-wire operation.

■ **NOTE**: Four-wire operation is only available as a non-isolated RS-485 supplied option.

Each communication port may be configured to operate at any of the standard baud rates (1200, 2400, 4800, and 9600). The RS-485 port shares the same baud rate with COM2 (or COM1 – see Section 5.3).

While the RS-232 communication ports do include some Electrostatic Discharge (ESD) protection circuitry, they are excluded from passing ANSI/IEEE C37.90.1-1998. Beckwith Electric recommends the use of RS-232 to fiber optic converters to avoid any question of surge-withstand capability.

A null modem cable (see Figure B-1) allows direct connection to a personal computer (PC), if desired.

CIRCUIT		SIGNAL	COM 1	COM 2
BB	RX	Receive Data	Pin 2	Pin 2
BA	TX	Transmit Data	Pin 3	Pin 3
CA	RTS	Request to Send	Pin 7	Pin 7
CB	CTS	Clear to Send		Pin 8
CD	DTR	Data Terminal Ready	Pin 4	Pin 4
CF	DCD	Data Carrier Detect		Pin 1
AB	GND	Signal Ground	Pin 5	Pin 5
		+15 V		Pin 1*
		-15 V		Pin 9*
		IRIG-B (+)		Pin 6*

*OPTIONAL - see 5.5, Circuit Board Switches and Jumpers
±15V (±15%) @100 mA max.

Table B-1 Communication Port Signals

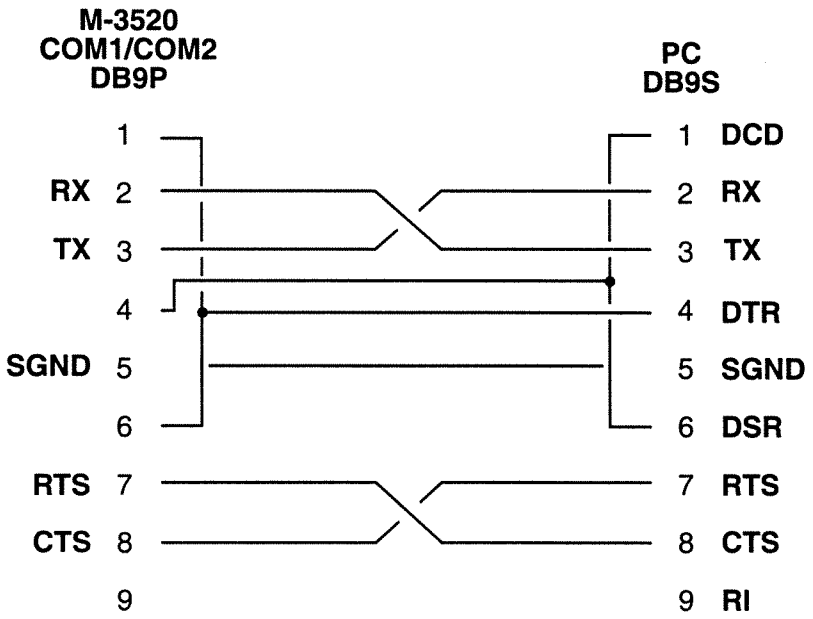


Figure B-1 Null Modem Cable

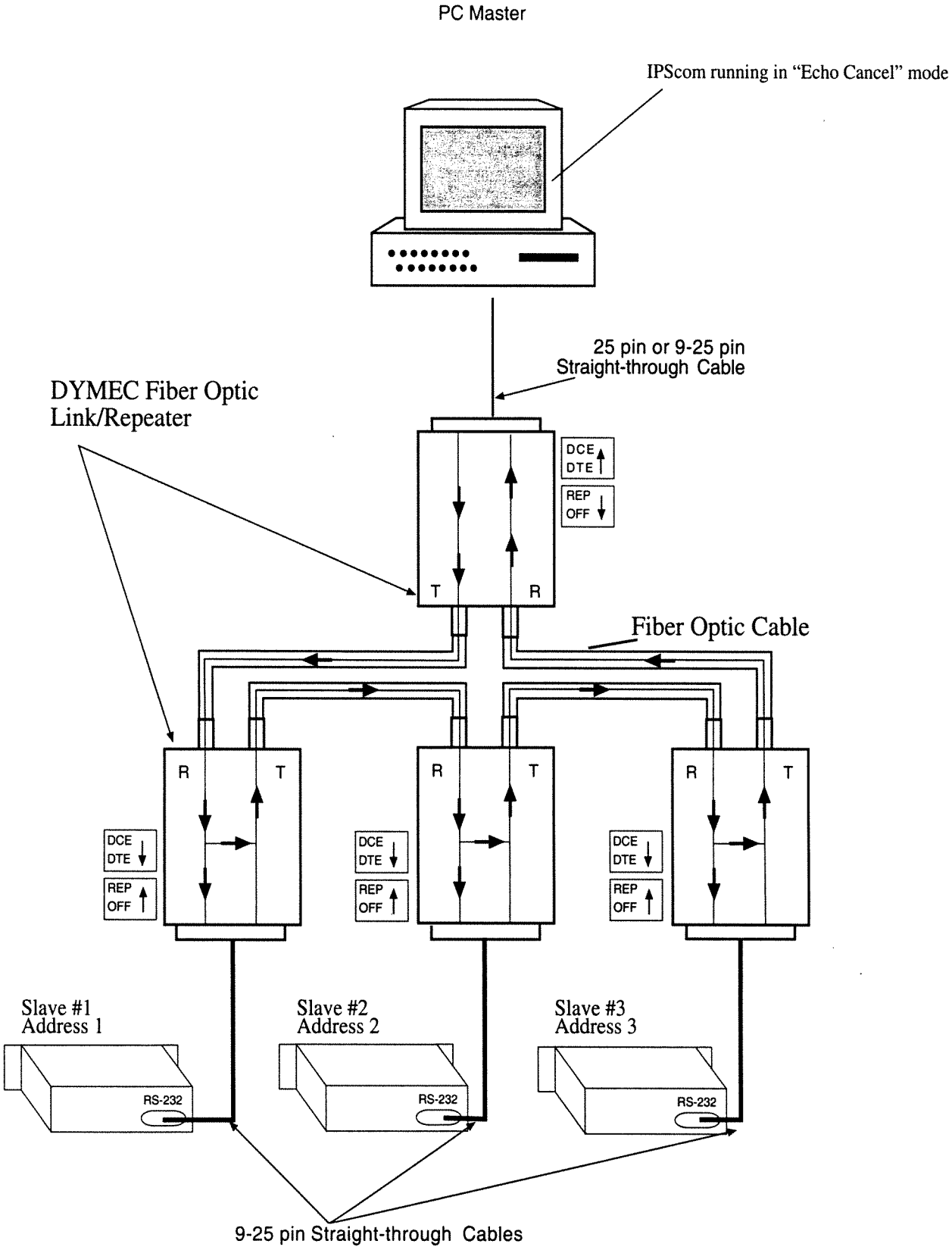
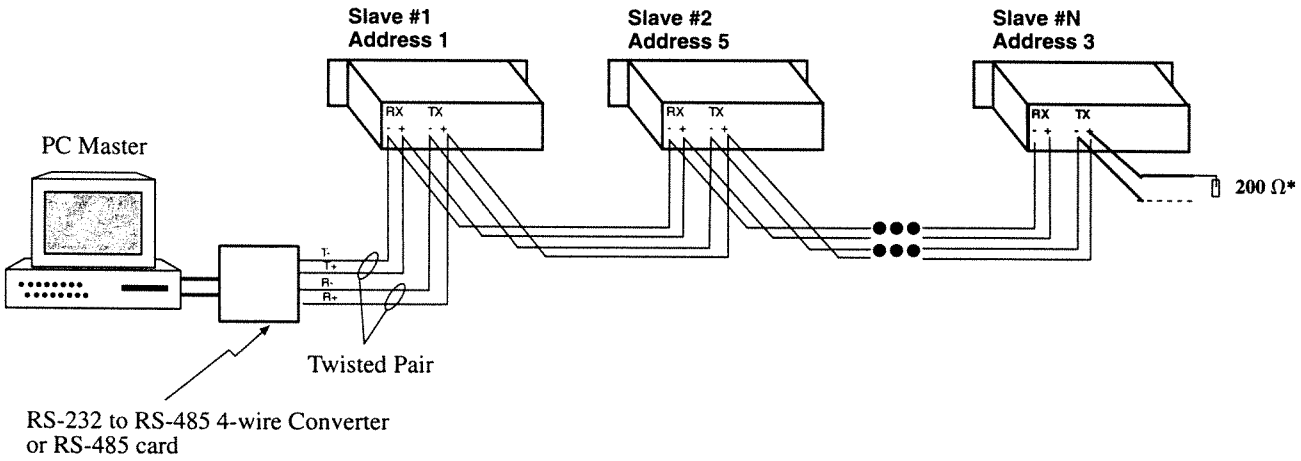
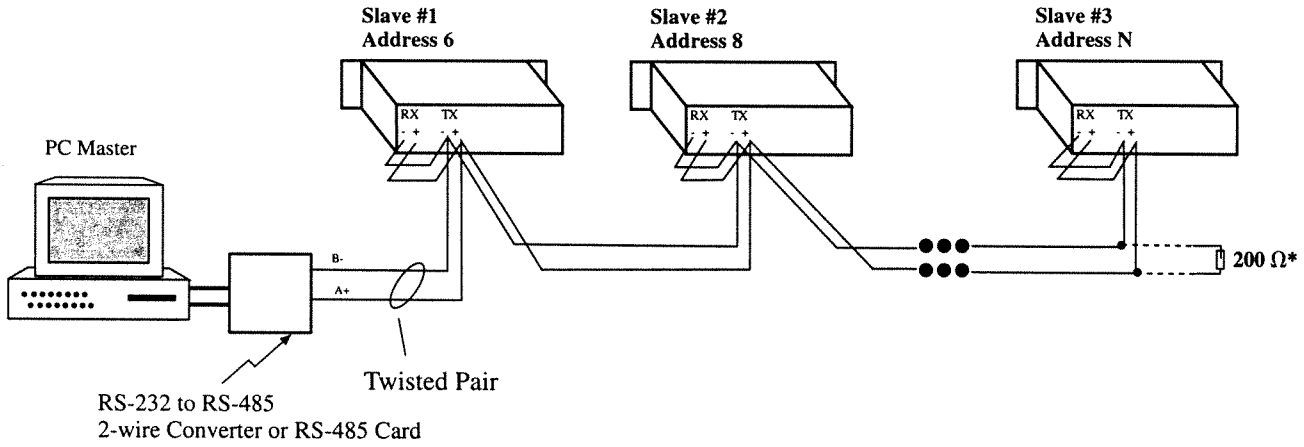


Figure B-2 RS-232 Fiber Optic Network

RS-485 4-Wire Network



RS-485 2-Wire Network



▲ **CAUTION**: Due to the possibility of ground potential difference between units, the units should be mounted in the same rack. If this is not possible, fiber optics with the appropriate converters should be used for isolation. The two-wire topology is preferable to the four-wire, as circuitry within the relay provides some isolation. Four-wire operation is only available when the four-wire RS-485 option is selected at the time of purchase.

■ **NOTE**: Each address on the network must be unique. Only the last physical slave on the network should have the termination resistor installed.

Figure B-3 RS-485 Networks

C Appendix C – Self-Test Error Codes

Error Code	Description
1	
2	Battery-backed RAM test fail
3	EEPROM write power-up fail
4	EEPROM read back power-up fail
5	Dual port RAM test fail
6	EEPROM write calibration checksum fail
7	EEPROM write setpoint calibration fail loss of power
8	EEPROM write setpoint checksum fail loss of battery backed RAM
9	DMA checksum/physical block fail
10	
11	DSP external program RAM fail
12	DSP A/D convert fail
13	DSP ground channel fail
14	DSP reference channel fail
15	DSP PGA gain fail
16	DSP DSP<->Host interrupt 1 fail
17	DSP DSP<->Host interrupt 2 set fail
18	DSP DSP<->Host interrupt 2 reset fail
19	DSP program load fail
20	
21	
22	DSP DPRAM pattern test fail
23	EEPROM write verify error
24	BBRAM test error
25	Uninitialized EEPROM

Table C-1A Error Codes

Error Code	Description
26	WARNING calibration checksum mismatch warning
27	WARNING setpoint checksum mismatch warning
28	WARNING low battery (BBRAM) warning
29	Supply/Mix PGA running test fail
30	
31	Unrecognized INT1 interrupt code
32	Values update watchdog fail
33	Abort error
34	Restart error
35	Interrupt error
36	Trap error
37	Calibration running check fail
38	
39	
40	87 high speed interrupt noise
41	
42	
43	
44	Oscillograph buffer overflow
45	Oscillograph buffer underflow
46	Failure of DSP to calculate calibration phasors
47	Uncalibratable input (gain)
48	Uncalibratable input (phase)
49	
50	Stack overflow

Table C-1B Error Codes (cont.)

D Appendix D – Inverse Time Curves

This Appendix contains Inverse Time Curve Families for M-3520 Intertie Protection Relay functions # 46, 51V, 51G, 67, and 67N.

Multiple of Tap Setting	Definite Time	Inverse Time	Very Inverse Time	Extremely Inverse Time
1.50	0.69899	4.53954	3.46578	4.83520
1.55	0.64862	4.15533	3.11203	4.28747
1.60	0.60539	3.81903	2.81228	3.83562
1.65	0.56803	3.52265	2.55654	3.45706
1.70	0.53558	3.25987	2.33607	3.13573
1.75	0.50725	3.02558	2.14431	2.85994
1.80	0.48245	2.81566	1.97620	2.62094
1.85	0.46068	2.62673	1.82779	2.41208
1.90	0.44156	2.45599	1.69597	2.22822
1.95	0.42477	2.30111	1.57823	2.06529
2.00	0.41006	2.16013	1.47254	1.92006
2.05	0.39721	2.03139	1.37723	1.78994
2.10	0.38606	1.91348	1.29093	1.67278
2.15	0.37648	1.80519	1.21249	1.56686
2.20	0.36554	1.72257	1.12812	1.47820
2.30	0.35293	1.54094	1.01626	1.32268
2.40	0.34115	1.39104	0.92207	1.19250
2.50	0.33018	1.26561	0.84190	1.08221
2.60	0.31999	1.15945	0.77301	0.98780
2.70	0.31057	1.06871	0.71334	0.90626
2.80	0.30189	0.99049	0.66127	0.83527
2.90	0.29392	0.92258	0.61554	0.77303
3.00	0.28666	0.86325	0.57515	0.71811
3.10	0.28007	0.81113	0.53930	0.66939
3.20	0.27415	0.76514	0.50733	0.62593
3.30	0.26889	0.72439	0.47870	0.58700
3.40	0.26427	0.68818	0.45297	0.55196
3.50	0.26030	0.65591	0.42977	0.52032
3.60	0.25697	0.62710	0.40879	0.49163
3.70	0.25429	0.60135	0.38977	0.46554
3.80	0.25229	0.57832	0.37248	0.44175
4.00	0.24975	0.53904	0.34102	0.40129
4.20	0.24572	0.50641	0.31528	0.36564
4.40	0.24197	0.47746	0.29332	0.33460
4.60	0.23852	0.45176	0.27453	0.30741
4.80	0.23541	0.42894	0.25841	0.28346

■ **NOTE:** The above times are in seconds and are given for a time dial of 1.0. For other time dial values, multiply the above by the time dial value.

Table D-1A M-3520 Inverse Time Overcurrent Relay Characteristic Curves

Multiple of Tap Setting	Definite Time	Inverse Time	Very Inverse Time	Extremely Inverse Time
5.00	0.23266	0.40871	0.24456	0.26227
5.20	0.23029	0.39078	0.23269	0.24343
5.40	0.22834	0.37495	0.22254	0.22660
5.60	0.22684	0.36102	0.21394	0.21151
5.80	0.22583	0.34884	0.20673	0.19793
6.00	0.22534	0.33828	0.20081	0.18567
6.20	0.22526	0.32771	0.19511	0.17531
6.40	0.22492	0.31939	0.19044	0.16586
6.60	0.22360	0.31150	0.18602	0.15731
6.80	0.22230	0.30402	0.18187	0.14957
7.00	0.22102	0.29695	0.17797	0.14253
7.20	0.21977	0.29027	0.17431	0.13611
7.40	0.21855	0.28398	0.17090	0.13027
7.60	0.21736	0.27807	0.16773	0.12492
7.80	0.21621	0.27253	0.16479	0.12003
8.00	0.21510	0.26734	0.16209	0.11555
8.20	0.21403	0.26251	0.15961	0.11144
8.40	0.21300	0.25803	0.15736	0.10768
8.60	0.21203	0.25388	0.15534	0.10422
8.80	0.21111	0.25007	0.15354	0.10105
9.00	0.21025	0.24660	0.15197	0.09814
9.50	0.20813	0.23935	0.14770	0.09070
10.00	0.20740	0.23422	0.14473	0.08474
10.50	0.20667	0.22923	0.14180	0.07943
11.00	0.20594	0.22442	0.13894	0.07469
11.50	0.20521	0.21979	0.13615	0.07046
12.00	0.20449	0.21536	0.13345	0.06667
12.50	0.20378	0.21115	0.13084	0.06329
13.00	0.20310	0.20716	0.12833	0.06026
13.50	0.20243	0.20341	0.12593	0.05755
14.00	0.20179	0.19991	0.12364	0.05513
14.50	0.20119	0.19666	0.12146	0.05297
15.00	0.20062	0.19367	0.11941	0.05104
15.50	0.20009	0.19095	0.11747	0.04934
16.00	0.19961	0.18851	0.11566	0.04784
16.50	0.19918	0.18635	0.11398	0.04652
17.00	0.19881	0.18449	0.11243	0.04539
17.50	0.19851	0.18294	0.11102	0.04442
18.00	0.19827	0.18171	0.10974	0.04362
18.50	0.19811	0.18082	0.10861	0.04298
19.00	0.19803	0.18029	0.10762	0.04250
19.50	0.19803	0.18014	0.10679	0.04219
20.00	0.19803	0.18014	0.10611	0.04205

■ **NOTE:** The above times are in seconds and are given for a time dial of 1.0. For other time dial values, multiply the above by the time dial value.

Table D-1B M-3520 Inverse Time Overcurrent Relay Characteristic Curves

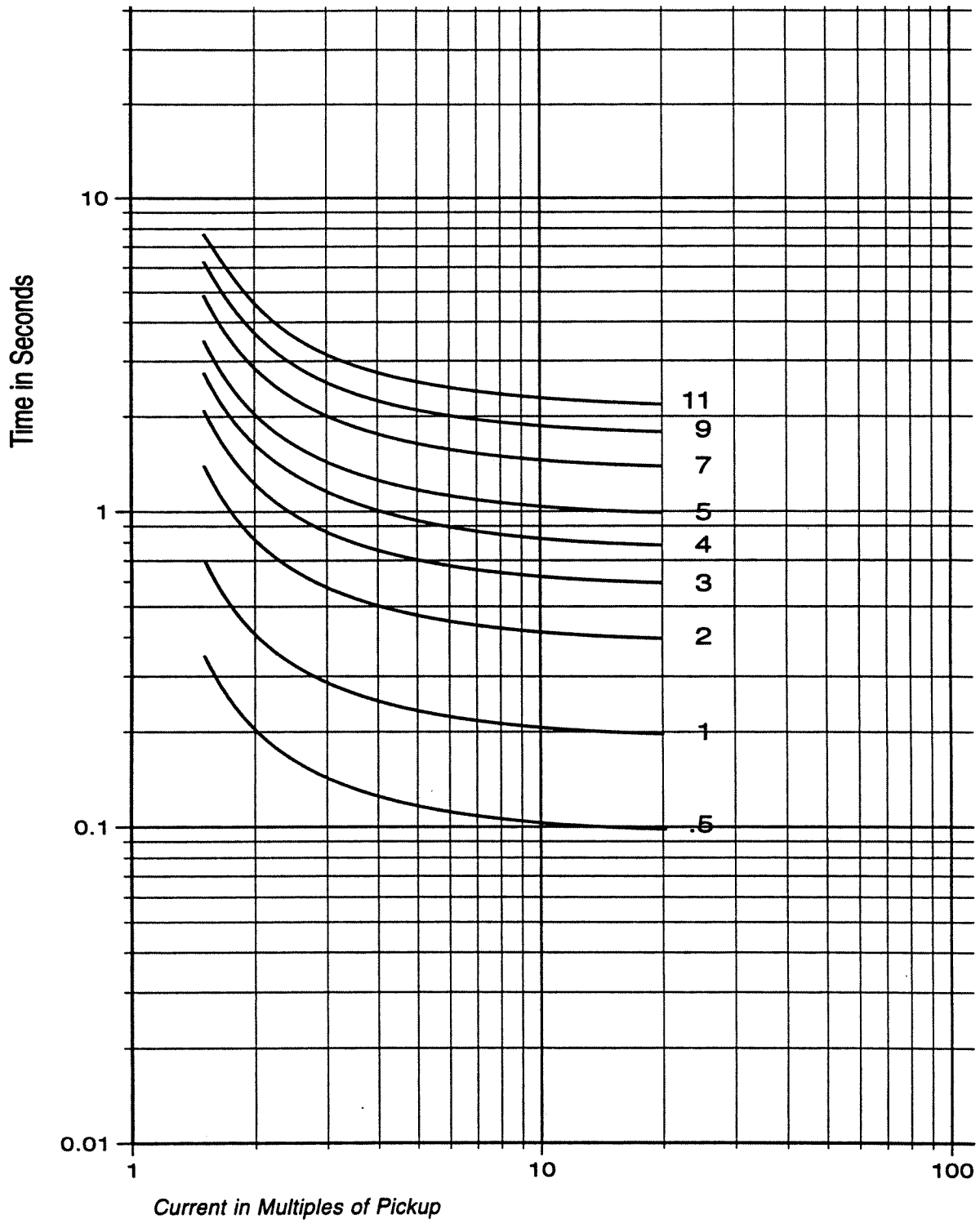


Figure D-1 Definite Time Overcurrent Curve

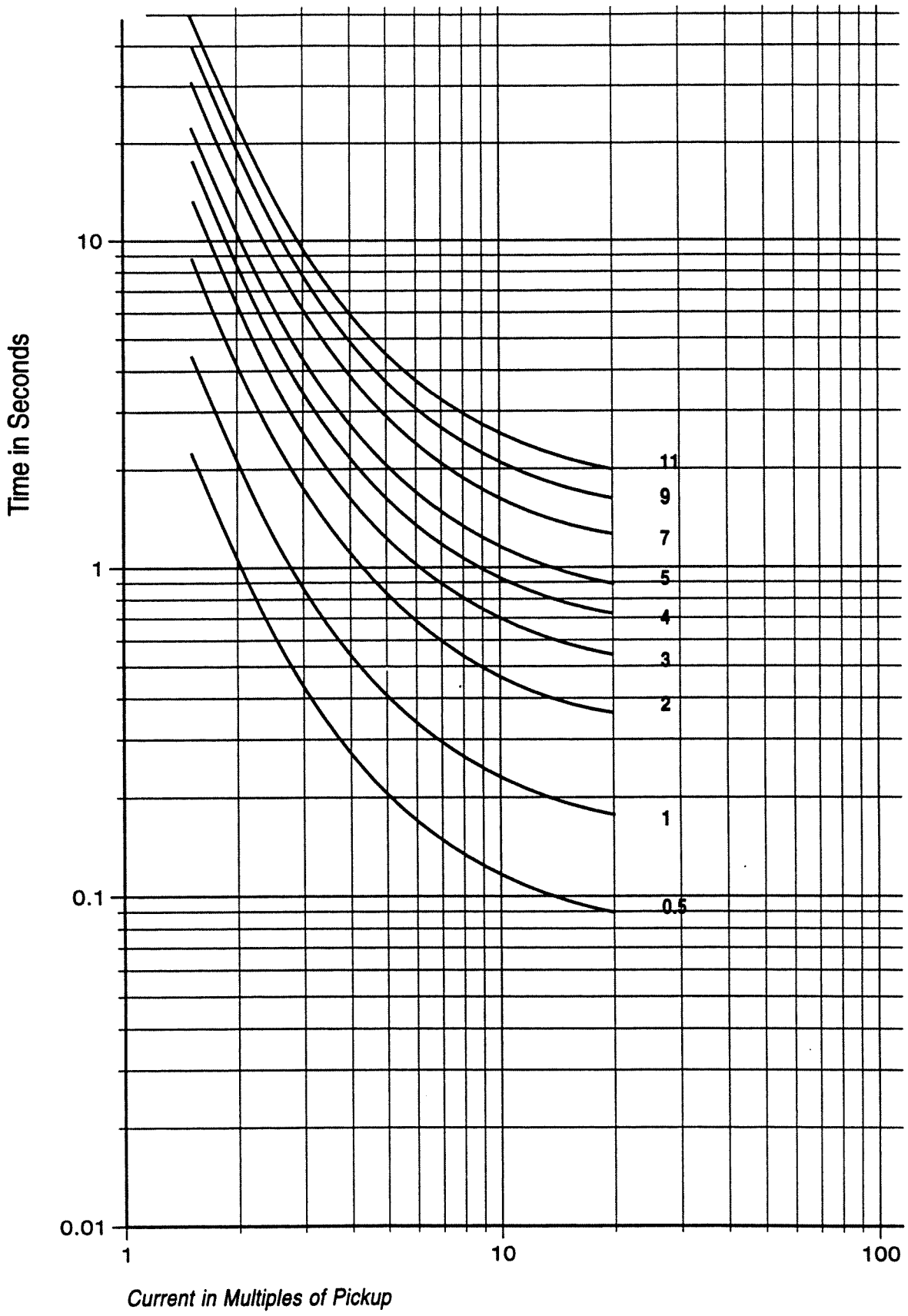


Figure D-2 Inverse Time Overcurrent Curve

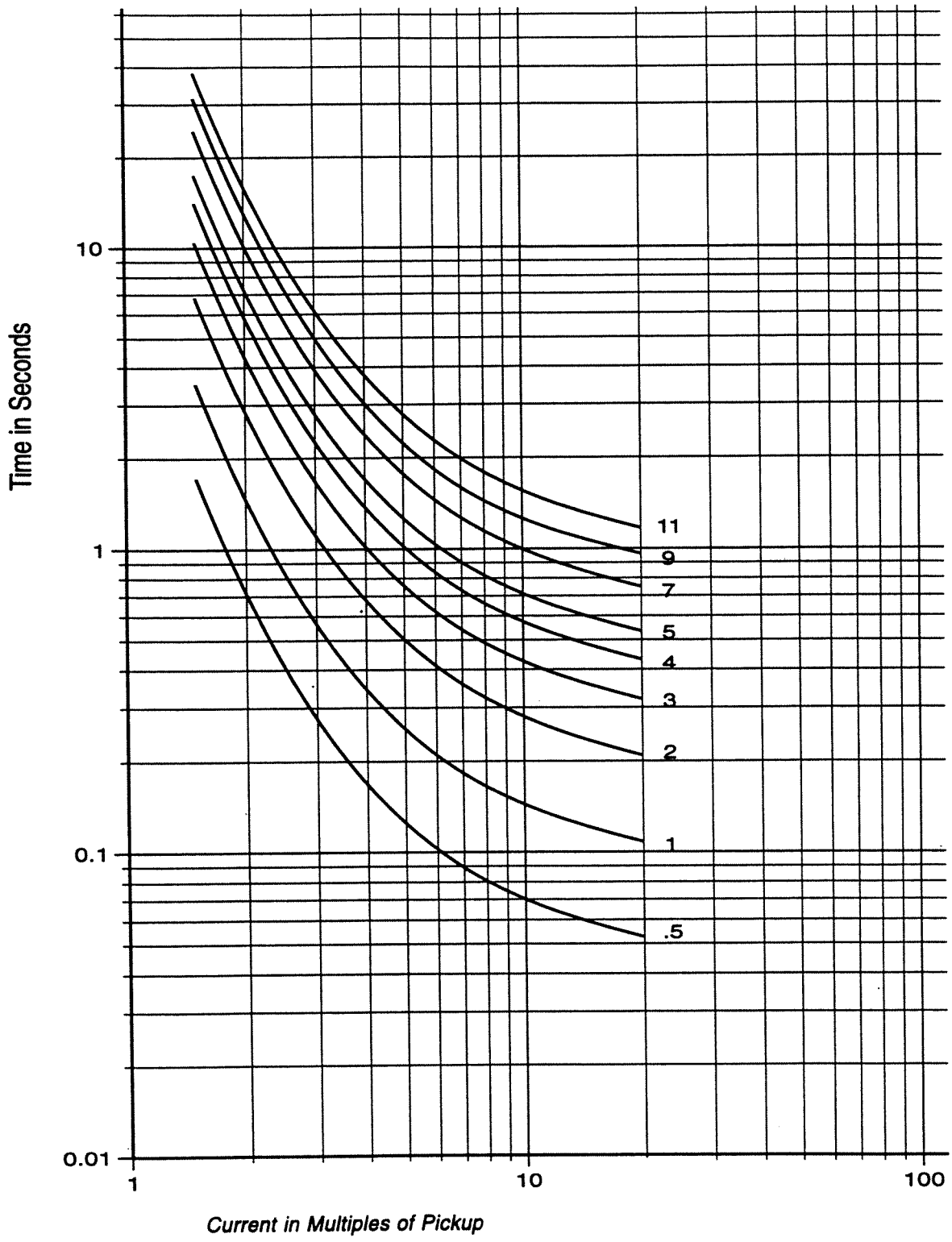


Figure D-3 Very Inverse Time Overcurrent Curve

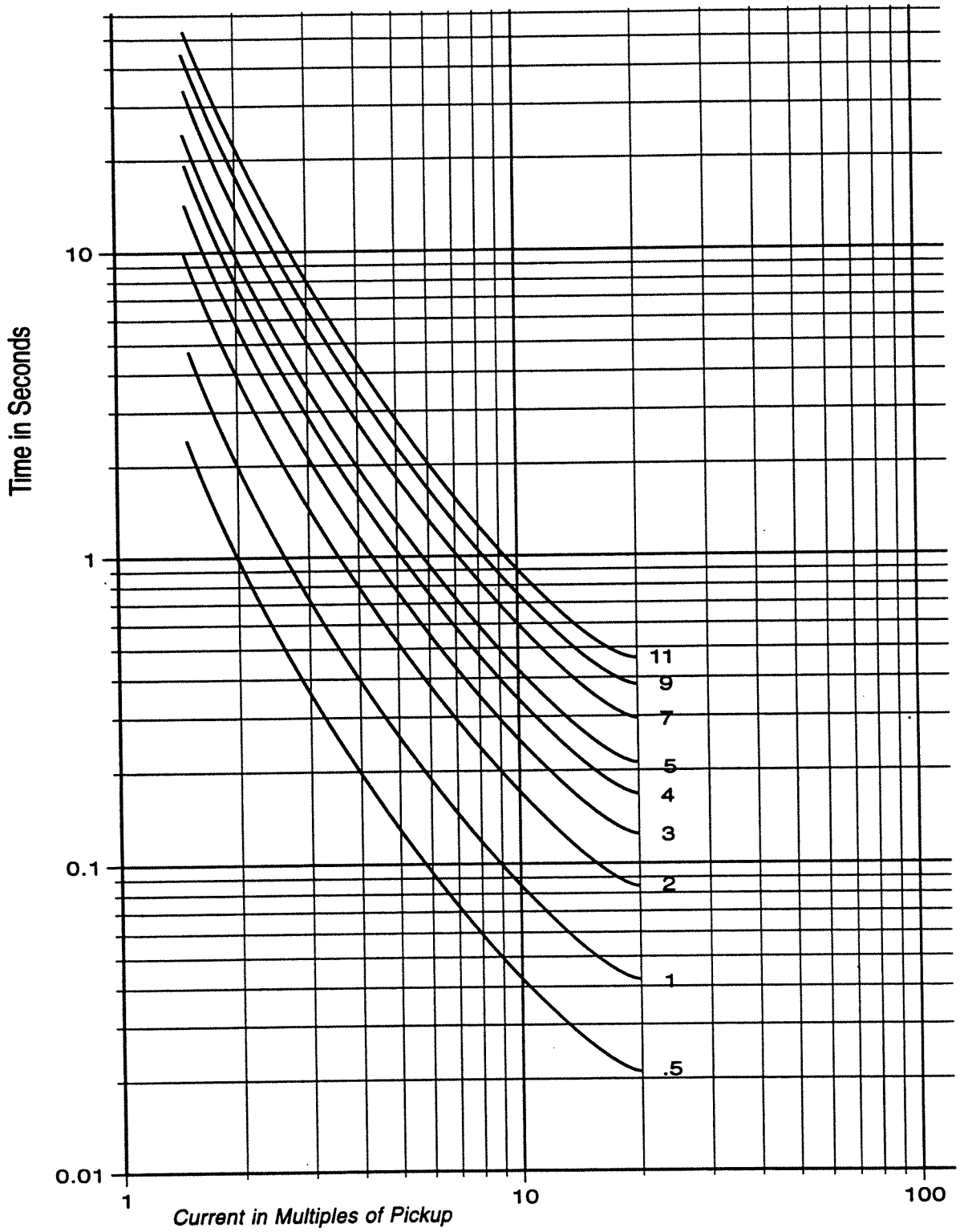


Figure D-4 Extremely Inverse Time Overcurrent Curve

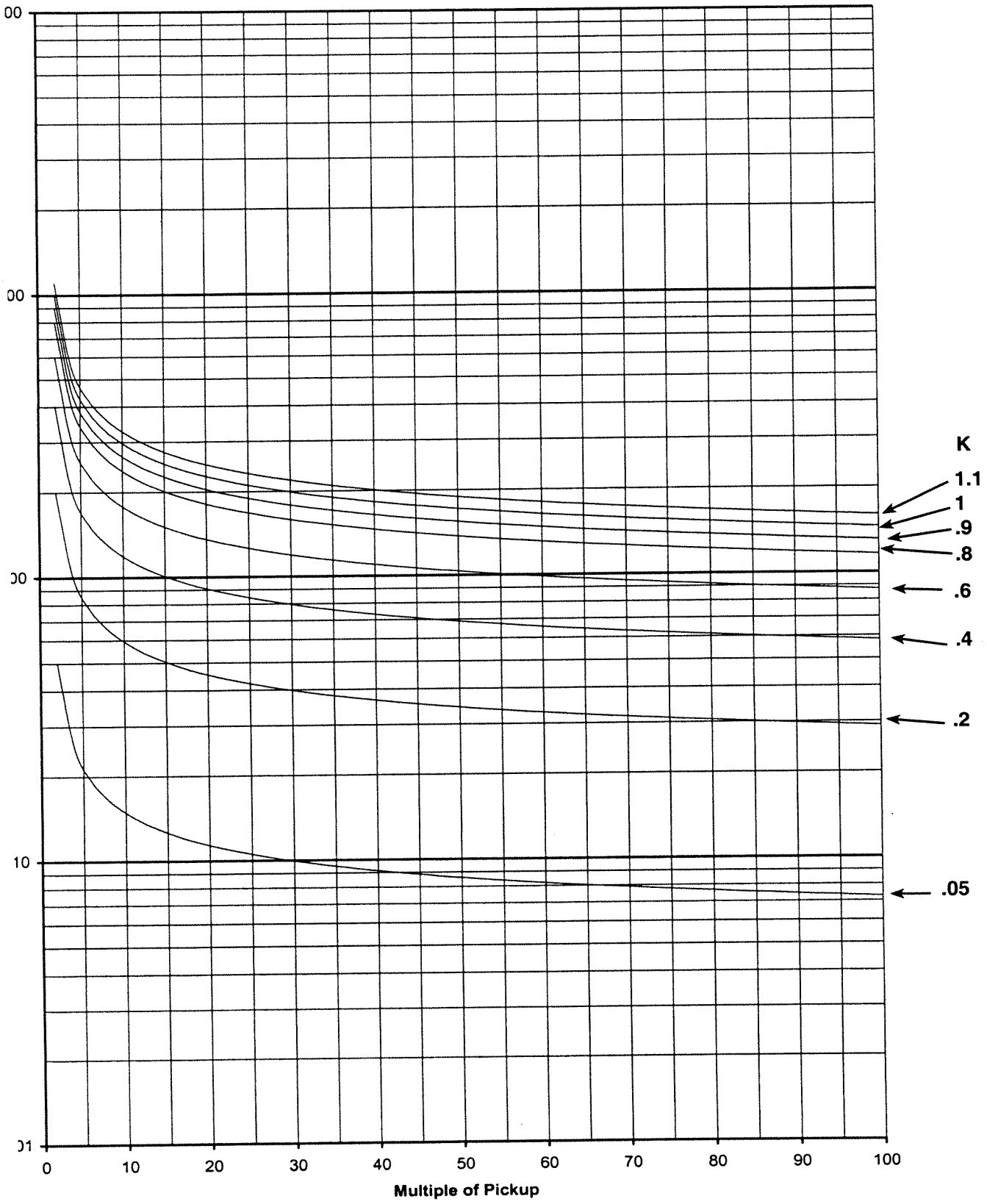


Figure D-5 IEC Curve #1 Inverse

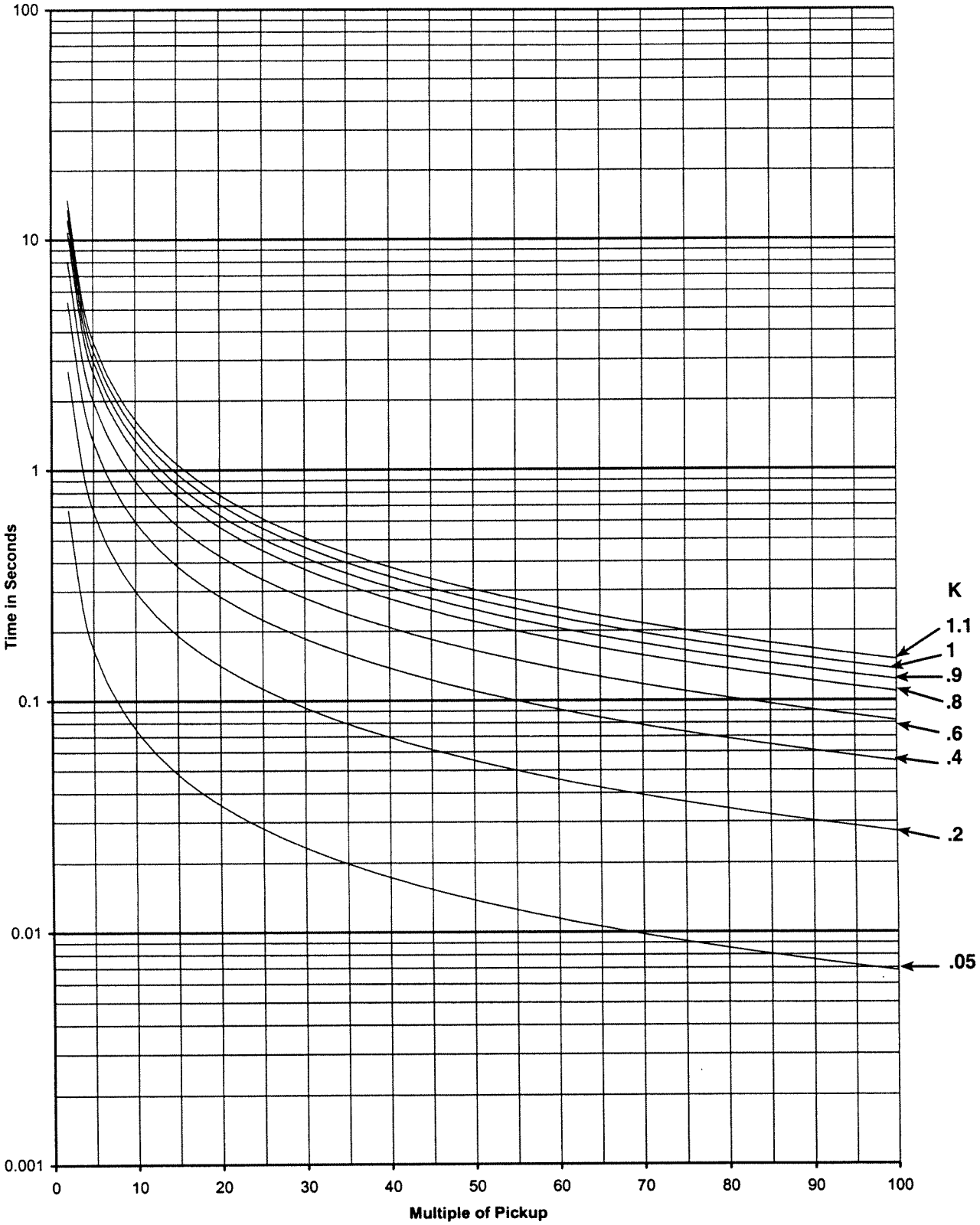


Figure D-6 IEC Curve #2 Very Inverse

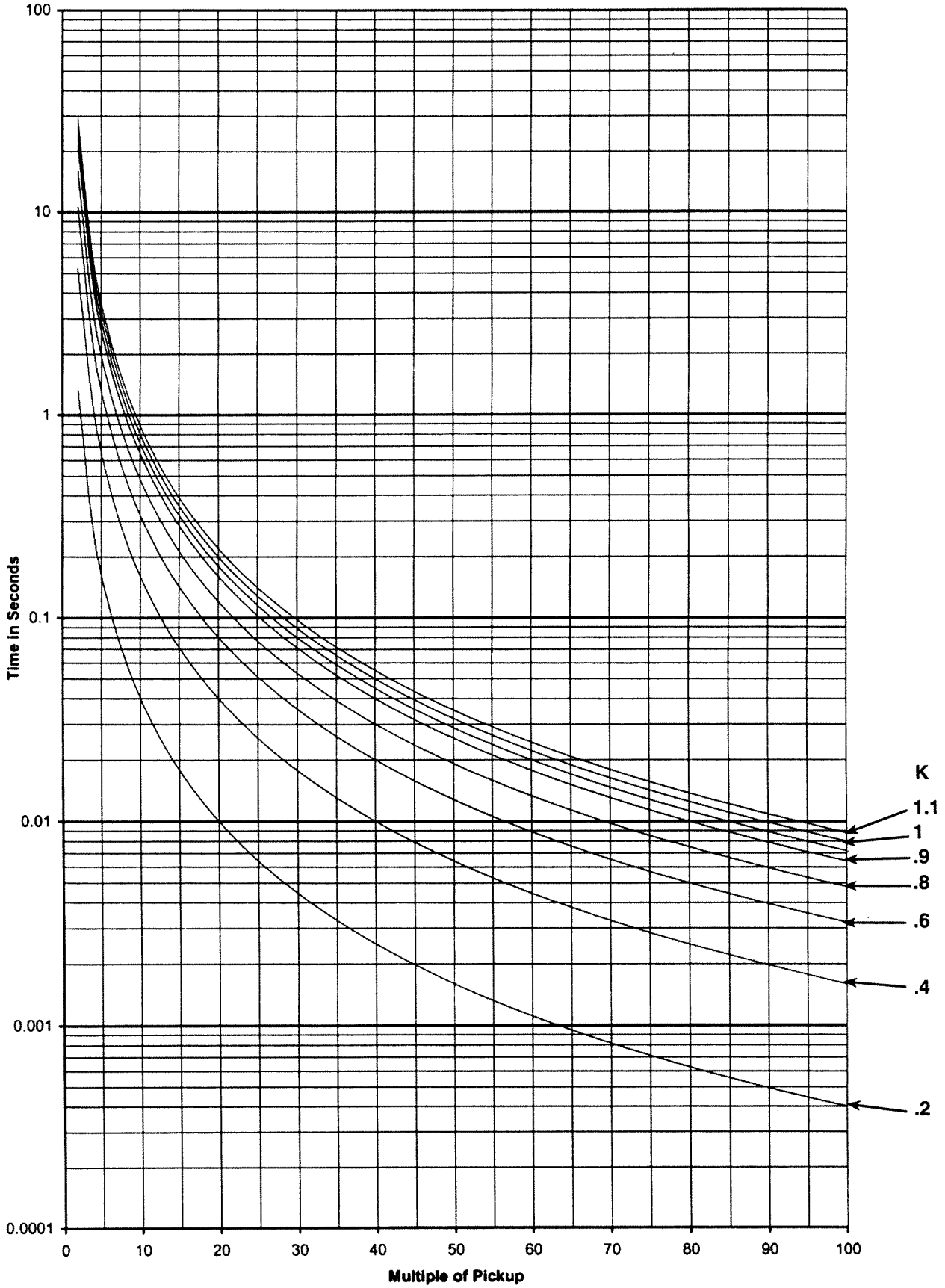


Figure D-7 IEC Curve #3 Extremely Inverse

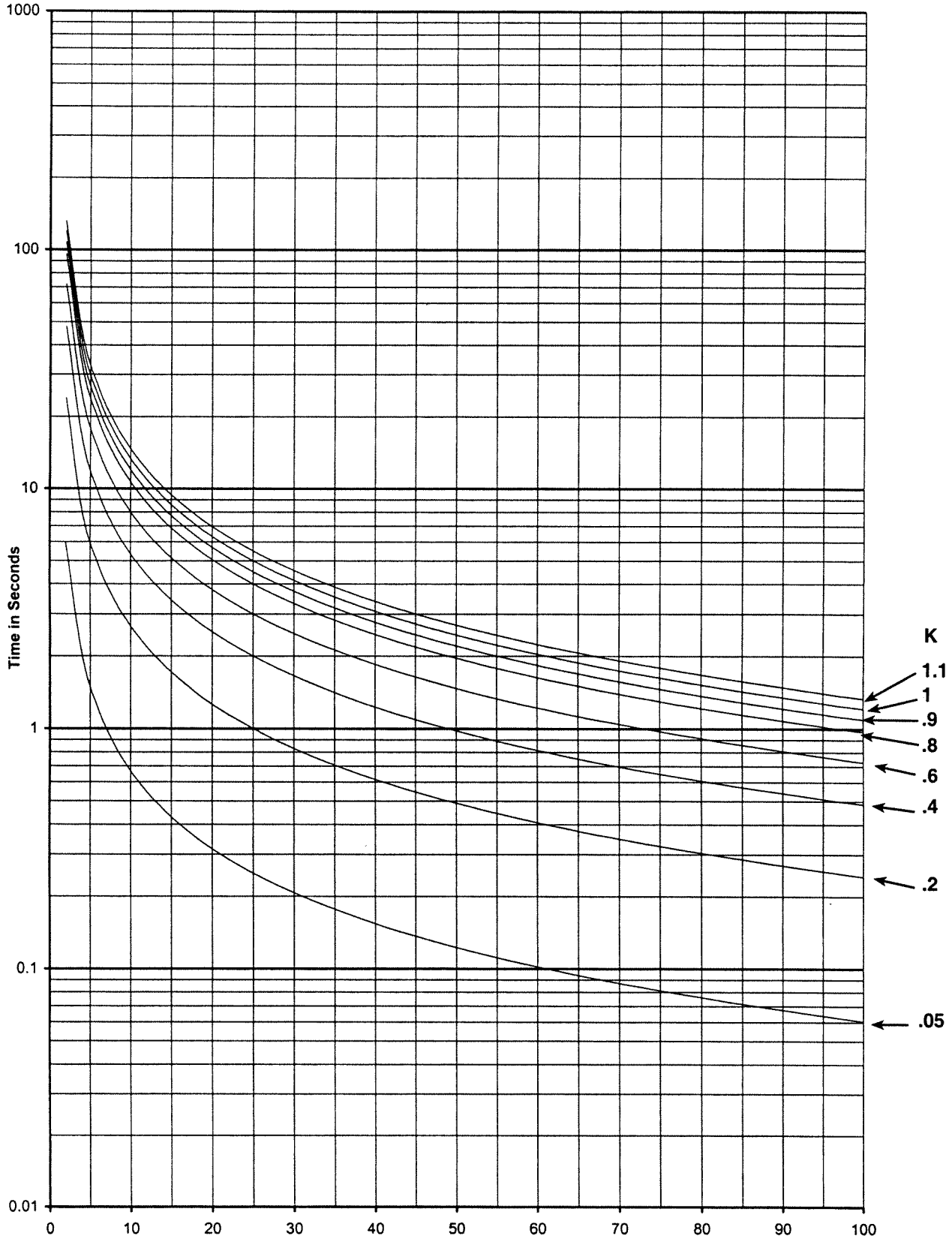


Figure D-8 IEC Curve #4 Long-Time Inverse

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1 Introduction

1.1 Instruction Book Contents

This instruction book is divided into six major chapters and four appendices.

Chapter 1: Introduction

Chapter one contains a brief description of the six chapters and four appendices contained in this handbook. It enumerates the functional capabilities of the M-3520 Intertie Protection Relay and provides a list (see Table 1-1) of device functions. This chapter also describes the accessories that may be used in conjunction with application of the protective relay.

Chapter 2: Application

Chapter two contains specific information for the person or group responsible for the application of the relay. The information provided includes functional diagrams, connection diagrams for typical applications, instructions on configuration of the unit (enabling required functions), and output contact assignments/input blocking designation. This chapter also illustrates the definition of system quantities and required equipment characteristics, describes the individual function settings and oscillograph recorder setup.

Chapter 3: Operation (Front Panel)

This chapter is designed for the person or group responsible for the operation and direct setting and configuration of the relay, and is limited to installations using the HMI (Man-Machine Interface) Module. This chapter includes an introduction to the front panel controls, the function and operation of the keypad, the characteristics of the display, indicators, Target Module, and the communication ports. It further describes the procedures for entering all required data to the M-3520.

Also included in this chapter is a description of the operation of the monitoring status and metering quantities, and of viewing the target history. This chapter references appropriate forms for recording and communicating the described data to the parties responsible for operation and installation of the relay

Chapter 4: Operation (Computer)

This chapter provides information for the person or group responsible for the operation and direct setting and configuration of the relay via personal computer, using the IPScom® M-3822 Communications Software package. It includes installation, setup information, and procedures for entering all data required to operate the relay. Specific descriptions of the monitoring functions, status and metering quantities are also provided.

Chapter 5: Installation

This chapter provides all the mechanical information, including dimensions, external connections and equipment ratings required for physical installation of the relay. For reference, the Three-Line Connection Diagram is repeated from Chapter 2. A commissioning checkout procedure is outlined, using the HMI option and IPScom to check the external CT and VT connections. Other tests, which may be desirable at time of installation, are described in Chapter 6.

Chapter 6: Testing

This chapter provides step-by-step test procedures for each M-3520 function as well as the diagnostic mode procedures and the autocalibration procedure using the HMI.

Appendix A: Configuration Record forms

This appendix supplies a set of forms to record and communicate the inputs required for the proper operation of the M-3520, as well as forms illustrating "As Shipped" settings for all functions.

Appendix B: Communications

This appendix describes the communications equipment, the protocol used, the communication ports, and the port signals.

Appendix C: Self-test Error Codes

This appendix lists all the M-3520 error codes and their descriptions.

Appendix D: Inverse Time Curves

This appendix contains graphs of the four standard Inverse Time Curves and the four IEC overcurrent curves.

1.2 M-3520 Intertie Protection Relay

The M-3520 Intertie Protection Relay (see Figure 1-1), is a microprocessor-based unit that uses digital signal processing technology to provide protection to the intertie between dispersed storage and generation (DSG) and a utility.

The M-3520 provides 12 base and 8 optional protective relay functions (see Table 1-1). The nomenclatures of these functions are derived from the standards of ANSI/IEEE C37.2-1991, Standard Electric Power Systems Device Function Numbers.

Six input contacts (located on rear side of unit) can be programmed to block any relay function and/or trigger the oscillograph recorder. Any of the functions or input contacts can be individually programmed to activate one or more of the eight programmable output contacts.

STANDARD FUNCTIONS	DESCRIPTION
27	Undervoltage
46	Negative Sequence Overcurrent
47	Negative Sequence Overvoltage
50	Instantaneous Overcurrent
50G	Instantaneous Neutral Overcurrent
51G	Inverse Time Neutral Overcurrent
51V	Inverse Time Overcurrent, with Voltage Control or Voltage Restraint
59	Overvoltage
60FL	VT Fuse Loss Detection
67	Phase Directional Overcurrent
79	Reconnect Enable
81	Over/Under Frequency
OPTIONAL FUNCTIONS	**DESCRIPTION**
21	Phase Distance
25	Sync Check
32	Reverse/Forward Power
59G/27G	Neutral Overvoltage/Undervoltage
59I	Peak Overvoltage
67N	Residual Directional Overcurrent
81R	Rate of Change of Frequency

Table 1-1 M-3520 Device Functions

With the optional M-3931 Human-Machine Interface Module (HMI), all functions can be set or examined via a local, menu-driven 2-line by 24-character display. The HMI also provides the capability for local metering of various quantities, including phase, neutral, and sequence voltages and currents; power factor, real, reactive, and apparent power measurements.

The relay provides storage of time-tagged target information for the 32 most recent trip events. Also included are self-test, self-calibration and diagnostic capabilities.

The function outputs can provide tripping and/or alarm contacts. Light Emitting Diodes (LEDs) are used for the targets to provide visual indication of a function operation. Three serial I/O ports provide remote communication capability.

A switching mode power supply provides the relay with the various power supply voltages required for operation. (A redundant power supply is available as an option.)

The serial interface ports, COM1 and COM2, are standard 9-pin RS-232C DTE-configured communications ports. The front-panel port, COM1, is used to locally set and interrogate the M-3520 via a portable computer. The second RS-232C port, COM2, is provided at the rear of the unit. An isolated RS-485 communication port, COM3, is also available at the relay's rear terminal block. Either rear-panel port, COM2 or COM3, can be used to remotely set and interrogate the M-3520 via a modem, network or direct serial connection. Detailed information on the use of the relay communications ports is provided in Appendix B, Communications, as well as Chapter 4, **Operation (Computer)**.

The unit provides up to 170 cycles of waveform data storage assignable to up to 4 events with selectable post-trigger delay. Once downloaded, the data can be analyzed using the optional M-3801 IPSplot® Oscillograph Analysis Software package.

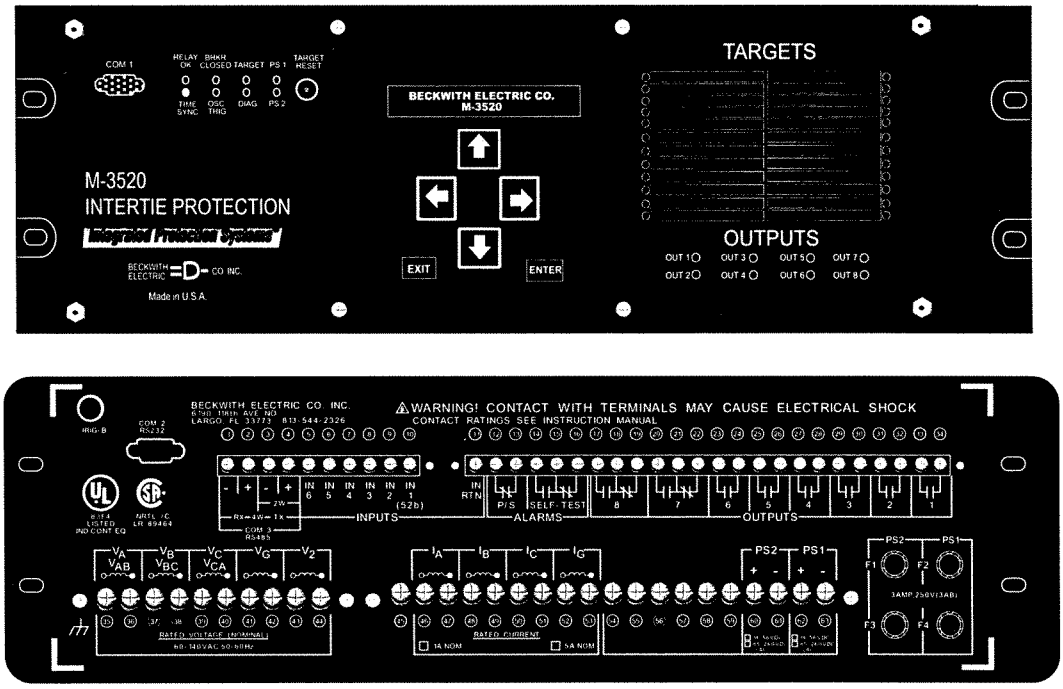


Figure 1-1 M-3520 Front and Rear Panels

1.3 Accessories

A copy of IPScom® communication software is shipped with each M-3520 Intertie Protection Relay. IPScom software will operate on an IBM PC-compatible computer running under Windows 95 or higher, providing remote access to the relay via either direct serial connection or modem. IPScom provides the following communication functions:

- Setpoint interrogation and modification
- Line status real-time monitoring
- Stored target interrogation
- Recorded oscillograph data downloading
- Real time Phasor display

M-3915 Target Module:

The optional target module shown in Figure 1-2 includes 24 individually labeled **TARGET** LEDs (Light Emitting Diodes) to target the operation of the functions on the front panel. Eight individually labeled **OUTPUT** LEDs will be lit as long as any output is picked up.

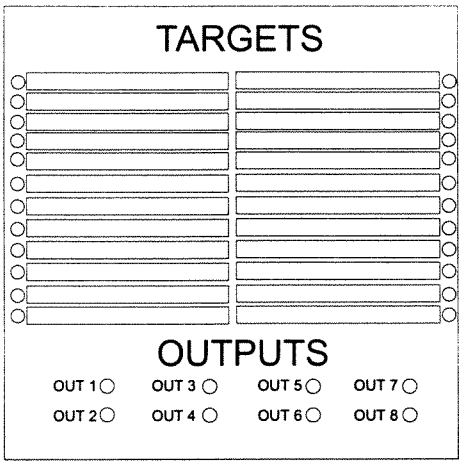


Figure 1-2 M-3915 Target Module

M-3931 Human-Machine Interface (HMI):

The optional HMI module, shown in Figure 1-3, provides a means to interrogate the M-3520 and to input settings, access data, etc. directly from the front of the relay. Operation of the HMI module is described in detail in Section 3.1, Front Panel Controls.

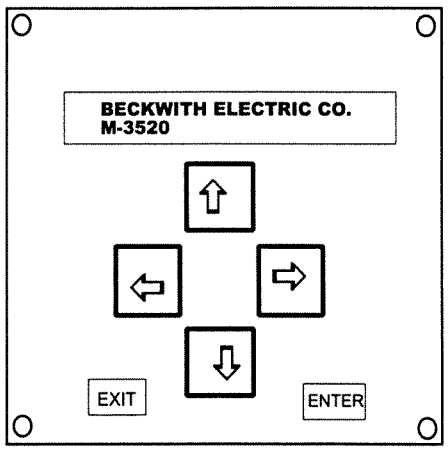


Figure 1-3 M-3931 Human-Machine Interface Module

M-3801A IPSplot® Oscillograph Analysis Software Package:

The IPSplot Oscillograph Analysis Software runs in conjunction with IPScom software package on any IBM PC-compatible computer running Windows 95 or higher, to enable the plotting and printing of waveform data downloaded from the M-3520 Intertie Protection.

M-3933/M-0423 Serial Communications Cable:

The M-3933 cable is a 10-foot RS-232 cable for use between the relay's rear-panel (COM2) port and a modem. This cable has a DB25 (25-pin) connector (modem) and a DB9 (9-pin) at the M-3520 end.

The M-0423 cable is a 10-foot null-modem RS-232 cable for direct connection between a PC and the relay's front-panel COM1 port or the rear COM2 port. This cable has DB9 (9-pin) connectors at each end.

M-3934 Redundant Low Voltage Power Supply:

Redundant 24/48 VDC supply.

M-3935 Redundant High Voltage Power Supply:

Redundant 110/250 VDC supply.

2 Application

2.1 Introduction

This chapter provides information for the person or group responsible for the application of the M-3520 Intertie Protection Relay. Individual relay functions can be programmed to activate any combination of eight output contacts (OUT1–8). Similarly, any relay function can be programmed to be blocked by any of six status inputs (IN1–6) or the internally generated VT Fuse Loss Status. The relay provides programmable setpoints for each relay function. Some relay functions provide two or more elements, each with a magnitude setting and associated time delay.

This chapter is designed to assist in the application aspects of the Intertie Protection system. Detailed information on the relay functions, configuration, setpoints, functional logic schemes, and oscillograph recorder is provided.

This chapter also specifies appropriate forms for recording and communicating the input settings to the parties responsible for operation and installation of the relay.

2.2 System Diagrams

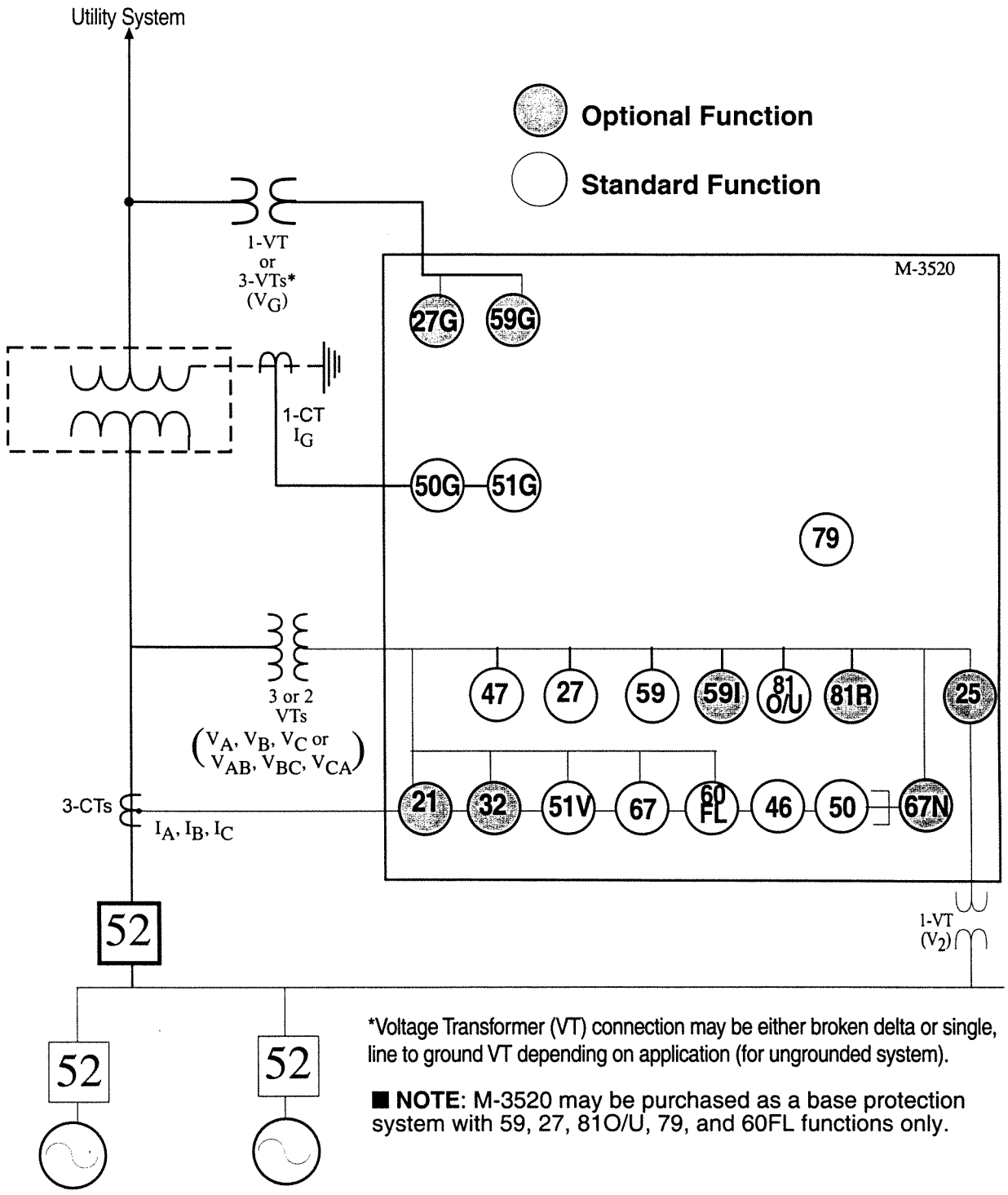


Figure 2-1 One-Line Functional Diagram

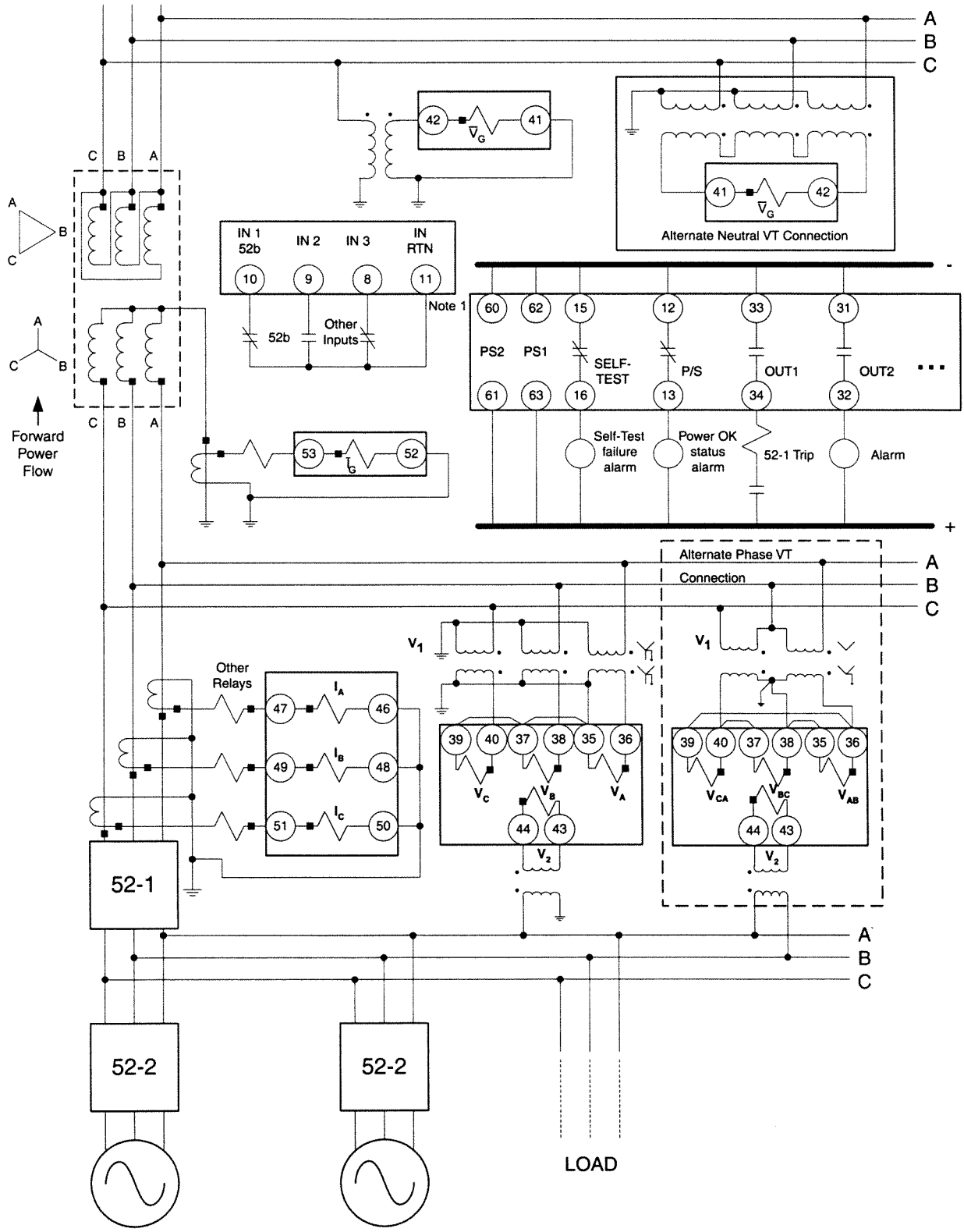


Figure 2-2 Three Line Connection Diagram

■ **Note:** Additional inputs and outputs can be selected by user.

2.3 Configuration

Functions

Configuring the M-3520 Intertie Protection Relay consists of enabling the relay functions to be used in a particular application. Once the output contacts (OUT1–8) are designated, each function will be receptive, according to the status inputs designated (IN1–6) to block the function.

Status inputs may also initiate other actions, such as triggering the Oscillograph Recorder. The status inputs and output contacts need to be chosen *before* configuring the individual functions. Both can be recorded on the **Relay Configuration Table** in Appendix A.

■ **NOTE:** At least one relay output must be selected to enable a function, otherwise the function is disabled.

Special Considerations

Status input IN1 is preassigned to be the 52b breaker contact. The FL blocking input represents the internally generated fuse loss status.

Outputs 1–6 are form "a" contacts (normally open) and outputs 7 and 8 are form "c" contacts (center tapped "a" and "b" contacts).

Outputs 1–4 contain special circuitry which allow them to operate slightly faster than the other outputs.

Each output may also be programmed for pulse operation. The seal-in time delay setting for the particular relay determines the length of time that relay is energized when programmed for pulse operation.

The following functions can be configured using enable/disable output, and status input blocking designations:

- 21 Phase Distance zone #1, zone #2
- 25 Sync Check
- 27 Undervoltage #1, #2
- 27G Neutral Undervoltage
- 32 Reverse/Forward Power #1, #2
- 46 Negative Sequence Overcurrent, Def, Inv
- 47 Negative Sequence Overvoltage #1, #2
- 50 Instantaneous Phase Overcurrent
- 50G Instantaneous Neutral Overcurrent
- 51G Inverse Time Neutral Overcurrent
- 51V Inverse Time Overcurrent with Voltage Control or Voltage Restraint
- 59 Overvoltage #1, #2
- 59I Peak Overvoltage
- 59G Neutral Overvoltage
- 60FL VT Fuse Loss
- 67 Phase Directional Overcurrent, Definite Time and Inverse Time
- 67N Residual Directional Overcurrent, Definite and Inverse Time
- 79 Reconnect Enable
- 81 Frequency: #1,#2, #3, #4
- 81R Rate of Change of Frequency #1, #2

```
27 #1 PHASE UNDERVOLTAGE
disable  ENABLE
```

This designation is required for each relay function. After enabling the function the user is presented with the following two screens.

```
27 #1 BLOCK INPUT
fl i6 i5 i4 i3 i2 i1
```

This screen assigns the blocking designations (up to six) for the enabled function. "OR" logic is used if more than one input is selected. If the "FL" is designated, the function will be blocked by the internally generated fuse loss status.

```
27 #1 RELAY OUTPUT
o8 o7 o6 o5 o4 o3 o2 o1
```

This screen assigns the output contacts (up to eight) for the particular relay function. If no output contacts are assigned, the function will be automatically disabled.

System Setup

The system setup consists of defining common information such as CT and VT ratios, nominal voltage and current ratings, VT configuration, phase rotation, etc. These parameters should be entered before proceeding to the configuration or setpoint and time delay settings for particular functions. The values or selections shown below are only examples. Record and communicate the following information using the Functional Configuration Record Form in Appendix A.

```
NOMINAL VOLTAGE
_______ volts
```

The secondary VT voltage when primary voltage is equal to the 1 per unit rating.

```
NOMINAL CURRENT
_______ amps
```

The secondary current of the phase CTs when the primary current is equal to the 1 per unit rating. Nominal voltage and current are used in the per unit power calculation.

```
V.T. CONFIGURATION
LINE-LINE line-ground →
```

```
V.T. CONFIGURATION
← line-gnd_to_line-line
```

Indicates the VT Configuration. When **LINE-GROUND** is selected, functions 27 and 59 may operate for line-ground faults. If this is not desired, the **LINE-GND_TO_LINE-LINE** selection may be used. When **LINE-GROUND TO LINE-LINE** is selected, the relay internally calculates line-line voltages from line-ground voltages for all voltage-sensitive functions. This Line-Ground to Line-Line selection should be used only for a VT nominal secondary voltage of 69 V (not for 120 V). For this selection, the nominal voltage entered should be line-line nominal voltage, which is $\sqrt{3}$ times line-ground nominal voltage. The V2 connected VT must be configured line-ground if VT CONFIGURATION from above is **LINE-GROUND**. If VT configuration is **LINE-LINE** or **LINE-GND_TO_LINE-LINE**, then V2 must be configured line-line.

```
SYNC-CHECK PHASE
A b c
```

Indicates selected phase for sync check (25) function.

```
PHASE ROTATION
a-c-b  A-B-C
```

Phase Rotation.

```
PULSE RELAY
o8 o7 o6 o5 o4 o3 o2 o1
```

Indicates outputs chosen for pulse operation. When selected, output will remain energized for the time delay specified in the **RELAY SEAL-IN TIME** (see below), and then drop out. With pulse operation, the selected relay will drop out after the delay, even if the tripping function remains out of band.

```
RELAY SEAL-IN TIME OUT1
_______ cycles
```

Relay seal-in may be specified for each of the 8 outputs. Seal-in specifies the minimum time the output must remain energized when picked up.

```
ACTIVE INPUT OPEN/close
    i6 i5 i4 I3 i2 i1
```

Selects the active state of the six status inputs. When highlighted (uppercase), the active state is an open circuit. When lowercase, the active state is closed circuit (default)

```
DELTA-Y TRANSFORM
DISABLE  enable
```

By enabling the **DELTA-Y TRANSFORM**, the relay will internally consider the 30° phase shift through the delta-wye unit transformer for 51V and 21 functions.

```
V.T. PHASE RATIO
    1.0:1
```

Ratio of the phase VT's.

```
V.T. V2 RATIO
    1.0:1
```

Ratio of the V2 VT

```
V.T. NEUTRAL RATIO
    1.0:1
```

Ratio of the neutral VT

```
C.T. PHASE RATIO
    10.1:
```

Ratio of the phase CTs

```
C.T. NEUTRAL RATIO
    10:1
```

Ratio of the neutral CT

2.4 Setpoints and Time Settings

21 Phase Distance

The phase distance function, designed for system phase fault protection, is implemented as a two-zone mho characteristic. Three separate distance elements are implemented to detect AB, BC, and CA fault types. The ranges, increments, and accuracy are shown in Table 2-1. The diameter, offset, system impedance angle (relay characteristic angle), and definite time delay need to be selected for each zone for coordination with the system relaying in the specific application.

When the Dispersed Storage and Generation (DSG) is connected to the system through a delta/wye transformer, proper voltages and currents (equivalent to the high side of the transformer) must be used in order for the relay to see correct impedances for system faults. By enabling the delta/wye transform feature (see Section 2.2, **System Diagrams**), the relay can internally consider the 30° phase shift through the delta-wye unit transformer, saving auxiliary VT's.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Phase Distance (21) (dual-zone mho characteristics)			
Circle Diameter #1, #2	0.1 to 100.0 Ω (0.5 to 500.0 Ω)	0.1 Ω	± 0.1 Ω or ± 5% (±0.5 Ω or ± 5%)
Offset #1, #2	-100.0 to 100.0 Ω (-500.0 to 500.0 Ω)	0.1Ω	±0.1 Ω or 5% (±0.5 Ω or 5%)
Impedence Angle	0° to 90°	1°	±1°
Time Delay #1, #2	1 to 8160 cycles	1 cycle	-1 to +3 cycles or ±1%

Table 2-1 Phase Distance (21) Setpoint Ranges

	Direct-Connected		Delta/Wye Transformer Connected	
	VT Connection		VT Connection	
	Line-to-Line	Line-to-Ground	Line-to-Line	Line-to-Ground
AB Fault	$\frac{V_{AB}}{I_a - I_b}$	$\frac{V_A - V_B}{I_a - I_b}$	$\frac{V_{BC} - V_{AB}}{(3)I_b}$	$\frac{V_B - V_0}{I_b}$
BC Fault	$\frac{V_{BC}}{I_b - I_c}$	$\frac{V_B - V_C}{I_b - I_c}$	$\frac{V_{CA} - V_{BC}}{(3)I_c}$	$\frac{V_C - V_0}{I_c}$
CA Fault	$\frac{V_{CA}}{I_c - I_a}$	$\frac{V_C - V_A}{I_c - I_a}$	$\frac{V_{AB} - V_{CA}}{(3)I_a}$	$\frac{V_A - V_0}{I_a}$

Table 2-2 Impedance Calculation

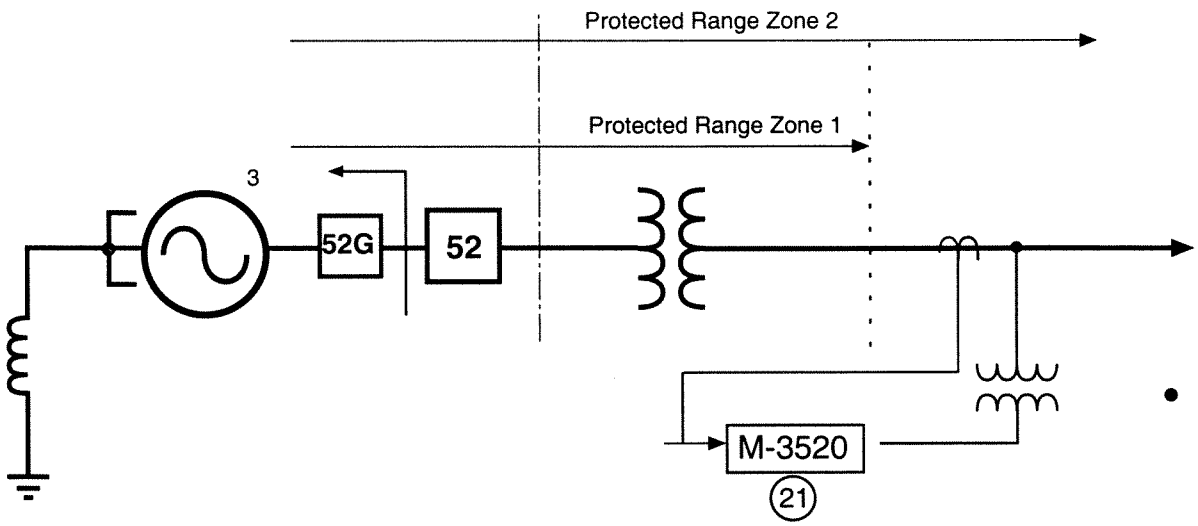


Figure 2-3 Phase Distance (21) Zones of Protection

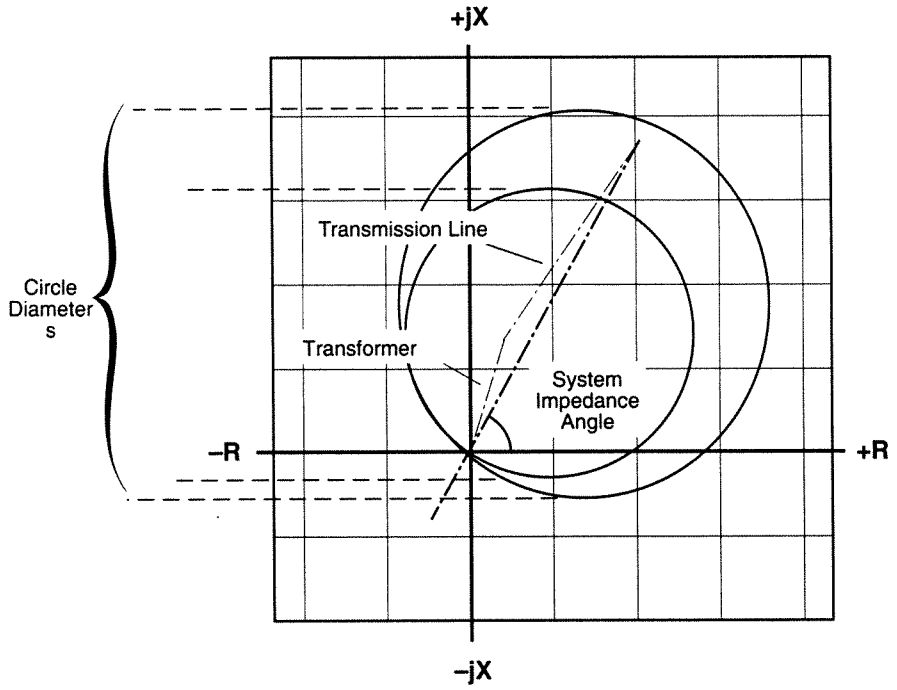


Figure 2-4 Phase Distance (21) Function Applied for System Phase Faults

All primary impedances (Z_{PRI}) must be reflected to relay quantities (Z_{SEC}). The primary ohms (Z_{PRI}) on the generator base needs to be multiplied by the ratio of the current transformer ratio (R_C) to the voltage transformer ratio (R_V).

$$Z_{SEC} = Z_{PRI} \times (R_C \div R_V)$$

If this function is enabled, the following settings are applicable:

```
21 #1 DIAMETER
_____ Ohms
```

Typically, the first zone of protection is set to an impedance value in excess of the first external protective section (typically the transformer plus part of the transmission line) to ensure operation for faults within that protective zone (see Figure 2-4). The second #21 zone can be set for the second external section of protection on the system (typically transmission Zone 1 distance relays) plus adequate overreach.

```
21 #1 OFFSET
_____ Ohms
```

A negative or positive offset can be specified to offset the mho circle from the origin. This offset is usually set at zero.

```
21 #1 IMPEDANCE ANGLE
_____ Degrees
```

The impedance angle should be set as closely as possible to the actual impedance angle of the zone being protected.

```
21 #1 DELAY
_____ Cycles
```

The time delays are set to coordinate with the primary protection of those overreached zones and, when applicable, with the breaker failure schemes associated with those protective zones.

```
21 #2 DIAMETER
_____ Ohms
```

```
21 #2 OFFSET
_____ Ohms
```

```
21 #2 IMPEDANCE ANGLE
_____ Degrees
```

```
21 #2 DELAY
_____ Cycles
```

25 Sync Check

The Synchronism (Sync) Check function is used to ensure that the voltage magnitude, phase angle and frequency of the Dispersed Storage and Generation (DSG) (V2) and the utility system (V1) are within acceptable limits before the intertie breaker is closed.

The sync check function has phase angle, delta frequency, and delta voltage checks.

Phase Angle Check

The phase angle is considered OK when the selected sync phase voltage (V1) and DSG voltage are within the Upper Volt Limit and Lower Volt Limit window and the measured phase angle is within the phase angle window.

Phase angle window is defined as twice the Phase Limit setting. For example, if the Phase Limit is set at 10 degrees, a phase angle window of 20 degrees exists between -10 degrees and +10 degrees. The basic diagram of the phase angle check is shown in Figure 2-5.

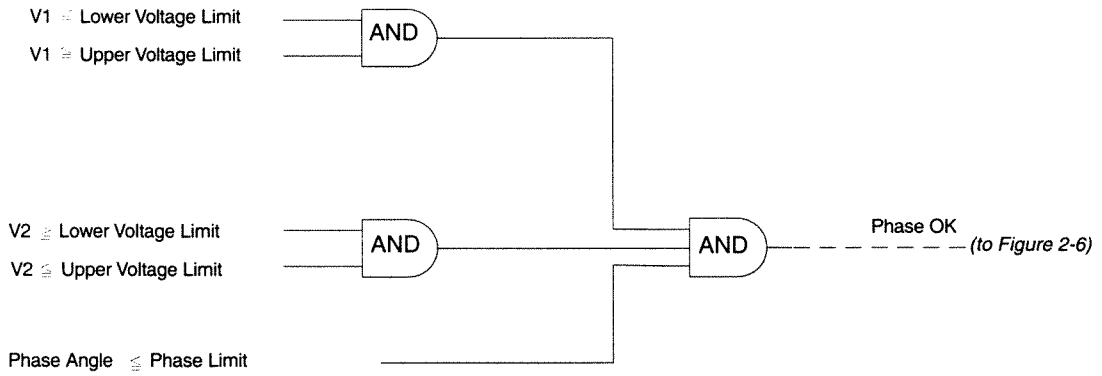


Figure 2-5 Phase Angle Check Logic Diagram

Delta Voltage and Delta Frequency Check

Delta voltage and delta frequency elements may be individually enabled or disabled, as desired. Delta voltage check will compare the absolute difference between the selected sync phase voltage (V1) and the measured DSG voltage (V2) with the Delta Volt limit setting. Likewise, the delta frequency measures the frequency difference between V1 and V2 voltage signals. The logic diagram of the above is shown in Figure 2-6.

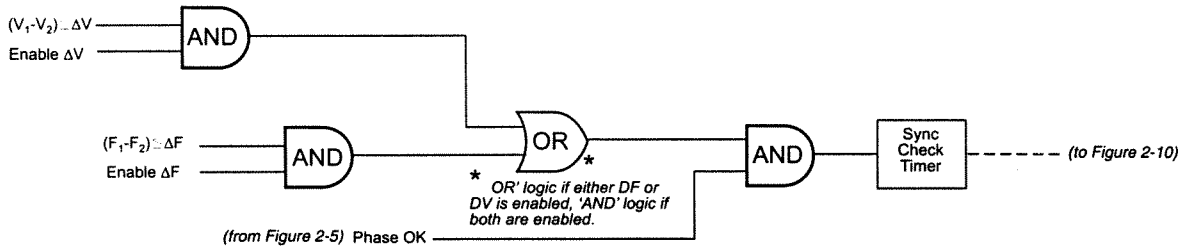


Figure 2-6 Delta Voltage and Delta Frequency Check Logic Diagram

Dead Line/Dead Bus Check

The Dead Volt Limit defines the Hot/Dead voltage level used in deadline/dead bus closing schemes. When the measured V2 voltage is equal to or below the Dead Volt Limit, V2 is considered dead. When the measured V2 is above the Dead Volt Limit, V2 is considered hot. The opposite side of the breaker uses the positive sequence voltage measurement (V1 below) for 3-phase consideration in determining hot/dead detection. Different combinations of hot line/dead bus closings may be selected, depending on how the buses are referenced. The logic diagram of the deadline/dead bus scheme is shown in Figure 2-7.

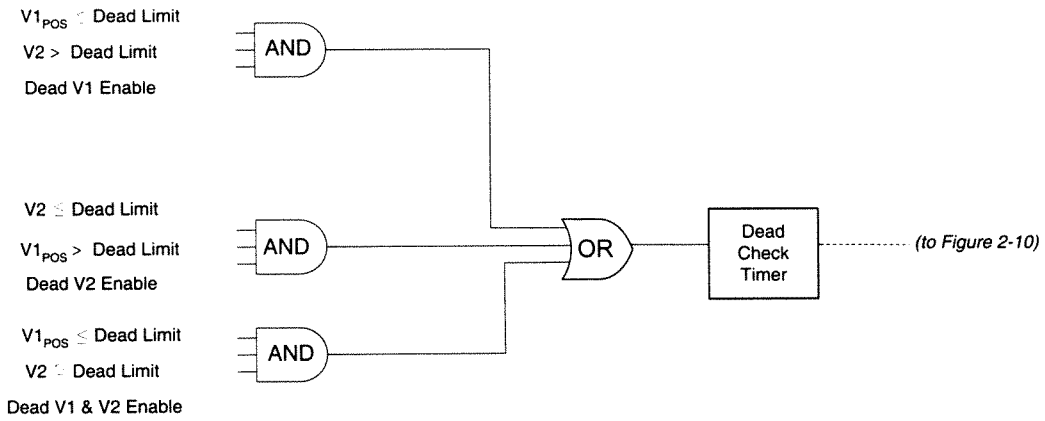


Figure 2-7 Dead Line/Dead Bus Check Logic Diagram

The Dead V1, Dead V2, and Dead V1 & V2 enable are software switches used to enable the dead line/dead bus logic. Further conditioning can be performed on the dead detection logic by selecting one or more input contacts (Dead Input Enable) to control the enabled dead detection element. For example, if INPUT2 (I2) is selected under the Dead Input Enable screen, and both the Dead V1 and Dead V2 elements are enabled, the dead check timer will start when INPUT2 is activated, and either V1 dead/V2 hot or V1 hot/V2 dead. This allows for external control of the desired dead closing scheme. Dead Input Enable selections are common to all dead detection elements. If no inputs are selected under the Dead Input Enable screen, and any dead element is enabled, the dead check timer will start immediately when the dead condition exists. The logic diagram in Figure 2-8 shows enabling/disabling of the dead line/dead bus scheme through contact inputs.

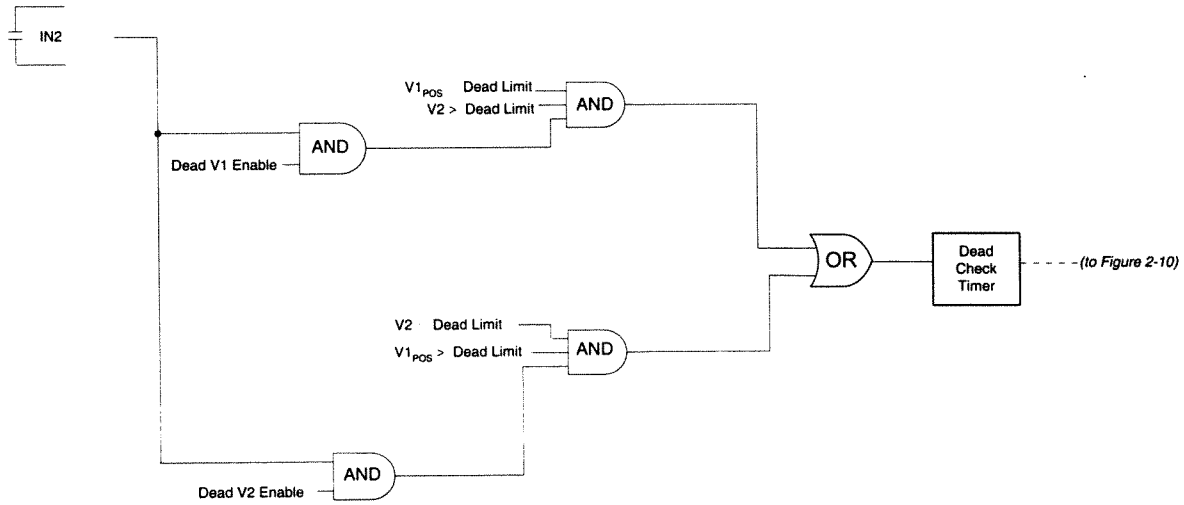


Figure 2-8 Dead Line/Dead Bus Check Input Initiate Logic Diagram

Eventually, the dead line/dead bus check, phase angle check, delta volt and delta frequency checks all combine through their appropriate timers and are directed to the programmed 25 output relay. The overall logic of the Sync Check (25) function is shown in Figure 2-9.

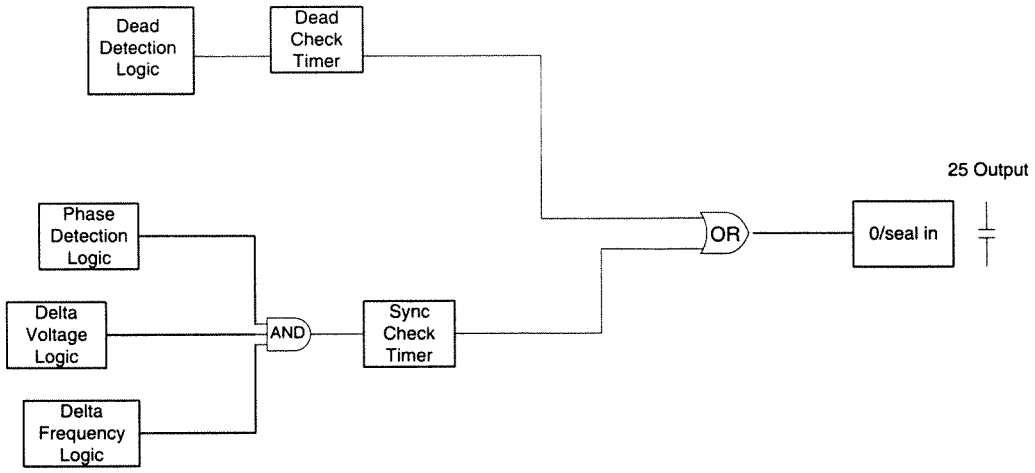


Figure 2-9 Sync Check (25) Function Logic Diagram

Supervision of 25 by 79

The Sync Check function (25) can be supervised by the reconnect enable (79) function. The "79 supervise 25" setting, if enabled, will hold both the dead check and sync check timers reset until the 79 timer expires. This, in effect, allows the 79 function to supervise the 25 operation.

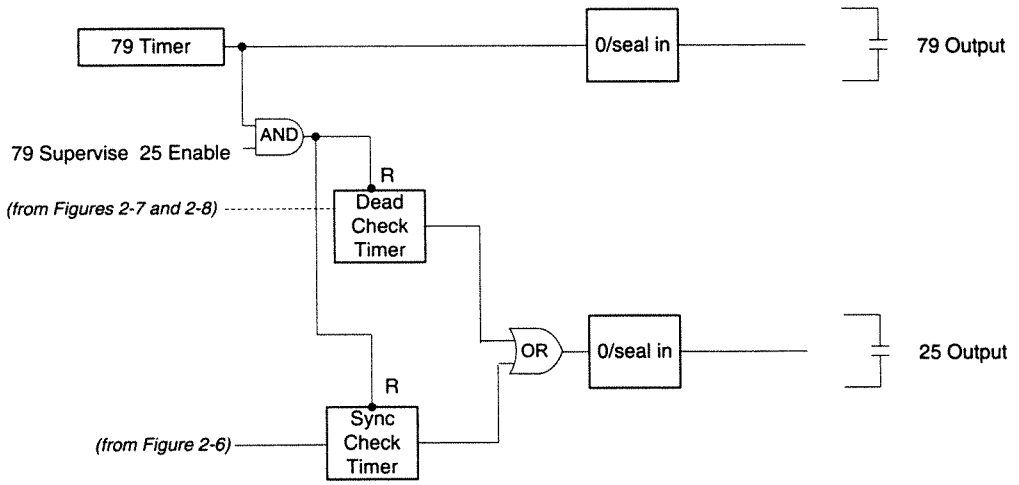


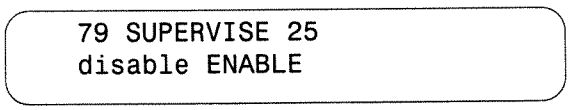
Figure 2-10 79 Supervise 25 Logic Diagram

Neither the 25 nor the 79 function are considered "tripping" functions, and therefore do not generate target information by default.

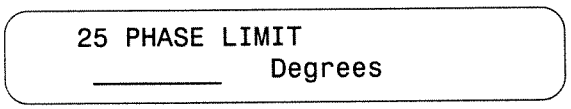
▲ **CAUTION**: Outputs chosen for the 79 and 25 functions should not be selected as target outputs in the Target Setup section. Advanced programming using the IPSutil™ program allows user to redefine either or both the 25 and 79 functions as targetable.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Sync Check (25)			
Phase Angle Window	0 to 90°	1°	±1°
Upper Voltage Limit	100 to 140 V	1V	±0.5 V or ±0.5%
Lower Voltage Limit	90 to 120 V	1V	±0.5 V or ±0.5%
Delta Voltage Limit	1.0 to 50.0 V	0.1V	±0.5 V
Delta Freqency Limit	0.001 to 0.500 Hz	0.001Hz	±0.0007 Hz or 5%
Sync Check Time Delay	1 to 8160 cycles	1 cycle	-1 to +3 cycles or 1%
Dead Voltage Limit	0 to 60 V	1 V	±0.5V
Dead Time Delay	1 to 8160 cycles	1 cycle	-1 to +3 cycles or ±1%
Sync Check may be operated as a stand-alone function or supervised by 79 (reconnect). Various combinations of input supervised hot/dead closing schemes may be supervised.			

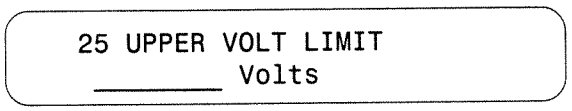
Table 2-3 Sync Check (25) Setpoints



If enabled, 79 timer will control 25 function.



Phase angle setting.



Upper voltage limit for phase angle acceptance.

25 LOWER VOLT LIMIT _____ Volts	Lower voltage limit for phase angle acceptance.
25 SYNC CHECK DELAY _____ Cycles	Sync check time delay.
25 DELTA VOLT disable ENABLE	Delta voltage element.
25 DELTA VOLT LIMIT _____ Volts	Delta voltage setting.
25 DELTA FREQUENCY disable ENABLE	Delta frequency element.
25 DELTA FREQUENCY LIMIT _____ Hz	Delta frequency setting.
25 DEAD VOLT LIMIT _____ Volts	Voltage less than this setting is defined as "DEAD"; above this setting as "HOT".
25 DEAD V1 disable ENABLE	Enables Dead V1/Hot V2 setting.
25 DEAD V2 disable ENABLE	Enables Hot V1/Dead V2 setting.
25 DEAD V1 & V2 DISABLE enable	Enables Dead V1/Dead V2 closing.
25 DEAD INPUT ENABLE i6 i5 i4 I3 i2 i1	Externally controlled dead closing.
25 DEAD DELAY _____ Cycles	Dead delay timer setting.

27 Undervoltage, 3 Phase

Voltage is commonly suggested as an efficient means to protect against islanding. Notably, unless the DSG includes very high-speed generator excitation response, the island case where load is greater than generation will result in a rapid drop of voltage. Except for those systems prone to ferroresonance, the voltage waveform will remain essentially sinusoidal, making the use of rms value of fundamental frequency component as the measurement for this function. An IEEE suggestion is that undervoltage relays be set at 90% to 95% of nominal voltage (in accordance with the lower limit allowed for supply to customers) with a 1 second time delay to prevent incorrect operation from a voltage dip caused by an external fault.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Undervoltage (27)			
Pickup #1, #2	5 to 180 V	1 V	±0.5 V or ±0.5%
Time Delay #1, #2	1 to 8160 cycles	1 cycle	-1 to +3 cycles or ±1%

Table 2-4 Undervoltage (27) Setpoint Ranges

If this function is enabled, the following settings are applicable:

```
27 #1 PICKUP
 _______ Volts
```

Relay volts are equal to the primary bus voltage divided by the VT ratio.

```
27 #1 DELAY
 _______ Cycles
```

The operating time of the function.

```
27 #2 PICKUP
 _______ Volts
```

```
27 #2 DELAY
 _______ Cycles
```

32 Directional Power, 3-Phase

The directional power function issues a trip command when the magnitude of the power flow (in either direction, as selected) exceeds the setpoint for the prescribed time. The forward and reverse power functions can be individually adjusted to trip when the total three-phase power is in the range of 0.002 pu to 3 pu.

The reverse power function has a three-phase option that, when selected, uses total 3-phase power measurement. When the Three-Phase Detect is not enabled, the M-3520 detects the power in any one phase, and operates it if the power in any one phase exceeds the setpoint.

The base volt amperes for one PU (per unit) is based on nominal voltage and nominal current setting.

For interconnection protection, with VT and CT connections as illustrated in Figure 2-2, reverse power is defined as power flow into the generator/customer, forward power as power flow to the utility.

▲ **CAUTION**: Proper CT polarity is important in defining the direction of the power flow.

If the Dispersed Storage and Generation (DSG) is allowed to supply power to the utility, the forward power function can be used to limit the amount of power flow into the utility. This function can also be set to very sensitive setting, to detect islanding conditions. The 32 functions should be applied with a time delay to prevent misoperation during transients.

FUNCTION	SETPOINT RANGES	INCREMENT	ACCURACY
Reverse/Forward Power (32)			
Pickup #1, #2	-3.000 to +3.000 pu	0.001 pu	±0.002 pu or 2%
Time Delay #1, #2	1 to 8160 cycles	1 cycle	+16 cycles or ±1%
The per-unit pickup is based on nominal VT secondary voltage and nominal CT secondary current settings. Single phase detection may be selected for line-to-ground connected VTs.			

Table 2-5 Directional Power (32) Setpoint Ranges

If this function is enabled, the following settings are applicable

```
32 #1 PICKUP
_________ PU
```

```
32 #1 DELAY
_________ CYCLES
```

```
32#1 THREE PHASE DETECT
disable ENABLE
```

```
32 #2 PICKUP
_________ PU
```

```
32 #2 DELAY
_________ Cycles
```

```
32 #2 THREE PHASE DETECT
disable ENABLE
```

46 Negative Sequence Overcurrent

The Negative Sequence Overcurrent function provides protection against possible damage due to unbalanced faults.

This function has a definite time element and an inverse time element. The definite time pickup value and definite operating time are normally associated with an alarm function. The inverse time element is usually associated with a trip function.

The inverse time function can be selected as one of the eight curve families: definite, inverse, very inverse, extremely inverse, and four IEC curves. The operator selects the pickup and time dial settings.

This protection must *not* operate for system faults that will be cleared by feeder/line relaying. This requires consideration of feeder line protection, bus differential, and breaker failure backup protections.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Negative Sequence Overcurrent (46)			
Definite Time			
Pickup	0.10 to 20.00 A (0.02 to 4.00 A)	0.01A	±0.1A or ±3% (±0.02A or ±3%)
Time Delay	1 to 8160 cycles	1 cycle	-1 to + 3 cycles or ±3%
Inverse Time			
Pickup	0.50 to 5.00 A (0.10 to 1.00 A)	0.01A	±0.1A or ±3% (±0.02 A or ±3%)
Characteristic Curves	Definite Time/Inverse/Very Inverse/Extremely Inverse/IEC Curves		
Time Dial Setting	0.5 to 11.0 0.05 to 1.10 (IEC curves)	0.1 0.01	±3 cycles or ±5%

Table 2-6 Negative Sequence Overcurrent (46) Setpoint Ranges

If this function is enabled, the following settings are applicable:

```
46DT PICKUP
_____ Amps
```

Negative sequence overcurrent pickup establishes the negative sequence overcurrent level above which the function timer will start.

```
46DT DELAY
_____ Cycles
```

This setting is the operating time of the function.

```
46IT PICKUP
_____ Amps
```

Negative sequence overcurrent pickup establishes the negative sequence overcurrent level above which the function timer will start.

```
46IT CURVE
DEF in vinv einv →
```

This setting selects, one of eight family of curves, as shown in Appendix D, Figures D-1 through D-8.

```
46IT TIME DIAL
_____
```

The appropriate curve in the selected family of curves is chosen here.

47 Negative Sequence Overvoltage

The Negative Sequence Overvoltage function 47 provides protection for voltage imbalance and reverse phase sequence.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Negative Sequence Overvoltage (47)			
Pickup #1, #2	5 to 180 V	1V	±0.5V or ±0.5%
Time Delay #1, #2	1 to 8160 cycles	1 cycle	-1 to + 3 cycles or ±1%

Table 2-7 Negative Sequence Overvoltage (47) Setpoint Ranges

If this function is enabled, the following settings are applicable:

```
47#1  PICKUP
_______ Volts
```

A pickup setting in the range of 10 to 30 V can reliably detect open phases and reverse phase sequence.

```
47#1 DELAY
_______ Cycles
```

A minimum time delay of 6 to 10 cycles will prevent misoperation during switching transients.

```
47#2 PICKUP
_______ Volts
```

```
47#2 DELAY
_______ Cycles
```

50 Instantaneous Overcurrent, 3-Phase

The Instantaneous Phase (50) functions provide fast tripping times for high fault currents. The settings for 50 should be chosen such that they will not respond to faults on the adjacent system.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Instantaneous Overcurrent (50)			
Pickup	1.0 to 240.0 A (0.2 to 48.0 A)	0.1 A	±0.1 A or ±3% (±0.02A or ±3%)
Time Delay	Fixed 2 cycles		±2 cycles

Table 2-8 50 Instantaneous Overcurrent, 3-Phase Setpoint Ranges

If this function is enabled, the following settings are applicable:

```
50 PICKUP
_________ Amps
```

50G Instantaneous Overcurrent, Neutral

The Instantaneous Neutral Overcurrent (50G) function provides fast tripping times for high fault currents. The settings for 50N should be chosen such that they will not respond to faults on the adjacent system.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Instantaneous Overcurrent, Neutral (50G)			
Pickup	0.5 to 240.0 A (0.1 to 48.0 A)	0.1 A	±0.1A or ±3% (±0.02 or ±3%)
Time Delay	Fixed 2 cycles		±2 cycles
The 50G can be supervised by the ground directional element (if the 67N option is selected).			

Table 2-9 50G Instantaneous Overcurrent, Neutral Setpoint Ranges

If this function is enabled, the following settings are applicable:

```
50G PICKUP
_________ Amps
```

Pickup setting.

```
DIRECTIONAL ELEMENT
disable ENABLE
```

50G may be directionally controlled. See 67N function for maximum sensitivity angle and polarization setup.

51V Inverse Time Overcurrent, with Voltage Control or Voltage Restraint

Time overcurrent relays are basic to any protection scheme. This is the main device used to trip circuits selectively and to time coordinate them with other up or downstream devices. For this function, eight complete series of inverse time characteristics are included. The eight curve families to be chosen from are definite, inverse, very inverse, extremely inverse, and four IEC curves. The pickup and time dial settings are selected from the relay menu.

The curves available for use are shown in Appendix D, Figures D-1 through D-8. They cover a range from 1.5 to 20 times the tap. For currents beyond 20 times the pickup setting, the relay operating time will remain 20 times the pickup setting. The 51V function has voltage control or voltage restraint elements. Under certain conditions, the Dispersed Storage and Generation (DSG) steady-state fault currents during a three-phase fault can decrease to below the full load current. In order to provide overcurrent protection for those conditions, the voltage control/restraint element should be enabled. The particular settings will be made by information from short-circuit (fault) studies and knowledge of the coordination requirements with other devices in the system that respond to time overcurrent.

When voltage restraint is selected, the tap setting of the 51VR is modified continuously according to the voltage inputs. The relay continues to operate independently of current decrement in the machine. The voltage restraint function is well-suited to small generators with relatively short time constants. Voltage restraint is disabled when shipped from factory. When the generator is connected to the system through a delta/wye transformer, proper voltages (equivalent to the high-side of the transformer) should be used for the 51VR or 51VC element. The M-3520 can internally determine the equivalent high-side voltages of the delta/wye unit transformer, saving auxiliary instrument transformers. The voltage-current pairs used are shown in Table 2-11.

For voltage controlled operation, the function is not active unless the voltage is below the voltage control setpoint, which can be used to help confirm that the overcurrent is due to a system fault. When applied, most users will set voltage control in the range of 0.7 to 0.9 per unit rms voltage. Voltage control is disable when shipped from the factory.

The various features of the 51V function, such as voltage control, voltage restraint, voltage transformations (for delta-wye unit transformers) can be programmed by the operator.

■ **NOTE**: This function should be blocked by fuse loss if in the voltage control mode. Fuse loss blocking is not desirable for the restraint mode because the pickup is automatically held at 100% Tap Setting (see Figure 2-11) during fuse loss conditions, and will continue to operate correctly.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Inverse Time Overcurrent, with Voltage Control or Voltage Restraint (51V)			
Pickup	0.5 to 12.00 A (0.10 to 2.40 A)	0.01A	±0.1A or ±3% (±0.02A or ±3%)
Characteristic Curve	Definite Time/Inverse/Very Inverse/Extremely Inverse/IEC		
Time Dial Setting	0.5 to 11.0 0.05 to 1.10 (IEC Curves)	0.1 0.01	± 3 cycles or ± 5%
Voltage Control (VC)	5 to 180 V	1 V	±0.5 V or ±5%
or			
Voltage Restraint (VR)	Linear Restraint		

Table 2-10 Inverse Time Overcurrent with Voltage Control/Restraint (51V) Setpoint Ranges

If this function is enabled, the following settings are applicable:

51V PICKUP _____ Amps	Sets phase current pickup for 51V.
51V CURVE DEF inv vinv einv →	Selects one of the eight inverse time curves as shown in Appendix D, Figures D-1 through D-8.
51V TIME DIAL _____	The appropriate curve in the selected family of curves is chosen here.
51V VOLTAGE CONTROL disable V_CNTL v_rstrnt	Restraint/control setting.
51V VOLTAGE CONTROL _____ Volts	Voltage control level.

Generator Directly Connected			Generator Connected Through Delta/Wye Transformer		
Current	Voltage		Current	Voltage	
	L-N	L-L		L-N	L-L
I_A	$(V_A-V_C)/\sqrt{3}$	V_{AB}	I_A	V_A	$(V_{AB}-V_{CA})/\sqrt{3}$
I_B	$(V_B-V_A)/\sqrt{3}$	V_{BC}	I_B	V_B	$(V_{BC}-V_{AB})/\sqrt{3}$
I_C	$(V_C-V_B)/\sqrt{3}$	V_{CA}	I_C	V_C	$(V_{CA}-V_{BC})/\sqrt{3}$

Table 2-11 Delta/Wye Transformer Voltage–Current Pairs

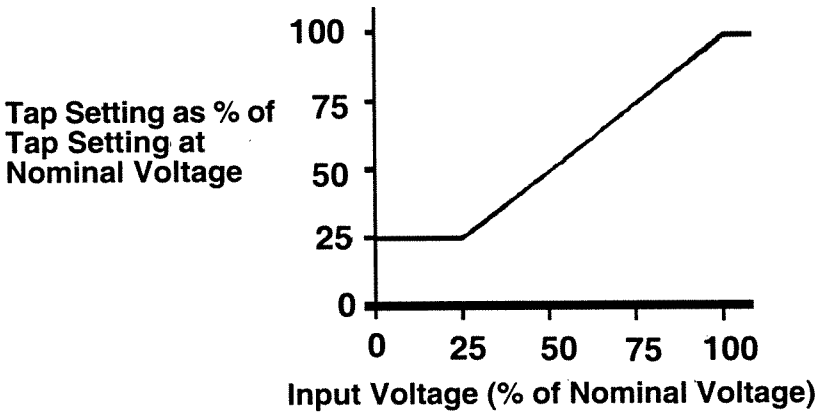


Figure 2-11 Voltage Restraint (51V) Characteristic

51G Inverse Time Neutral Overcurrent

Neutral Inverse Time Overcurrent relay is used to trip circuits selectively for ground faults, and to time coordinate with up or down stream relays. For this function, eight complete series of inverse time characteristics are included. The eight curve families to be chosen are definite, inverse, very inverse, extremely inverse, and four IEC curves. The operator selects the time dial within each family setting and pickup setting through the M-3520 menu.

The curves available for use are shown in Appendix D, Figures D-1 through D-8. They cover a range from 1.5 to 20 times the pickup. For currents beyond 20 times the pickup setting, the relay operating time will remain the same as 20 times the pickup setting.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Inverse Time Neutral Overcurrent (51G)			
Pickup	0.25 to 12.00 A (0.05 to 2.40 A)	0.01A	±0.1A or ±3% (±0.02A or ±3%)
Characteristic Curve	Definite Time/Inverse/Very Inverse/Extremely Inverse/IEC curves		
Time Dial Setting	0.5 to 11.0 0.05 to 1.10 (IEC Curves)	0.1 0.01	±3 cycles or ±5%

Table 2-12 Inverse Time Neutral Overcurrent (51G) Setpoint Ranges

If this function is enabled, the following settings are applicable:

```
51G PICKUP
_______ Amps
```

Sets ground current pickup.

```
51G CURVE
DEF inv vinv einv →
```

Selects one of the eight inverse time curves as shown in Appendix D, Figures D-1 through D-8.

```
51G TIME DIAL
_______
```

The appropriate curve in the selected family of curves is chosen here.

```
DIRECTIONAL ELEMENT
disable ENABLE
```

51G may be directionally controlled. See 67N function for maximum sensitivity angle and polarization setup.

59I Peak Overvoltage

Most overvoltage relays operate based on the RMS value of voltage. There is, however, a system phenomenon known as ferroresonance which may occur on a lightly loaded, islanded system. As the name implies, a system experiencing ferroresonance is in resonance, but the inductance is highly nonlinear, being variable as the transformer core cycles in and out of magnetic saturation. At this time, the voltage waveform will be expected to be very rich in harmonics, to the extent that it is possible that the peak voltage of the nonsinusoidal wave will be dangerously high, even though the RMS value of the same voltage remains in an acceptable range.

Because it is necessary to describe voltage for this purpose in terms of the peak value of voltage (not RMS), it is convenient to define the parameter setpoints in per unit of the peak of the nominal sinusoidal waveform. The per unit value is based on the nominal voltage setting. As an example, for a nominal voltage of 120 V, the one per unit instantaneous peak voltage is 120 x $\sqrt{2}$ = 170 V.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Peak Overvoltage (59I)			
Magnitude	1.05 to 1.50 pu	0.01 pu	±0.03 pu*
Time Delay	1 to 8160 cycles	1 cycle	-1 to +3 cycles or ±1%
Instantaneous voltage magnitude response; intended for ferroresonance protection.			
**For fundamental (60 Hz/50 Hz) signal only. For distorted input signals, the accuracy degrades as the order of the harmonic signal increases. The accuracy applies to voltages below 180 V.*			

Table 2-13 Peak Overvoltage (59I) Setpoint Ranges

If this function is enabled, the following settings are applicable:

```
59I PICKUP
_______ PU
```

Typical pickup setting is between 1.3 to 1.5 PU.

```
59I DELAY
_______ Cycles
```

A time delay of 10 cycles provides fast protection and prevents misoperation during system disturbances.

59 Overvoltage, 3-Phase

Voltage is commonly suggested as an efficient means to protect against islanding. Notably, unless the Dispersed Storage and Generation (DSG) includes very high-speed generator excitation response, the island case where load is less than generation will result in a rapid rise of voltage. Except for those systems prone to ferroresonance, the voltage waveform will remain essentially sinusoidal, making the use of rms value of the fundamental frequency component as the measurement.

IEEE suggests that the first setpoint (with a short time delay) be set up at 150% of the nominal voltage, and the second setpoint (with a long time delay) be set at 106 to 110% of the nominal voltage to prevent nuisance trips (*Intertie Protection of Consumer-Owned Sources of Generation, 3 MVA or Less*; IEEE Publication 88TH0224-6-PWR).

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Overvoltage (59)			
Pickup #1, #2	5 to 180 V	1 V	±0.5 V or ±0.5%
Time Delay #1, #2	1 to 8160 cycles	1 cycle	-1 to +3 cycles or ±1%

Table 2-14 Phase Overvoltage (59) Setpoint Ranges

If this function is enabled, the following settings are applicable:

```
59 #1 PICKUP
_______ Volts
```

Pickup and Time Delay settings for 59 function. Set typically at 130% to 150%

```
59 #1 DELAY
_______ Cycles
```

Set typically at 3 to 6 cycles.

```
59 #2 PICKUP
_______ Volts
```

Set typically at 106% to 110%.

```
59 #2 DELAY
_______ Cycles
```

Set typically at 30 to 60 cycles.

59G/27G Overvoltage/Undervoltage, Neutral Circuit or Zero Sequence

The neutral Overvoltage/Undervoltage functions 59G/27G provide protection for ground faults on the system.

Applications of 59G/27G, shown in Figures 2-12 and 2-13, are for detecting ground faults on the utility side of the power transformer. Protection schemes are applied based on using one or three voltage transformers (VT).

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Neutral Overvoltage (59G)			
Pickup	5 to 180 V	1 V	±0.5 V or ±0.5%
Time Delay	1 to 8160 cycles	1 cycle	-1 to +3 cycles or ±1%

Table 2-15 Neutral Overvoltage (59G) Setpoint Ranges

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Neutral Undervoltage (27G)			
Magnitude	5 to 180 V	1 V	±0.5 V or ±0.5%
Time Delay	1 to 8160 cycles	1 cycle	-1 to +3 cycles or ±1%

Table 2-16 Neutral Undervoltage (27G) Setpoint Ranges

If these functions are enabled, the following settings are applicable:

```
59G PICKUP
_________ Volts
```

```
59G DELAY
_________ Cycles
```

```
27G PICKUP
_________ Volts
```

```
27G DELAY
_________ Cycles
```

Ground Fault Detection using 59G and Broken-Delta VTs

The 59G may be used to detect system phase voltage unbalance in conjunction with three VTs. To do so, the VT secondaries are connected in "broken" delta; i.e., they are in delta except that one corner is open, and the 59G device is inserted, as illustrated in Figure 2-12.

In this case, voltage at 59G in Figure 2-13 will be zero so long as the three-phase voltages are balanced, but will rise above zero with any zero-sequence unbalanced condition, as will be expected with any real world utility ground fault.

When the relay burden is small, the transformers in this scheme will be subject to ferroresonance and high voltage oscillations unless a shunt resistor is used. The shunt resistor will damp high transient voltage oscillations, and will usually hold peak values to less than twice normal crest voltage to ground (*Applied Protective Relaying*, Westinghouse Electric Corporation, 1982).

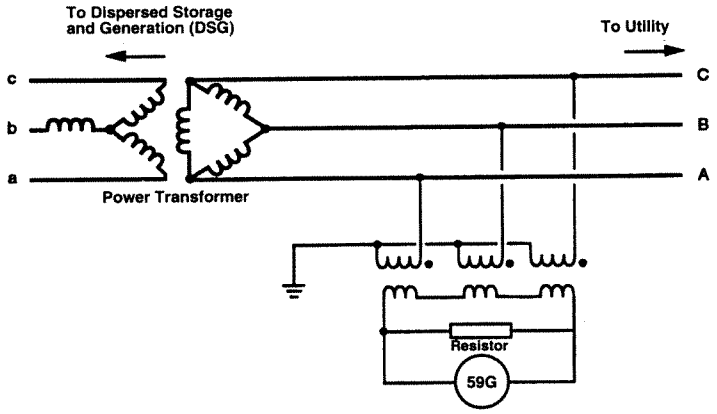


Figure 2-12 Ground Fault Detection Using 59G and Broken-Delta VTs

Ground Fault Detection Using 27G and 59G with One VT

An alternate, but not recommended, scheme uses the 27G and 59G devices with one VT rated for line-to-line voltage, but connected from any one phase to ground as shown in Figure 2-13. This scheme will detect the most common line-to-ground faults in the following manner:

- A fault on the phase that includes the VT will pull that phase voltage low and initiate operation of the 27G device.
- A fault on either phase without the VT will result in line-to-line voltage (or $\sqrt{3}$ x normal line-to-neutral voltage) appearing at the VT, initiating operation of the 59G.

For this scheme to work, the capacitance to ground of the lines must be fairly closely balanced and high enough to keep the neutral of the system at close to ground potential. The shunt resistor helps to minimize the chance of ferroresonance or neutral inversion. (*Applied Protective Relaying*, Westinghouse Electric Corporation, 1982.)

▲ Caution: This scheme should be used with caution since it can result in high overvoltages due to ferroresonance and neutral inversion.

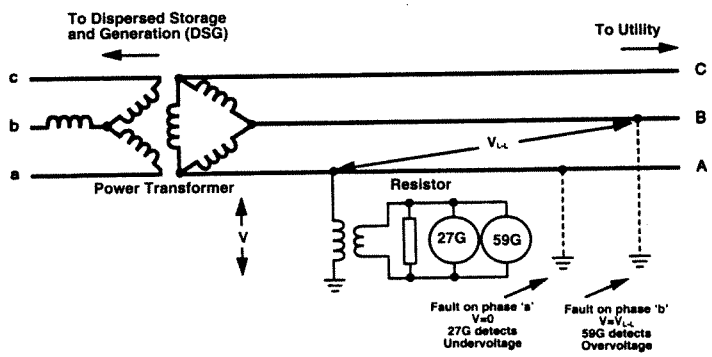


Figure 2-13 Ground Fault Detection Using 27G and 59G with One VT

60FL Fuse Loss

Since some functions may inadvertently operate when a VT fuse is blown, provisions are incorporated for both internal and external fuse loss detection. Functions which misoperate on VT fuse loss such as 21, 32, 51V, and 67 can be programmed to disable during a VT fuse-loss condition. The status of the fuses can then be monitored via remote communications or locally if the optional M-3931 HMI Module is in service.

For internal detection of a fuse-loss condition, positive and negative sequence quantities are compared. The presence of negative sequence voltage in the absence of negative sequence current is considered to be a fuse loss condition. An additional supervising condition includes a minimum positive sequence voltage to assure VT inputs are being applied to the relay.

A timer, associated with the fuse loss logic, is available, to assure proper coordination for conditions which may appear as a fuse loss such as secondary VT circuit faults which will be cleared by local low voltage circuit action.

For the specific application where the above logic cannot be considered reliable (such as when current inputs to the relay are not connected, sustained positive sequence current during fault conditions is minimal, or negative sequence currents are not present during fault conditions), provision is made for disabling the 60FL Fuse Loss internal logic by not selecting "FL" from the 60FL Input Initiate choices.

Provision is also made in the relay to input external status contact(s) of other fuse loss detection protection. These external contacts may be input to any of the input contacts (IN1 to IN6) and programmed to initiate the 60FL function.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
VT Fuse Loss Detection (60FL)			
A VT fuse loss condition is detected by using the positive and negative sequence components of the voltages and currents. VT fuse loss output can be initiated from internally generated logic or from input contacts.			
Time Delay	1 to 8160 cycles	1 cycle	-1 to +3 cycles or ±1%

Table 2-17 Fuse Loss (60FL) Setpoint Ranges

If this function is enabled, the following settings are applicable:

```
60FL INPUT INITIATE
FL i6 i5 i4 i3 i2 i1
```

The initiating inputs are user-designated. The operation of any of the externally-connected contacts (across these M-3520 inputs) will start the associated time delay to the 60FL function operation.

```
60FL DELAY
_____ Cycles
```

The time delay is to be set to coordinate for conditions which may appear as a fuse loss but will be corrected by other protection (such as a secondary VT circuit fault which will be cleared by low voltage circuit action).

67 Phase Directional Overcurrent

For intertie protection applications, the phase directional overcurrent relay allows greater selectivity for utility system faults, since the directional element can be set to look directly towards the utility system. When the directional element is disabled, the 67DT operates like an instantaneous overcurrent. Likewise, the 67IT function operates like an inverse time overcurrent function (51) when its directional element is disabled. Special high-speed processing occurs when the 67DT time delay is set to minimum (1 cycle). A three-phase option on the 67DT function allows the 67DT to only respond to 3-phase faults. When three-phase detection is disabled, and any one phase current exceeds pickup, timing will begin. The directional elements are polarized from positive sequence voltage and positive sequence current. In order to obtain maximum sensitivity for fault currents, the directional element is provided with a maximum sensitivity angle adjustment (MSA). This setting is common to both the 67DT and 67IT elements. The directional detection algorithm is equipped with a pre-fault voltage memory of eight cycles to provide correct directional discrimination for bolted three-phase faults.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Phase Directional Overcurrent (67)			
Definite Time*			
Pickup	1.0 to 240.0 A (0.2 to 48.0 A)	0.1 A	±0.1 A or 3% (±0.02 A or 3%)
Time Delay	1 to 8160 cycles	1 cycle	-1 to + 3 cycles or ±1%
Inverse Time*			
Pickup	0.50 to 12.00 A (0.10 to 2.40 A)	0.01 A	±0.1 A or ±3% (±0.02 A or ±3%)
Characteristic Curves	Definite Time/Inverse/Very Inverse/Extremely Inverse/IEC Curves		
Time Dial Setting	0.5 to 11.0 0.05 to 1.10 (IEC curves)	0.1 0.01	±3 cycles or ±5%
Maximum Sensitivity (Torque) Angle (MSA)	0 - 359°	1°	

**High speed operation results when delay programmed for one cycle; response time is less than 1 ½ cycles.*

Directional sensing for 67DT or 67IT may be disabled.
Sensitivity at MSA is 0.5 VA, uses Positive Sequence Voltage and current for polarization, prefault memory 8 cycles.

Table 2-18 Phase Directional Overcurrent (67) Setpoint Ranges

If this function is enabled, the following settings are applicable:

67DT PICKUP _____ Amps	Pickup value for the 67DT element.
67DT DIRECTIONAL ELEMENT disable ENABLE	Directional discrimination enable. When disabled, this function will work like a standard overcurrent function (50DT).
67DT THREE PHASE DETCT DISABLE enable	When enabled, all three phase currents must exceed the setpoint for the function to operate.
67DT DELAY _____ Cycles	Time delay. When programmed for 1 cycle, high-speed operation results (.75 ±0.5 cycles).
67IT PICKUP _____ Amps	Pickup value for the 67IT setting.
67IT DIRECTIONAL ELEMENT disable ENABLE	Directional discrimination enable. When disabled, this function will work like a standard inverse time overcurrent relay (51).
67IT CURVE def INV vinv einv →	Curve Selection. Four standard curves and four IEC curves are available.
67 IT TIME DIAL _____	Time Dial Setting.
67 MAX SENSITIVITY ANGLE _____ DEGREES	Used to polarize the directional elements. This setting is common to both the 67DT and 67IT when the directional elements are enabled.

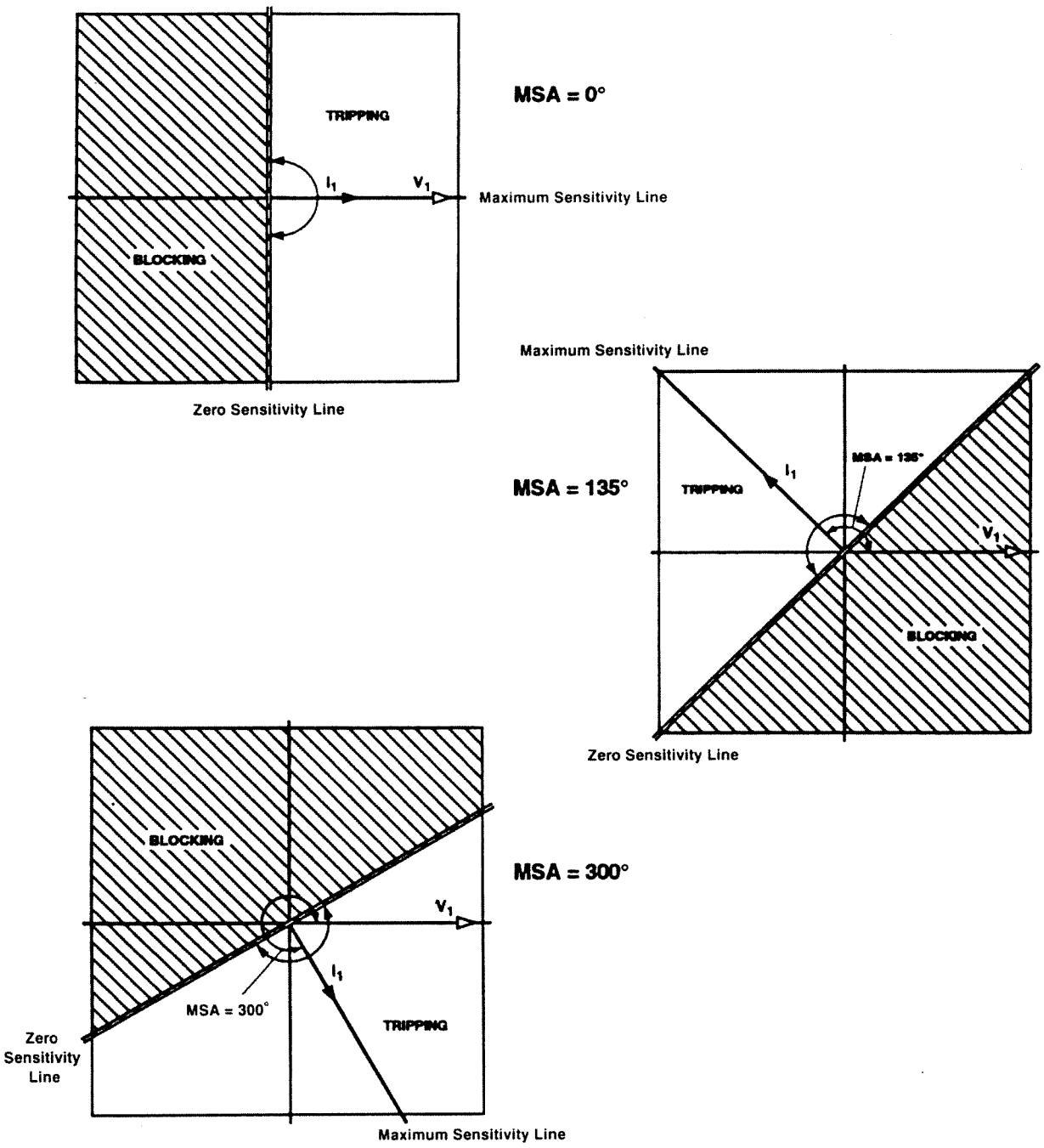


Figure 2-14 Phase Directional Overcurrent (67) Trip Characteristics

67N Residual Directional Overcurrent

The residual directional overcurrent (67N) function provides protection from ground faults. This function includes an inverse time overcurrent element, and a directional element. The directional element may be polarized as five different types:

Type 1: $3V_0$ and $3I_0$, where V_0 and I_0 are zero-sequence voltage and zero sequence current, respectively.

Type 2: V_N (broken delta voltage applied at the V_N input) and $3I_0$.

Type 3: $3V_2$ and $3I_2$, where V_2 and I_2 are negative sequence voltage and current, respectively.

Type 4: I_N and $3I_0$, where I_N is the neutral current (typically connected to the transformer neutral).

Type 5: Dual polarized with Type 1 or Type 4.

All types are designed to trip using $3I_0$ current.

■ **NOTE**: When I_N is connected as the residual current from phase CTs, type 4 and 5 must not be used.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Residual Directional Overcurrent (67N)			
Definite Time*			
Pickup	0.5 to 240.0 A (0.1 to 48.0 A)	0.1 A	±0.1 A or 3% (±0.02 A or ±3%)
Time Delay	1 to 8160 cycles	1 cycle	-1 to +3 cycles or ±1%
Inverse Time*			
Pickup	0.25 to 12.00 A (0.05 to 2.40 A)	0.01 A	±0.1 A or ±3% (±0.02 A or ±3%)
Characteristic Curve	Definite Time/Inverse/Very Inverse/Extremely Inverse/IEC Curves		
Time Dial	0.5 to 11.0 0.05 to 1.10 (IEC Curves)	0.1 0.01	±3 cycles or ±5%
Ground Directional Element			
Max. Sensitivity Angle (MSA)	0 to 359 °	1°	
Polarization**	1 to 5	1	

** Directional control for 67NDT or 67NIT may be disabled.*
*** Polarization can be zero sequence, negative sequence, current (polarized), or dual polarized.*

Table 2-19 Residual Directional Overcurrent (67N) Setpoint Ranges

If this function is enabled, the following settings are applicable:

67 PICKUP _____ Amps	Pickup value for the 67N element.
67N DIRECTIONAL ELEMENT disable ENABLE	Directional discrimination enable. When disabled, this function will work like a 51N.
67N DELAY _____ Cycles	Time Dial setting.
67N MAXIMUM SENSITIVITY ANGLE _____ Degrees	Used to polarize the directional elements. This includes all five types of polarization. These settings are found under the NEUTRAL DIR SETUP screen.
67NIT POLARIZATION TYPE1 type2 type3 →	

79 Reconnect Enable Time Delay

The reconnect relay is a permissive programmable output that may be set to close from 1 to 8160 cycles after all tripping functions are within limits. The 79 function is unique in that it is not considered a tripping function, and therefore does not trigger target storage by default. The 79 function is enabled, and its output selected through the configuration setup, just as other functions. In addition to the time delay setting, the reconnect function requires the user to designate which outputs are defined as trip outputs. The reconnect relay will initiate timing when all outputs defined as trip outputs release.

For example: If function 27#1 is programmed to output 5 (for alarm), 27#2 to output 1 (for trip), 81#1 to output 6 (for alarm), 81#2 to output 2 (for trip), 59G to output 2 (for trip), and 79 to output 8 (for reconnect), then OUT1 and OUT2 should be selected as trip outputs for the reconnect function. Schematic representation of this example is shown below:

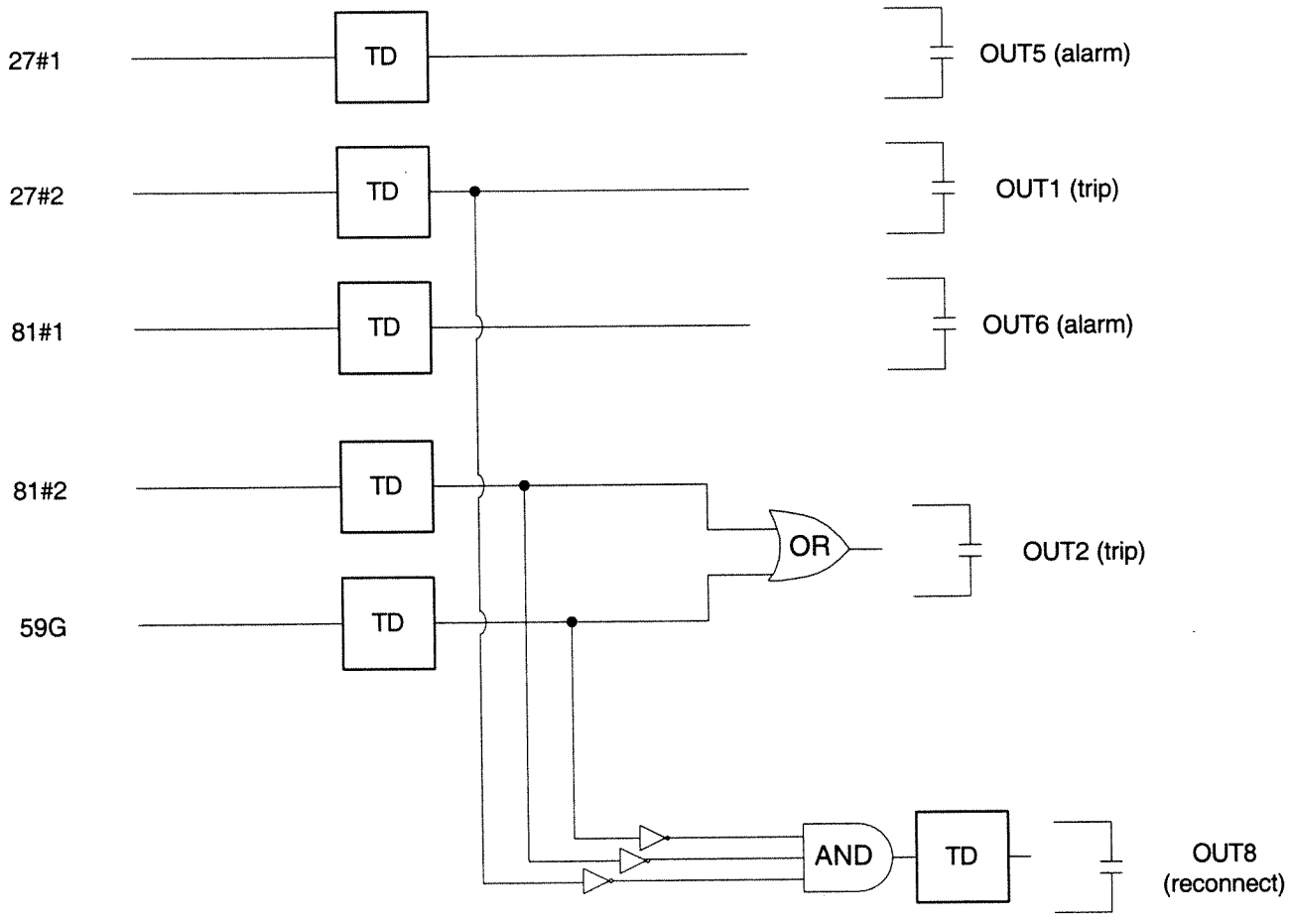


Figure 2-15 79 Function Logic Diagram

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Reconnect Enable Time Delay (79)			
Reconnect Delay	1 to 8160 cycles	1 cycle	-1 to +3 cycles or ± 1%
May supervise 25 (Sync Check) , if purchased. *Reconnect timer starts when all outputs designated as trip outputs drop out.*			

Table 2-20 Reconnect Enable Time Delay (79) Setpoint Ranges

If this function is enabled, the following settings are applicable:

```
79 RECN INITIATE (TRIP)
o8 o7 o6 o5 o4 o3 02 o1
```

Designated trip output selection. All trip outputs must drop out to start reconnect timer.

```
79 DELAY
_____ Cycles
```

Reconnect time delay.

81 Frequency

When dispersed storage and generation (DSG) is suddenly islanded, the frequency will quickly shift from 60.0 Hz (except for the improbable case of an exact generation and load match), making the measurement of frequency an excellent means to detect the island condition. If the only purpose is to detect the island condition, the frequency relay 81U and 81O can be set to operate at 59.5 Hz and 60.5 Hz, respectively (on a 60 Hz system), with a time delay of about 10 cycles.

A second school of thought advocates that the DSG should definitely not be severed from the utility at the slow side while the frequency remains as high as 59.5 Hz. This concept follows from the premise that if the drop in frequency is due to a major loss of system generation, it is at just this time that all available DSG should be kept on-line to help prevent a complete system collapse. If this is the objective, it may be useful to set one underfrequency characteristic at 57.5 to 58.0 Hz with a very short time delay, but allowing a higher frequency, say 59.0 Hz, to be maintained for several seconds.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Frequency (81)			
Pickup #1, #2, #3, #4	50.00 to 67.00 Hz 40.00 to 57.00 Hz*	0.01 Hz	±0.02 Hz
Time Delay #1,#2, #3, #4	2 to 65,500 cycles	1 cycle	-2 to +3 cycles or ± 1 %
The pickup accuracy applies to 60 Hz models at a range of 57 to 63 Hz, and to 50 Hz models at a range of 47 to 53 Hz. Beyond these ranges, the accuracy is ±0.1 Hz.			
**This range applies to 50 Hz nominal frequency models.*			

Table 2-21 Frequency (81) Setpoints

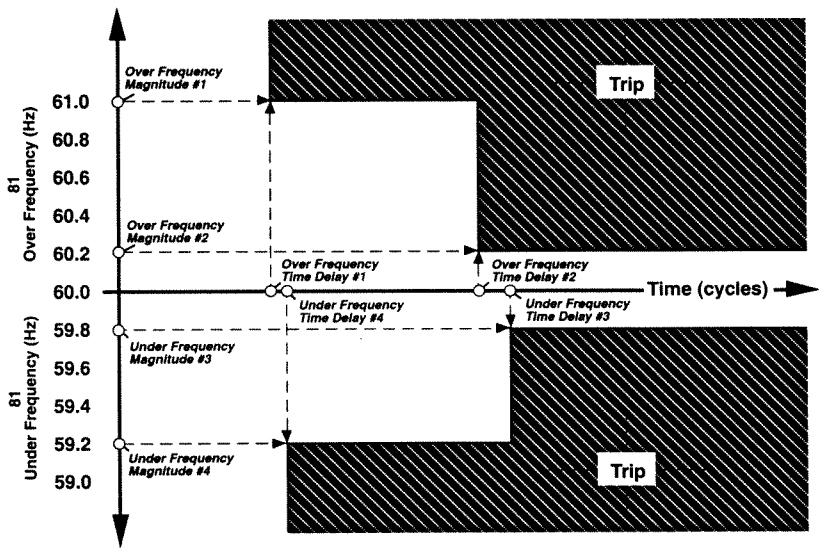


Figure 2-16 Typical Settings of 81 Function

If this function is enabled, the following settings are applicable:

81 #1 PICKUP
_____ Hz

81 #1 DELAY
_____ Cycles

81 #2 PICKUP
_____ Hz

81 #2 DELAY
_____ cycles

81 #3 PICKUP
_____ Hz

81 #3 DELAY
_____ Cycles

81 #4 PICKUP
_____ Hz

81 #4 DELAY
_____ Cycles

81R Rate of Change of Frequency

The Rate of Change of Frequency function can be used to detect islanding conditions. When the DSG (Dispersed Storage and Generation) is islanded, the frequency either increases or decreases rapidly, depending upon the generator-load mismatch. In some cases, it will be difficult for over/underfrequency relay functions to detect islanding. The Rate of Change of Frequency function provides proper detection of islanding conditions under these circumstances.

The function also has an automatic disable feature, to disable 81R function during unbalanced faults and other system disturbances. This feature uses negative sequence voltage to block 81R function. When the measured negative sequence voltage exceeds the inhibit setting, the function 81R is blocked. The time delay and magnitude settings of 81R should be based on simulation studies, and the setpoint ranges are given in Table 2-22, below.

FUNCTION	SETPOINT RANGE	INCREMENT	ACCURACY
Rate of Change of Frequency (81R)			
Pickup #1, #2	0.10 to 20.0 Hz/S	0.01 Hz/S	±0.05 or ±5%
Time Delay #1,#2	1 to 8160 cycles	1 cycle	+20 cycles
Inhibit*	0 to 99%	1%	±0.5%

** The inhibit function disables 81R function when the negative sequence voltage exceeds the set percentage of the positive sequence voltage.*

Table 2-22 Rate of Change of Frequency (81R) Setpoint Ranges

```
81R #1 PICKUP
_______ Hz/s
```

```
81R #1 DELAY
_______ Cycles
```

```
81R #2 PICKUP
_______ Hz/s
```

```
81R #2 DELAY
_______ Cycles
```

```
81R NEG SEQ VOLT INHIBIT
    25%
```

2.5 Oscillograph Recorder

The oscillograph recorder provides comprehensive data recording of all monitored waveforms (voltage, current, status inputs and output contacts) at 16 samples per cycle. Oscillograph data can be downloaded via the communications ports to any IBM compatible PC running M-3820 IPScom® communications software. Once downloaded, the waveforms can be examined using M-3821 IPSplot® Oscillograph data analysis software.

The recorder can be triggered manually through serial communications using IPScom or automatically using programmed status inputs (IN1–6) or programmed output contact (OUT1–8) operation. When untriggered, the recorder continually records waveform data, keeping the most recent data in memory. The recorders memory may be partitioned into any one of the following:

- one 170 cycle record
- two 112 cycle records
- three 84 cycle records
- four 68 cycle records

When triggered with a specific post trigger delay, the recorder continues recording for the delay period and keeps a snapshot of waveform data in its memory for downloading via IPScom.

■ **NOTE:** If more events or triggers occur before downloading than the number of partitions being used, the oldest record will be overwritten. Records are not retained if power to the relay is interrupted.

A post trigger delay of 5% to 95% may be specified. After triggering, the recorder will continue to store data for the programmed portion of the total record before rearming for the next record. For example, a setting of 80% will result in a record with 20% pre-trigger and 80% post trigger data.

The **OSC TRIG** LED on the front panel will indicate when oscillograph data has been recorded and is available for download.

The setup of the Oscillograph Recorder includes the following settings:

```
RECORDER PARTITIONS
  4
```

"Recorder Partitions" designates the number of partitions that the oscillograph recorder will use. Whenever this number is changed, the post-trigger delay is automatically reset to 5%

```
TRIGGER INPUTS
  I6 i5 i4 i3 i2 i1
```

The trigger inputs designate the contact whose operation will trigger the recorder to record an event. Operation is "OR"ed if more than one input is selected.

```
TRIGGER OUTPUTS
o8 o7 o6 o5 o4 o3 o2 o1
```

The trigger outputs are relay output contacts whose operation will trigger the recorder to record an event. Operation is "OR"ed if more than one output is selected.

```
POST TRIGGER DELAY
    5%
```

The post trigger delay assigns the amount, in percent, of the individual data record occurring after the trigger. The remaining portion consists of pre-trigger data.

2.6 Target History Recorder

The 32 most recent target events are stored in the unit's memory. A target is triggered whenever an output (designated as a trip output) operates.

The setup of the Target History Recorder includes the following setting:

```
TRIGGER OUTPUTS
o8 07 06 05 04 03 02 01
```

Designated tripping output. In this sample, O1–O7 are trip outputs, and o8 is used for reconnect.

2.7 IRIG-B Time Sync

The M-3520 Intertie Protection Relay has the ability to accept either a modulated or demodulated IRIG-B signal. The modulated signal is connected via the rear panel BNC connector, and is the default configuration.

A demodulated TTL level signal may also be used by connecting the signal source to two unused pins on the rear panel COM2 RS-232 connector (see table B-1). For demodulated operation, several jumpers need to be reconfigured (see Section 5.5, Circuit Board Switches and Jumpers).

When valid IRIG-B time information is received, the TIME SYNC LED is illuminated, and the hour, minute, and seconds of the on-board real-time clock (RTC) are corrected to the new IRIG-B time at five (5) minutes before the hour. Extended time information, accurate to 1 ms, is appended to all oscillograph and target time tags.

3 Operation (Front Panel)

This chapter provides information on the operation of the optional M-3931 Human-Machine Interface Module (HMI) front panel controls to maneuver through the menus, enter values, set and interrogate the M-3520 Intertie Protection Relay.

3.1 Front Panel Controls

The relay has been designed to be set and interrogated locally with the optional M-3931 HMI. An integral part of this design is the layout and function of the front panel indicators and controls; see Figure 3-1, Front Panel.

The indicators and controls consist of a 2 x 24-character display, and a 6-button keypad. These controls are used by the operator to navigate the system menus, and to set and interrogate the unit. Detailed information on using these controls is provided in this chapter.

Alphanumeric Display

To assist the operator in setting and interrogating the relay, the display shows menus, which guide the operator to the desired function or setpoint value. These menus consist of two lines. The bottom line shows lower case abbreviations of each menu selection with the current menu selected and highlighted in uppercase. The top menu line provides a description of the current menu selection (see Figures 3-2 and 3-3).

While the unit is not in use, and has not operated, the user logo lines are displayed. If the unit has operated, the display cycles through a sequence of screens summarizing the operation status conditions (targets) until **ENTER** is pressed, at which time the first-level menu is displayed.

Arrow Buttons

The left and right arrow buttons are used to choose among menu selections shown on the display. When entering values, these buttons are used to select the digit (by moving the cursor) of the displayed setpoint that will be increased or decreased by the use of the up and down arrow buttons.

The up and down arrow buttons *only* increase or decrease input values, or change between upper and lower case inputs. Upper case inputs are active whereas lower case inputs are inactive. If the up or down arrow button is held in when adjusting numerical values, the speed of the increment or decrement is increased, after a small delay.

EXIT Button

Use the **EXIT** button to exit from a displayed screen to the immediately preceding menu. Any changed setpoint will not be saved if the selection is aborted via the **EXIT** button.

ENTER Button

The **ENTER** button is used to choose a highlighted menu selection, to replace a setpoint or other programmable value with the currently displayed value, or to select one of several displayed options, such as to **ENABLE** or **DISABLE** a function.

Target/Status Indicators and Controls

The target/status indicators and controls consist of the following LEDs: Power Supply (**PSI** and **PS2**) **RELAY OK**, the Oscillograph Recorder (**OSC TRIG**), **BREAKER CLOSED**, **TARGET**, **DIAGNOSTIC** and **TIME SYNC**

Power Supply (PS1 and PS2) LED.

The green power LED indicator(s) remains illuminated for the appropriate power supply whenever power is applied to the unit. Power supply PS2 is available as an option.

Relay OK LED

The green **RELAY OK** LED is controlled by the relay's microprocessor. A flashing **OK** LED indicates proper program cycling. The LED can also be programmed to illuminate continuously, if desired.

Oscillograph (OSC TRIG) Recorder LED

The **OSC TRIG** LED illuminates to indicate that oscillograph data has been recorded in the unit's memory.

Breaker (BRKR) CLOSED LED

The red **BRKR CLOSED** LED illuminates when the breaker status input (52b) is open.

Target Indicators and Target Reset

Normally, the 24 **TARGET** LEDs are not illuminated. Upon operation, LEDs corresponding to the cause(s) of the operation will light and stay illuminated until reset. The eight **OUTPUT** LED's will reflect the present state of the **OUT1–OUT8** output contacts. Pressing and releasing the **TARGET RESET** button will momentarily light all LEDs (providing a means to test them) and allows resetting of the **TARGET** LEDs if the condition causing the operation has been removed. Detailed information about the cause of the last 32 operations is retained in the unit's memory for access through the alphanumeric display via the **VIEW TARGET HISTORY** menu.

Pressing and holding the **TARGET RESET** button displays the present *pickup* status of the M-3520 functions on the target indicators.

Time Sync LED

The green **TIME SYNC** LED illuminates to indicate that the IRIG-B time signal is being received and validated.

Diagnostic LED (DIAG LED)

The diagnostic LED flashes upon occurrence of a detectable self-test error. The LED will flash the Error Code Number. For example, for error code 32, the LED will flash 3 times, followed by a short pause, and then 2 flashes, followed by a long pause, and then repeat. For units equipped with the HMI, the Error Code Number is also displayed on the screen.

Accessing Screens

To prevent unauthorized access to functions, the software allows assignment of access codes. If access codes have been assigned, the access code entry screen will be displayed after **ENTER** is pressed from the default message screen.

■ **NOTE**: The relay is shipped with the access code feature disabled.

The M-3520 has three levels of access codes, which determine the extent of access to M-3520 functions for each user. The higher the Level number, the greater access permitted.

Level **1** access - provides access to read setpoints, monitor status and view target history.

Level **2** access - provides all level 1 access, plus the ability to change setpoints.

Level **3** access - provides all level 1 & 2 access, plus the ability to change configuration parameters.

Each access code is a user defined 1 to 4 digit number. If the level 3 access code is set to 9999, the access code feature is disabled. When access codes are disabled, the access screens are bypassed. Access codes are altered by choosing the **ALTER ACCESS CODES** menu under **SETUP UNIT** menu. (These codes can only be altered by a level 3 user).

Default Message Screens

When the M-3520 is powered and unattended, user logo lines are displayed. The display automatically returns to the logo screens after five minutes of unattended operation.

If a function has operated and not been reset, it will display the time and date of the operation and automatically cycle through screens for each applicable target. (This sequence is illustrated in Figure 3-2.) In either case, pressing **ENTER** will begin local mode operation, thereby displaying the access code entry screen, or if access codes are disabled, the first level menu will be displayed.

Serial Interfaces (COM1, COM2 and COM3)

The serial interface **COM1** port (front) and **COM2** port (rear) are standard 9-pin RS-232C DTE configured communications ports.

The **COM1** port will normally be used for local setting and interrogating of the relay via a portable computer running IPScom®. IPScom only supports communications using BECO 2200 protocol. **COM1** port protocol is fixed at BECO 2200. An additional **COM3** port (RS-485) is available at the rear terminal block. Either the **COM2** port or the **COM3** port will normally be used for remote setting and interrogation of the relay via a network, direct connection or permanently wired modem.

COM2 and **COM3** have the option of setting the protocol to BECO2200 or MODBUS. **COM1** communicates at a fixed 8 bits, no parity and 2 stop bits (8,N, 2 standard BECO 2200 settings). However, **COM2** and **COM3** have the option of setting parity (none, odd or even), if configured for MODBUS protocol. Detailed information on the use of the communications ports is provided in Appendix B, **Communications**.

The protocol description document and the communication data base document may be requested from the factory or from Beckwith's web site at www.beckwithelectric.com.

Communication Specifications

The following descriptions apply for use of MODBUS protocol:

1. MODBUS protocol is not supported on **COM1**.
2. Parity is supported on **COM2** and **COM3**; valid selections are 8,N, 2; 8,O,1 or 8,E, 1.
3. ASCII mode is not supported (RTU only).
4. Standard baud rates from 300 to 9600 are supported.
5. Only the following MODBUS commands are supported:
   a. Read holding register (Function 03).
   b. Read input register (function 04)
   c. Force single coil (function 05)
   d. Preset single register (function 06).
6. MODBUS does not support oscillograph record downloading.

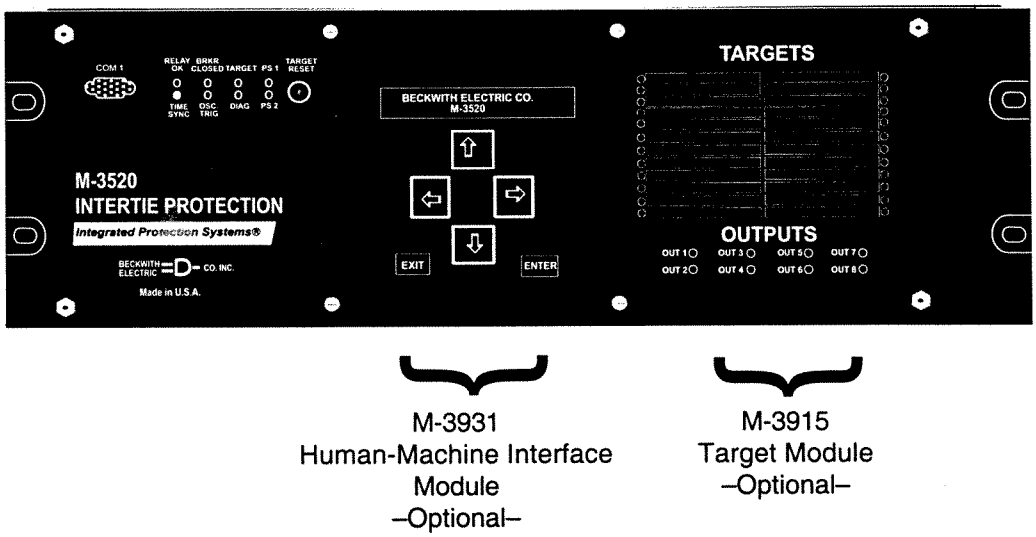


Figure 3-1 M-3520 Front Panel

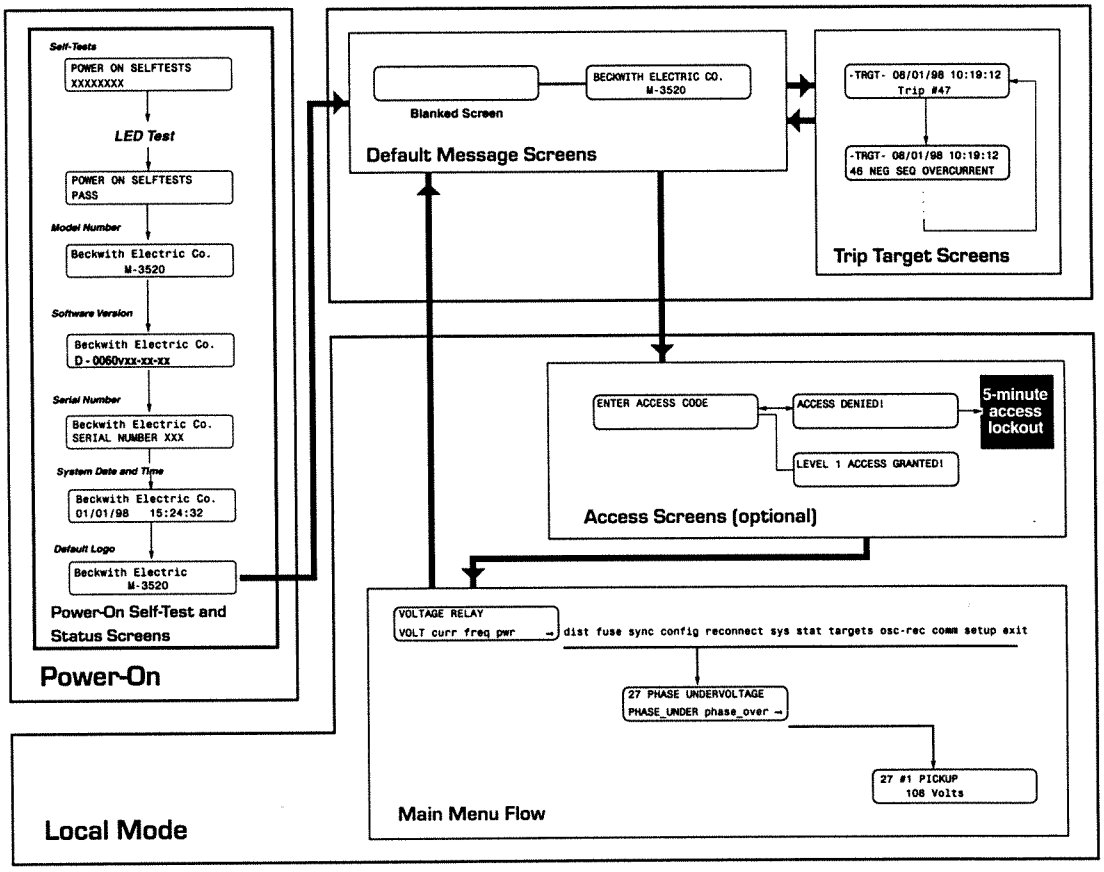


Figure 3-2 Screen Message Menu Flow

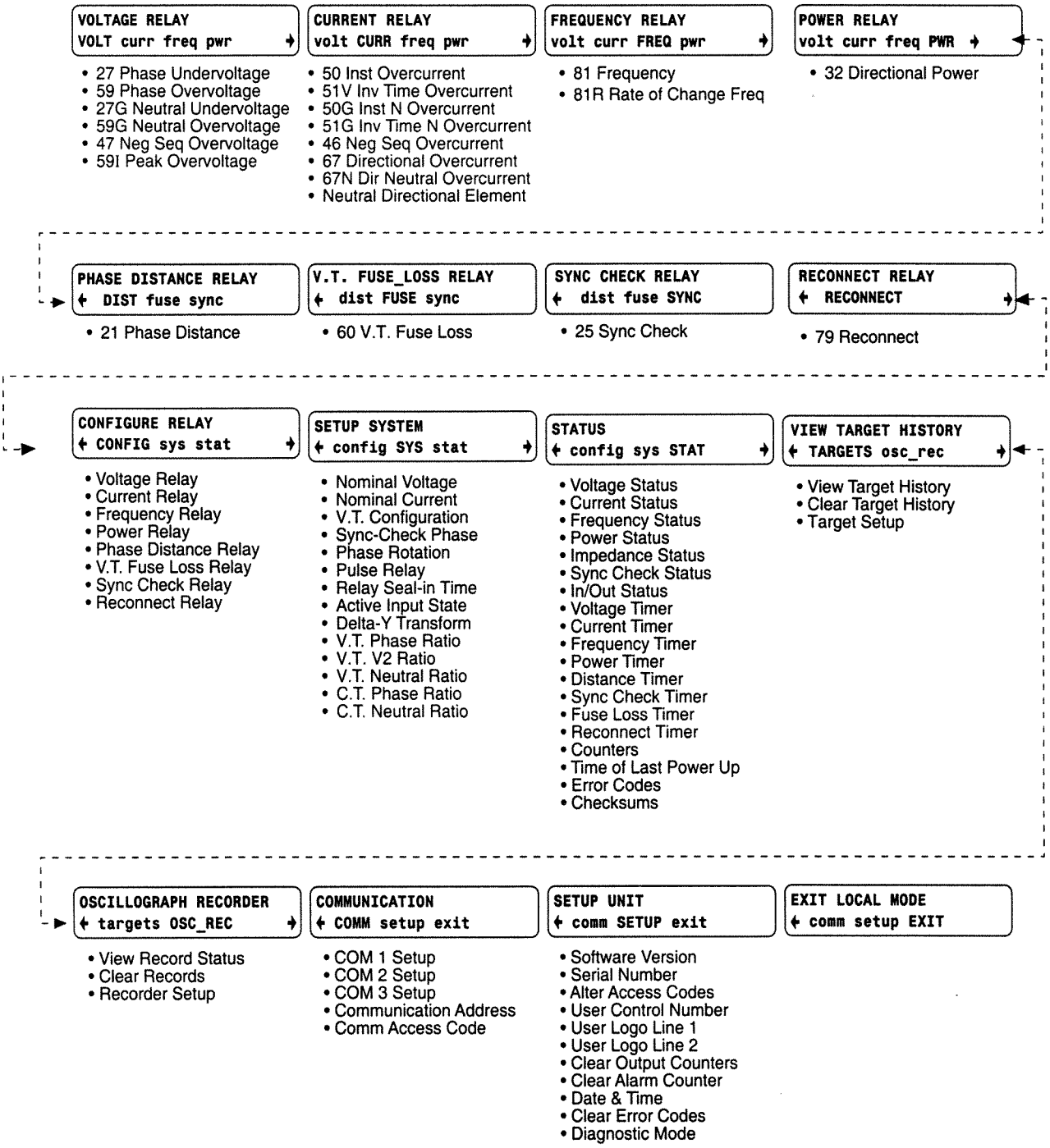


Figure 3-3 Main Menu Flow

3.2 Initial Setup Procedure/Settings

The relay is shipped with the initial configuration settings as listed in Appendix A, and recorded in the Record forms. Selected settings that are unique to the application may be recorded on the appropriate record form as calculated from Chapter 2, **Application.**

Setup Procedure

1. Connect power to the relay's rear power terminals, as marked on the rear panel's power supply label and as shown in Figure 5-4, External Connections.
2. Whenever initially powered up, the relay performs a number of self-tests to ensure its proper operation. During the self-tests, the display shows an "X" for each test successfully executed. If all tests are successful, the unit will briefly display the word **PASS**. Then it will cycle through a series of status screens, including the model number, software version number, serial number, date and time as set in the system clock, and the user logo screen will be displayed. (Figure 3-2 illustrates this sequence of screens.)
3. If any test should fail, the error LED will flash, an error code will be displayed and the relay will not allow operation to proceed. In such a case, the error code should be noted and Beckwith Electric contacted. A list of error codes and their descriptions are provided in Appendix C, **Error Codes**. Assuming that various voltage functions are enabled, and there are no voltage inputs connected, various voltage targets will be identified as having operated
4. If remote communication is used, the baud rate, address, and other parameters for the communication ports must be set. Refer to the instructions in subsection Communications Data (located at end of this procedure). Also refer to Chapter 4, **Operation (Computer)**, on M-3820 IPScom®.
5. To setup the unit with general information required, including altering access codes, clearing output counters, setting date and time, installing user logos, and other adjustments, refer to Section 3.2, Setup Unit Data.
6. If desired, calibrate the unit following the calibration procedure described in subsection 6.3, Auto Calibration. For units without HMI, refer to Section 5.5, Circuit Board Switches & Jumpers.

   ■ **NOTE:** The relay has been fully calibrated at the factory using very precise and accurate test equipment. There is no need for recalibration before initial installation. Further calibration is only necessary if a component was changed and will be only as accurate as the test equipment used.
7. Finish relay configuration in the **SETUP SYSTEM** menu. This is the general system and equipment information required for relay operation. See Figure 3-4, Setup System Menu. This includes such items as CT and VT ratios, VT configurations, and Nominal values.
8. Enable the desired functions under the **CONFIGURE RELAY** menu.

   ■ **NOTE**: Disabling unused functions improves the response time of the indicators and controls.
9. Enter the desired setpoints for the enabled functions.
10. Enter the desired information for the oscillograph recorder.
11. Enter the desired information for the target recorder.
12. Install the relay and connect external input and output contacts according to the rear panel terminal block markings as shown in Figure 5-4, External Connections.

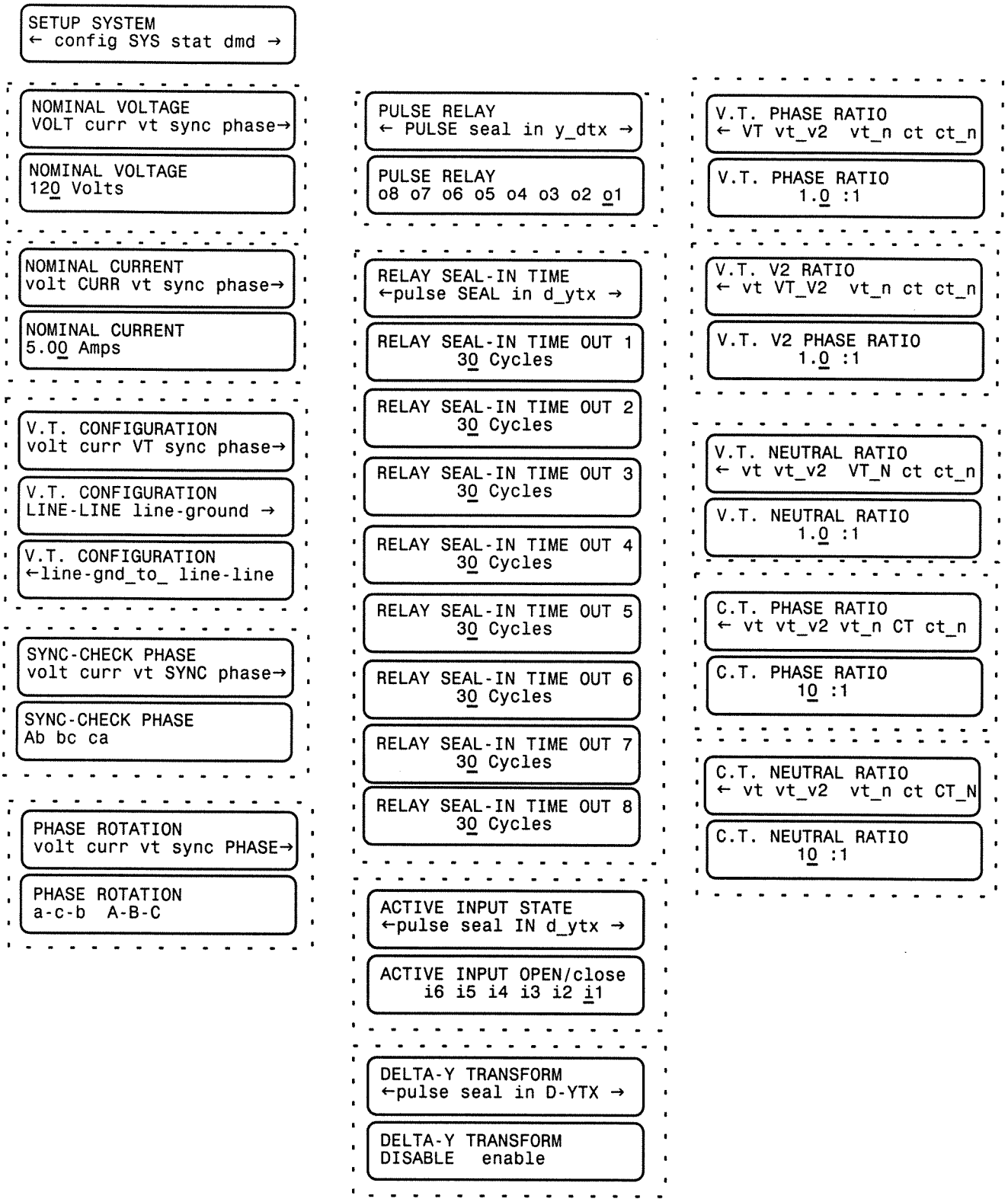


Figure 3-4 Setup System Menu

Communication Data

The general information that is required to complete the input data of this section includes:

- Baud rate for **COM1** and **COM2** communication ports. **COM3** uses the same baud rate as **COM2** (default) or **COM1** (jumper selectable).
- Communications address used to access multiple relays via a multidrop communication line.
- Communications access code (used for communication system security; entering an access code of 9999 disables the communication security feature).
- Communication protocol and dead sync time for **COM2** and **COM3.**
- Parity for **COM2** and **COM3** if MODBUS protocol is used.

Before entering the communication data, the Communication Data & Unit Setup Record (see Appendix A, Form A-1) should be completed.

Figure 3-5 is a sample of the Communication Data & Unit Setup Record Form. Refer to the column on the left for communication data. It is organized in the same order as in the relay menu.

The values shown in the Communication Data column of Figure 3-5 represent the default or "as shipped" values for these setpoints. Communication data for units purchased without the M-3931 HMI module may be altered by using the IPSutil™ utility package which is shipped with the IPScom® software package. Establishing communication with the relay using the default parameters is required before other setpoints may be altered.

Setup Unit Data

The general information that is required to complete the input data in this section includes:

- Access codes
- Control numbers
- Date and time
- User logo
- Diagnostic mode

Before entering the setup data, the Communication Data & Unit Setup Record (see Appendix A, Form A-1) should be completed.

Figure 3-5 is a sample of the Communication Data & Unit Setup Record Form. Refer to the two columns on the right for setup data.

The relay already contains factory settings for setup data, which can be used to familiarize the user with the **SETUP UNIT** menu.

Setup System

Information required in this section includes:

- Nominal Voltage and Current
- VT Configuration
- Sync-Check Phase
- Phase Rotation
- Pulse Relay
- Relay Seal-in Time
- Active Input State
- Delta-Y Transform
- VT Phase, Neutral and V2 Ratios
- CT Phase and Neutral Ratios

See Figure 3-4 for Sample Settings related to input for this Section. Settings are self explanatory, and are required for proper operation of the M-3520 relay.

Configure Relay Data

The relay is shipped with a certain group of standard functions (along with any purchased optional functions).Both standard and optional functions are fully configurable. (Unpurchased functions cannot be enabled.)

Functions designated as DISABLED are inactive and will not be available for tripping. All menus associated with inactive functions will be unavailable.

The general information required to complete the input data on this section includes:

- Enable/disable function
- Output choices (OUT1–8)
- Input blocking choices (IN1–6 and/or fuse loss)

Setpoints and Time Settings

The general information that is required to complete the input data in this section includes individual relay function:

- Pickup settings (converted to relay quantities)

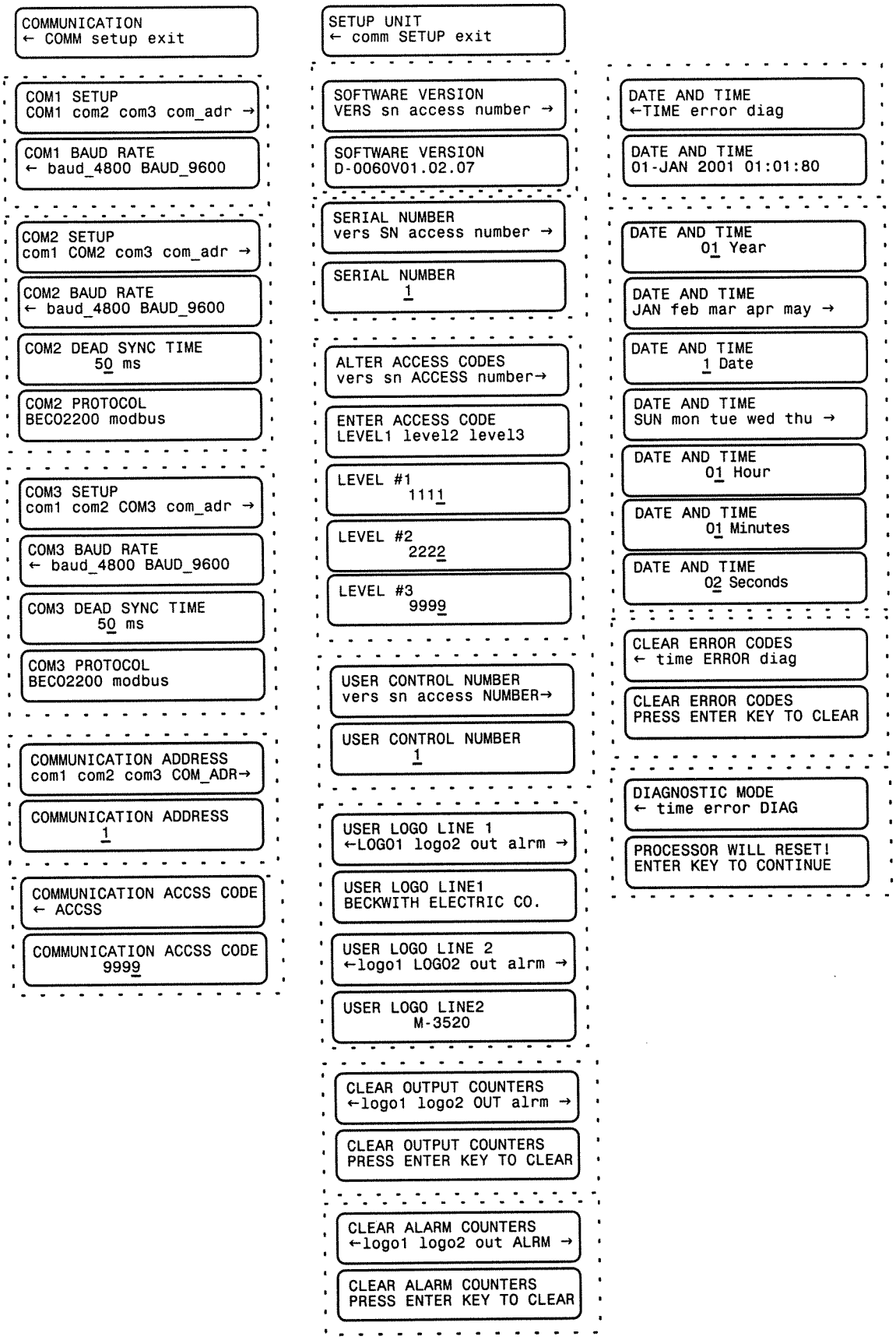


Figure 3-5 Communication Data & Unit Setup Menu

- Time delay settings
- Time dials and curves
- Power in PU, etc.

Input descriptions are detailed in Section 2.4, Setpoints and Time Settings. Make sure to complete the Setpoint & Timing Record Form in Appendix A before entering the setpoint and time setting data.

The relay already contains factory settings for setpoint and time setting data, which can be used to familiarize you with these menus.

Oscillograph Recorder Data

The oscillograph recorder provides comprehensive data recording of all monitored waveforms, storing up to 170 cycles of data. The total record length is programmable for one (170 cycles), two (113 cycles), three (85 cycles each), or four (68 cycles) event records. The oscillograph recorder is triggered either remotely, via designated status input signals or through relay output operations.

When untriggered, the recorder continuously records waveform data, keeping the data in buffer memory. When triggered, the recorder continues storing data for a period of time, as defined by the user, thereby keeping the most recent records in memory for downloading to a personal computer.

If more events or triggers occur than the number of records (partitions) designated before downloading of data, triggering the recorder overwrites the oldest of the event records. Be sure to complete the Setpoint & Timing Record Form in Appendix A before entering the oscillograph recorder settings.

The relay already contains factory settings for oscillograph recorder setup, which can be used to familiarize the user with the **OSCILLOGRAPH RECORDER** menu.

The HMI module allows the user to view time stamps for recorded events, and to clear all records in order to provide a fresh starting point for event triggering.

Target History Recorder

The **VIEW TARGET HISTORY** menu selection enables the user to review the targets for the previous 32 target conditions. A target is triggered whenever a designated output is operated or closed. The target history for each operation cycles continuously through a sequence of screens until **EXIT** is pressed. A target includes:

- pickup information which indicates any function which is timing,
- an indication whose function or functions have operated and timers expired,
- phase and ground currents at the time of trip, and individual phase element information at the time of the trigger, if the operating function was a 3-phase function,
- input and output status, and
- a time tag of the trigger.

The time tag of the trigger will be in the following format:

HH(Hours); MM(min); SS.xxx(seconds).

The xxx will be 000 if the IRIG-B signal is not connected or not synched. Otherwise, it will give seconds to the nearest thousands of a second.

CLEAR TARGET allows the user to clear all operation history for further target recording.

TARGET SETUP allows the user to select which outputs will trigger a target record. In most cases only tripping function outputs will be programmed to trigger targets. Outputs designated for reconnect or sync-check are usually not included in this set.

■ **NOTE:** If a second function is used in an attempt to operate an output that has already operated, it will not trigger a new target since no new output has been operated or closed. If the second function operation closes a different unoperated output, a new target will be triggered. Targets are captured or recorded only when an output operates.

3.3 Checkout Status/Metering

The relay has two menu selections concerning monitoring status and demand values. This section describes the operation of these selections.

Status/Metering

Access the **STATUS** menu as follows:

1. Press **ENTER** to bring up the main menu.
2. Press the right arrow button until **STATUS** appears on the top line of the display.
3. Press **ENTER** to access the **STATUS** submenu and begin the monitoring.

■ **NOTE:** Each category listed below is a submenu item. Pressing the **ENTER** button moves the item down within that menu, allowing monitoring of values within that submenu category. To exit a specific category and continue to the next menu category, press the **EXIT** button.

All metering values in this section (with the exception of power metering) are secondary level quantities.

The menu categories for monitored values are:

VOLTAGE STATUS
Phase voltages, neutral voltage, V2 voltage, positive sequence voltage, negative sequence voltage, zero sequence voltage

CURRENT STATUS
Phase currents, neutral current, positive sequence current, negative sequence current, zero sequence current

FREQUENCY STATUS
Frequency, Rate of change of frequency

POWER STATUS
Real power, Reactive power, Apparent power, Power factor

IMPEDANCE STATUS

SYNC CHECK STATUS

IN/OUT STATUS
Status of input and output contacts

The following timer status can also be monitored:

VOLTAGE TIMER
27, 27G, 47, 59, 59I, 59G

CURRENT TIMER
46, 50, 50G, 51G, 51V, 67

FREQUENCY TIMER
81, 81R

POWER TIMER
32

DISTANCE TIMER
21

SYNC CHECK TIMER
25

FUSE LOSS TIMER
60FL

RECONNECT TIMER
79

Timers for the inverse time functions are displayed in percentage where 100% corresponds to the full value of the integrating timer.

If the associated function time setting is less than 2 cycles, the indicated status will be less than actual. The following miscellaneous status can also be monitored:

COUNTERS **OUT1–8 plus alarm**

TIME OF LAST POWER UP

ERROR CODES **Last error code log**

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4 Operation (Computer)

This chapter contains information on configuring and interrogating the M-3520 Intertie Protection Relay via a personal computer running the M-3822 IPScom Communications Software package.

4.1 Installation and Setup

The IPScom Communications Software package runs under Microsoft® Windows 95 operating system, or later. This version of IPScom only supports communication via the BECO 2200 protocol.

IPScom is available in the following IBM PC-compatible format: one 3.5" double-sided, high density (DS/HD 1.44 MB) disk.

The M-3822 IPScom software is not copy-protected and can be copied to a hard disk. For more information on your specific rights and responsibilities regarding the M-3822 IPScom software, refer to the licensing agreement enclosed with your software, or contact Beckwith Electric Co.

Hardware Requirements

IPScom will run on any IBM PC-compatible computer that provides at least the following:

- 8Mb of RAM
- Microsoft Windows 95 or later
- One 3.5" double-sided, high-density (DS/HD 1.44 MB) disk drive.
- One serial (RS-232) communication port
- VGA monitor
- Mouse or pointing device.
- Windows-compatible printer

The M-3520 is provided with three serial communication ports. Two serial interface ports, COM1 and COM2 are standard 9-pin RS-232 DTE-configured ports. The front panel port, COM1, can be used as a temporary connection to locally set and interrogate the relay by computer. The second RS-232 COM2 port is provided at the rear of the unit.

An RS-485 configured port, COM3 is located at the rear terminal block of the unit. Either COM2 or COM3 can be used to remotely set and interrogate the relay via a modem, whereas all three ports may be used for direct serial connection.

■ **NOTE:** The RS-232 standard specifies a maximum cable length of 50 feet for RS-232 connections. Successful operation cannot be guaranteed for cable lengths exceeding this recommendation. Every effort should be made to keep cabling as short as possible. Low capacitance cable is recommended.

Use of IPScom® and M-3520 Intertie Protection Relay via Modem

In order to use IPScom to communicate with the relay via a modem, the following must be provided for the unit.

- Hayes-compatible external modem; 1200, 2400, 4800, or 9600 baud.
- Serial modem cable with 9-pin connector for the system and the applicable connector for the modem.

Similarly, the computer running IPScom must also have access to a Hayes-compatible internal or external modem. Pin-outs for communication cables are provided in Appendix B.

Use of IPScom and M-3520 Intertie Protection Relay via Direct Serial Connection

In order to use IPScom to communicate with the relay via direct serial connection, a serial "null modem" cable is required. The cable must be provided with a 9-pin connector (DB9P) for the system, and an applicable connector for the computer (usually DB9S or DB25S). Pin-outs for a null modem adapter are provided in Appendix B, **Communications**. A 10-foot, null modem RS-232 cable may be purchased from Beckwith Electric Co. (part number M-0423).

Installation

Before installing the IPScom program, make a copy of the software disks for archive purposes.

Figure 4-1 IPScom Program Icon

IPScom can be run from a hard disk. An installation utility (setup.exe) has been provided to make the process easier.

Installing IPScom

1. Insert software disk1 in your drive.
2. Select Run from the Start Menu.
3. In the Run dialog box, specify the file to be installed by typing either *A:\Setup* or *B:\Setup*, depending on the drive in which the software diskette is inserted.
4. The installation utility establishes a program folder (Becoware) and subdirectory (IPScom). After installation, the IPScom program item icon (see Figure 4-1) is located in Becoware. The application files are located on drive C, in the new subdirectory IPScom (C:\\Becoware\\Ipscom).

Installing IPSutil™

IPSutil is utility software used to program system-level parameters for units shipped without the M-3931 HMI Module. The IPSutil.exe file is automatically installed in the Becoware folder, along with the IPScom files, and does not require separate installation.

Installing the Modems

Using IPScom to interrogate, set or monitor the relay via a modem requires both a remote modem connected at the relay location and a local modem connected to the computer with IPScom installed.

The local modem can be initialized, using IPScom, by connecting the modem to the computer, and selecting the **COMM** menu in IPScom. Select **MODEM**, enter the required information, and fi-

nally select **INITIALIZE** from the expanded Communications dialog box. The following steps outline the initialized modem setup procedure.

1. Connecting the modem to the computer:
   a. If the computer has an external modem, use a standard straight-through RS-232 modem cable to connect the computer and modem (M-3933). If the computer has an internal modem, refer to the modem's instruction book to determine which communications port should be selected.
   b. The Hayes-compatible modem must be attached to (if external) or assigned to (if internal) the same serial port as assigned in IPScom®. While IPScom can use any of the four serial ports (COM1 through COM4), most computers support only COM1 and COM2.
   c. Connect the modem to the telephone line and power up.

2. Connecting the Modem to the Relay:

Setup of the modem attached to the relay may be slightly complicated. It involves programming the parameters (via the AT command set), and storing this profile in the modem's nonvolatile memory.

After programming, the modem will power up in the proper state for communicating with M-3520. Programming may be accomplished by using "Hyperterminal" or other terminal software. Refer to your modem manual for further information.

■ **NOTE:** The relay does not issue or understand any modem commands. It will not adjust the baud rate and should be considered a "dumb" peripheral. It communicates with 1 start, 8 data, and 1 stop bit.

   a. Connect the unit to an external Hayes-compatible modem by attaching a standard RS-232 modem cable to the appropriate serial communications port on both the unit and the modem.
   b. Connect the modem to the telephone line and power up.

The modem attached to the unit must have the following AT command configuration:

E0	No Echo
Q1	Don't return result code
&D3	On to OFF DTR, hang-up and reset
&S0	DSR always on
&C1	DCD ON when detected
S0=2	Answer on second ring

The following commands may also be required at the modem:

&Q6	Constant DTE to DCE
N0	Answer only at specified speed
W	Disable serial data rate adjust
\Q3	Bi-directional RTS/CTS relay
&B1	Fixed serial port rate
S37	Desired line connection speed

There are some variation in the AT commands supported by manufacturers of Hayes-compatible modems. Refer to the hardware user documentation for a list of supported AT commands and direction on issuing these commands.

Setting Up the M-3520 Intertie Protection Relay for Communication

The initial setup of the relay for communication must be completed by the optional M-3931 HMI Module or via direct serial connection using the default "As Shipped" communication parameters. Refer to Communication Data and Unit Setup "AS SHIPPED" form located in Appendix A, **Forms**.

For units shipped without the optional HMI Module, the communication parameters may be altered by first establishing communication using the default parameters and the IPSutil™ program.

IPSutil is an auxiliary program shipped on the same disk with the IPScom program. It is used exclusively for altering communication and setup parameters on units shipped without the M-3931 HMI Module.

■ **NOTE:** Communication is inhibited while the relay is in local mode (being accessed via the HMI). To ensure the M-3520 is available for remote communication, press **ENTER** at the **EXIT LOCAL MODE** menu item, or press the **EXIT** key several times to back out of the menu tree to the top level screen.

Multiple Systems Setup

The individual addressing capability of IPScom® and the relay allows multiple systems to share a direct or modem connection when connected via a communications-line splitter (see Figure 4-2). One such device enables 2 to 6 units to share one communications line.

▲ **CAUTION:** Units connected to a communications line splitter must have a unique communications address. If two or more units share the same address, corrupted communications will result.

Serial Multidrop Network Setup

Individual remote addressing also allows for communications through a serial multidrop network. Up to 32 relays can be connected using the same 2-wire or optional 4-wire RS-485 communications line.

Appendix B, Figure B-2 illustrates a setup of RS-232 Fiber Optic network, and Figure B-3 illustrates a 2-wire and 4-wire RS-485 network.

Other communication methods are possible using the M-3520 Intertie Protection Relay. An Application Note, "*Serial Communication with Beckwith Electric's Integrated Protection System Relays*" is available from the factory, or from our website at www.beckwithelectric.com.

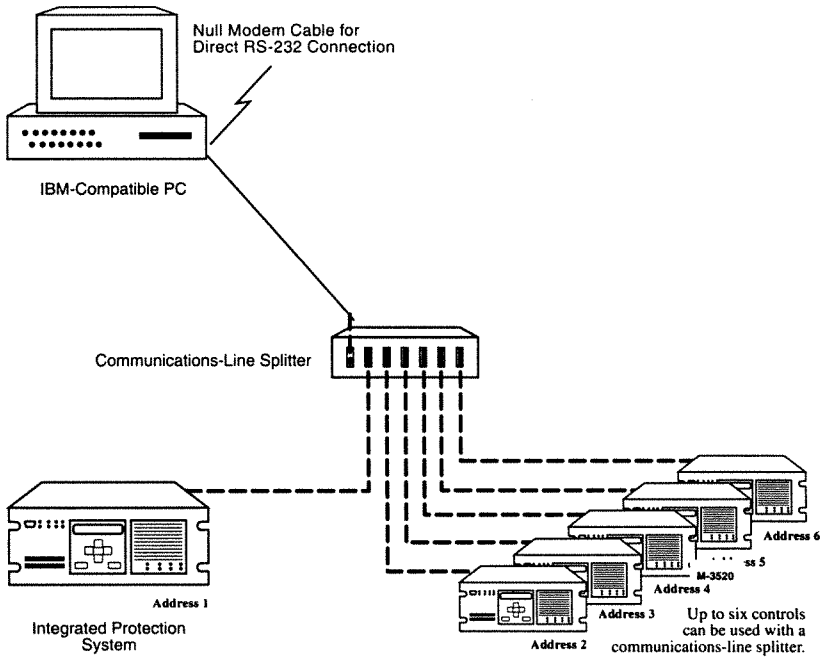


Figure 4-2 Multiple Systems Addressing Using Communications-Line Splitter

4.2 Operation

Activating Communications

After the relay has been set up, the modems initialized, and IPScom installed, communication is activated as follows:

1. Choose the IPScom icon from the Becoware folder.
2. The IPScom splash screen is displayed briefly, providing the software version number and copyright information. This information is also available by choosing the **About...** command from the **Help** menu.
3. Choose the **COMM** menu selection. Complete the appropriate information on the window for the relay to be addressed.
   a. If communication is through a modem, choose the Modem command button to expand the communications dialog box.

Choose the desired relay location and choose **Dial** button. This action establishes contact and automatically opens the communication to the relay.

b. If computer is serially connected through the front port, choose the **Open COM** button. This action establishes communications.

4. Enter any valid IPScom command(s) as desired.

5. To end communication when communicating by modem, choose the **Hang Up** command button from the expanded Communication dialog box. To close the communication channel when connected locally, choose the **Close COM** command button.

Overview

When IPScom is run, a menu and status bar is displayed (as shown below). This section describes each IPScom menu selection and explains each IPScom command in the same order as they are displayed in the software program. For detailed information on each dialog box field (function), refer to Chapter 2, **Application**.

When starting IPScom, the initial menu choices are the **File** menu or the **Comm** menu. The choice specifies whether the operator desires to write to an data file or to communicate directly with the relay.

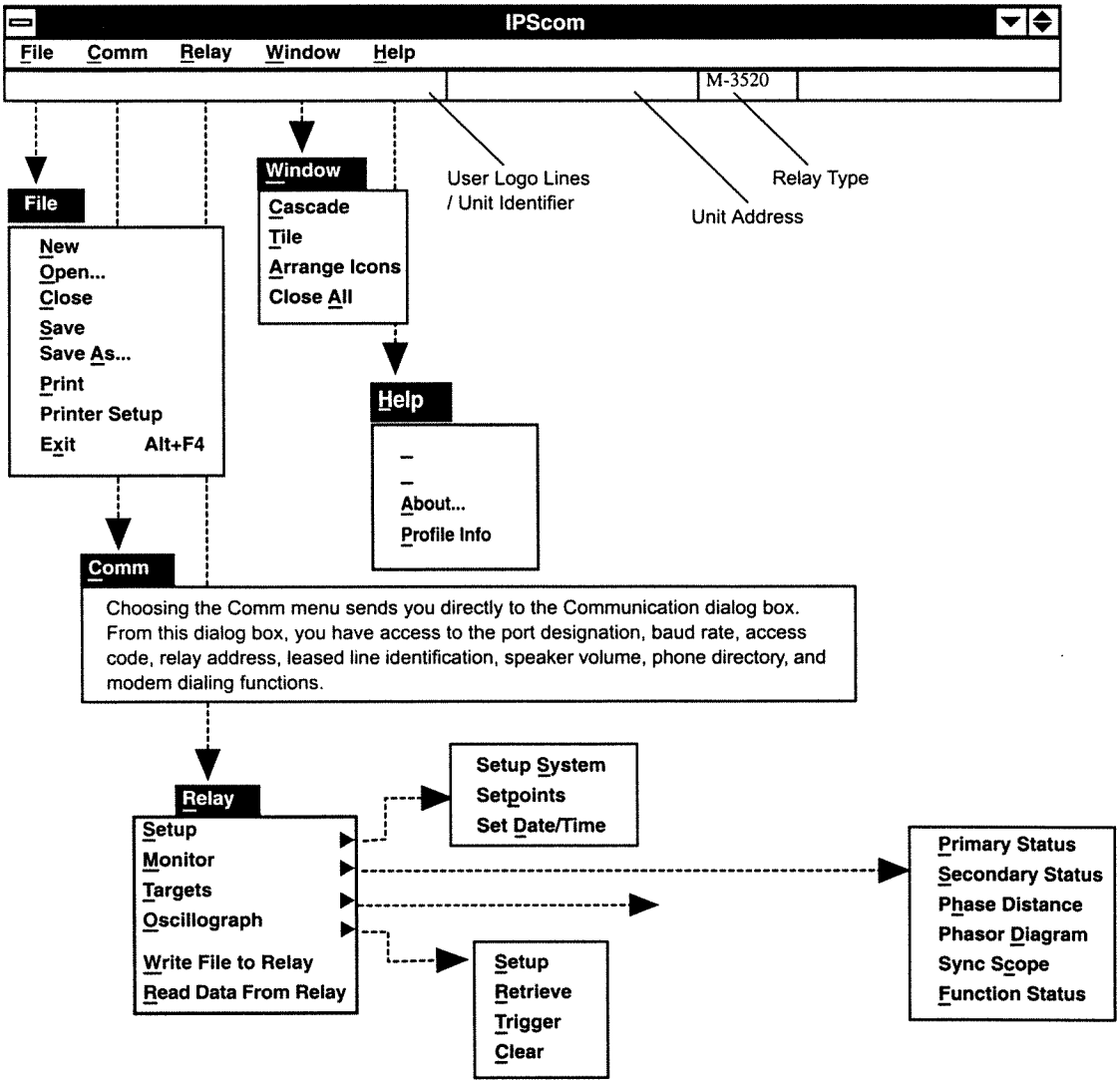
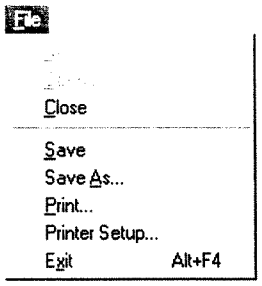


Figure 4-3 IPScom® Menu Selections

File Menu



The **File** menu enables the user to create a new data file, open a previously created data file, close, print, and save the file. The IPScom® program can also be exited through the **File** menu.

Since IPScom can be used with several Beckwith protection systems in addition to the M-3520 Intertie Protection Relay, the format and contents of a file must be established depending on which protective system is being addressed. When not connected to one of the protection systems, using the **New** command, a new file is established with the New Device Profile dialog box (see Figure 4-5). Choosing the **OK** command button, allows the new data file to be named by using the **Save** or **Save As**...commands.

■ **NOTE:** By choosing the **New** command, unit and setpoint configuration values are based on factory settings specified for the profiled protection system.

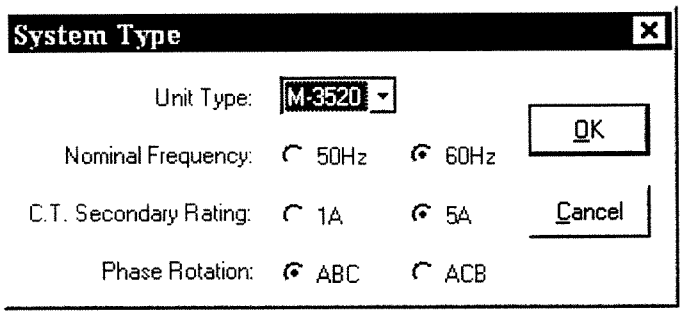


Figure 4-4 New Device Profile Dialog Box

Path: File menu / New command

COMMAND BUTTONS

OK Saves the currently displayed information.

Cancel Returns you to the IPScom main window; any changes to the displayed information are lost.

The **Save** and **Save As**... commands allow resaving a file or renaming a file, respectively. The **Open** command allows opening a previously created data file. With an opened data file, use the **Relay... Setup...** menu items to access the setpoint windows.

If communication can be established with a relay, it is always safer to use the **Read Data From Relay** command (found under the **Relay** menu) to update the PC's data file with the relay data. This file now contains the proper system type information, eliminating the need to set the information manually.

The **Print** and **Printer Setup** commands allow user to select printer options and print out all setpoint data from the data file or directly from the relay, if a relay is communicating with the PC. The **Exit** command quits the IPScom program.

Comm Menu

File Comm Relay Window Help

The **Communication** dialog box (see Figure 4-5) allows setup of the IPScom communication data to coordinate with the relay and, by choosing the **Modem** button, establishment of contact for remote locations. When communicating by way of a fiber optic loop network, echo cancelling is available by checking the **Echo Cancel** box. This command masks the sender's returned echo.

If communication is established through the modem, the **Dial** button should be pressed after the dial string is selected. If necessary, the **Initialize** button can be used to send the initialization string to the modem. If checked, the **Bring Up Terminal Window After Dialing** box provides an advanced control on modem communications, such as communications where modem switch is involved at the remote site.

If the modem was not used to establish communication, press the **Open COM** button to start. If the relay has been defaulted with the communication access code 9999, a message window will appear showing access level #3 was granted. Otherwise, another dialog box will appear to prompt the user to enter the access code in order to establish the communication. **Close COM** discontinues communication.

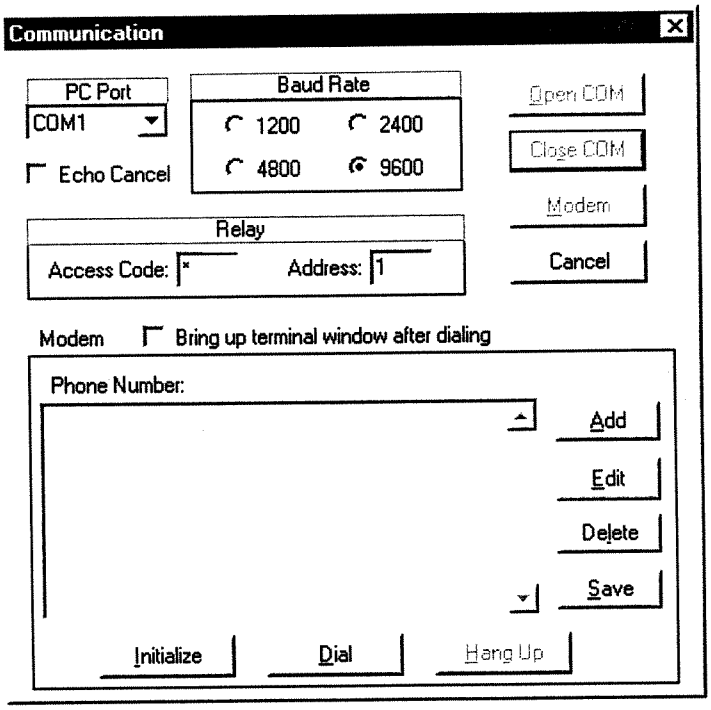


Figure 4-5 Communication Dialog Box

Path: Comm menu

COMMAND BUTTONS

Cancel Returns you to the IPScom main window; any changes to the displayed information are lost.

Open COM Initiates contact with the protective system, either by direct serial or modem communication.

Close COM Breaks communication with the protective system, for both direct serial or modem communication.

Modem Displays the expanded Communication dialog box.

Add Displays the Add/Edit dialog box, allowing you to type a protective system's unit identifier, phone number, and communication address.

Edit Displays the Add/Edit dialog box, allowing you to review and change the user lines (unit identifier), phone number, and communication address of a selected entry.

Delete Deletes a selected entry.

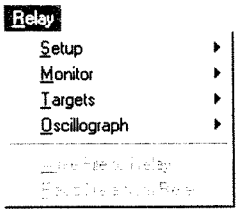
Initialize Allows you to send special setup or other AT commands directly to the modem.

Dial Dials the entry selected from the directory.

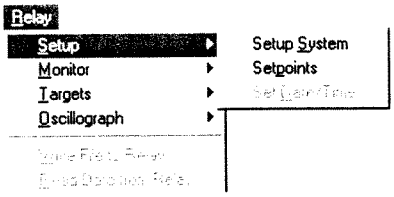
Hang Up Ends modem communication, allowing you to dial again.

Bring up Terminal Window After Dialing A built-in terminal window allows an interactive communication with modem and relay.

Relay Menu



The **Relay** menu provides access to the windows used to set, monitor, or interrogate the relay. Four submenus are provided: **Setup, Monitor, Targets** and **Oscillograph** as well as two commands, **Write File To Relay** and **Read Data From Relay**.



The **Setup** submenu provides three commands: **Setup System**, **Setpoints**, and **Set Date/Time**. The **Setup Relay** command displays a dialog box (see Figure 4-6) which allows the input of pertinent information regarding the system on which the relay is applied (see Section 2.3, Configuration, System Setup).

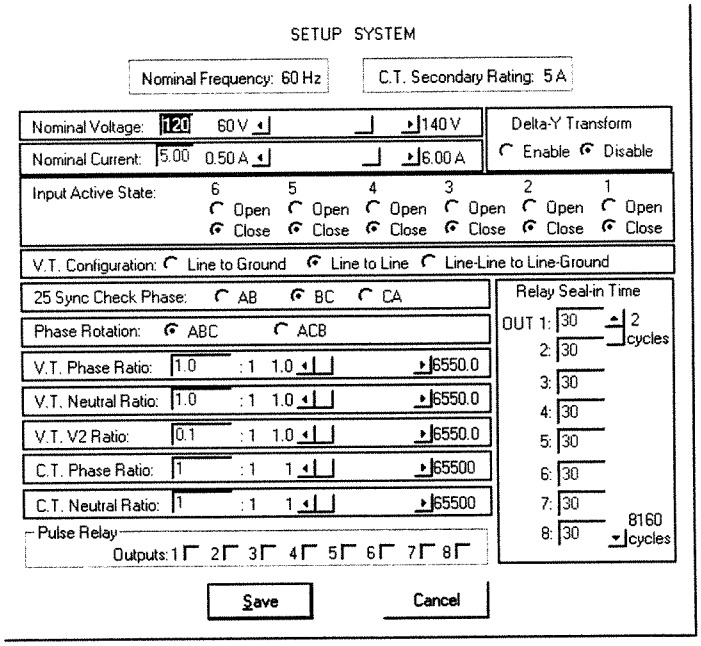


Figure 4-6 Setup System Dialog Box

Path: Relay menu / Setup submenu / Setup Relay window

SETUP SYSTEM COMMAND BUTTONS

Save When connected to a protection system, sends the currently displayed information to the u n i t . Otherwise, saves the currently displayed information.

Cancel Returns you to the IPScom® main window; any changes to the displayed information are lost.

■ **NOTE:** Checking the inputs for the Active Input Open parameter designates the "operated" state established by an *opening* rather than a closing external contact.

The **Setpoints** command displays the Relay Setpoints dialog box (see Figure 4-7) from which the individual relay function dialog boxes can be accessed. Choosing a relay function button (#46, for example), will display the corresponding function dialog box (see Figure 4-8).

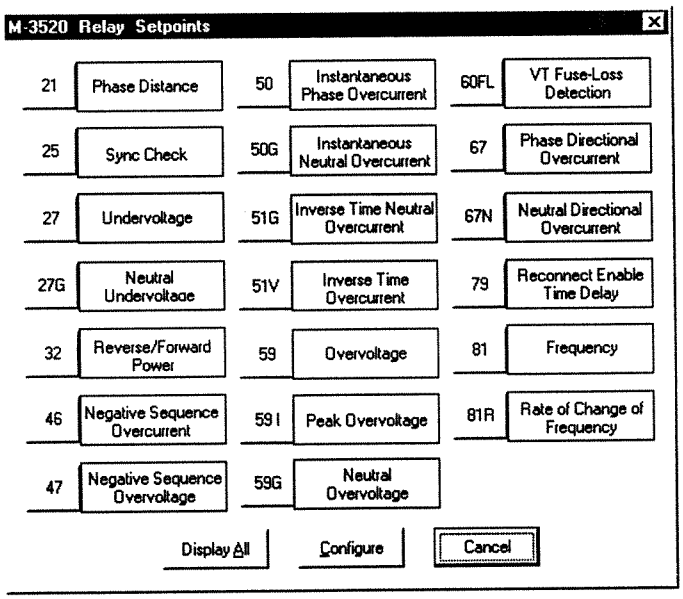


Figure 4-7 Relay Setpoints Dialog Box

Path: Relay menu / Setup submenu / Setpoints window

COMMAND BUTTONS

Display All – Opens the All Setpoints Table dialog box.

Configure – Opens the Configure dialog box.

Cancel – Saves the currently displayed information and returns to the IPScom main window.

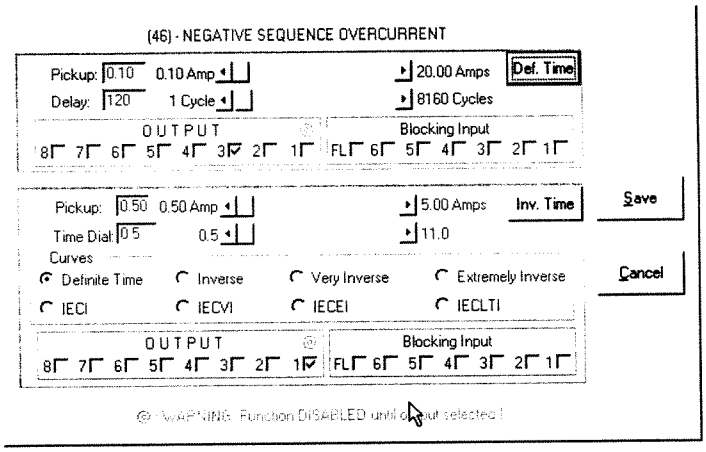


Figure 4-8 Negative Sequence Overcurrent Setpoint Dialog Box

Path: Relay menu / Setup submenu / Setpoints window/ 46 command button OR 46 jump hotspot within All Setpoints Table or Configure dialog box

COMMAND BUTTONS

Save When connected to a protection system, sends the currently displayed information to the unit. Otherwise, saves the currently displayed information and returns you to the Relay Setpoints, All Setpoints Table, or Configure dialog box.

Cancel Returns you to the Relay Setpoints, All Setpoints Table, or Configure dialog box; any changes to the displayed information are lost.

The **Relay Setpoints** dialog box gives access to two additional dialog boxes: **All Setpoints Table** and **Configure**. Choosing the **Display All** command button displays the **All Setpoints Table** dialog box (see Fig. 4-9). This dialog contains a list of settings for each relay within a single window to allow scrolling through all relay setpoint configuration values.

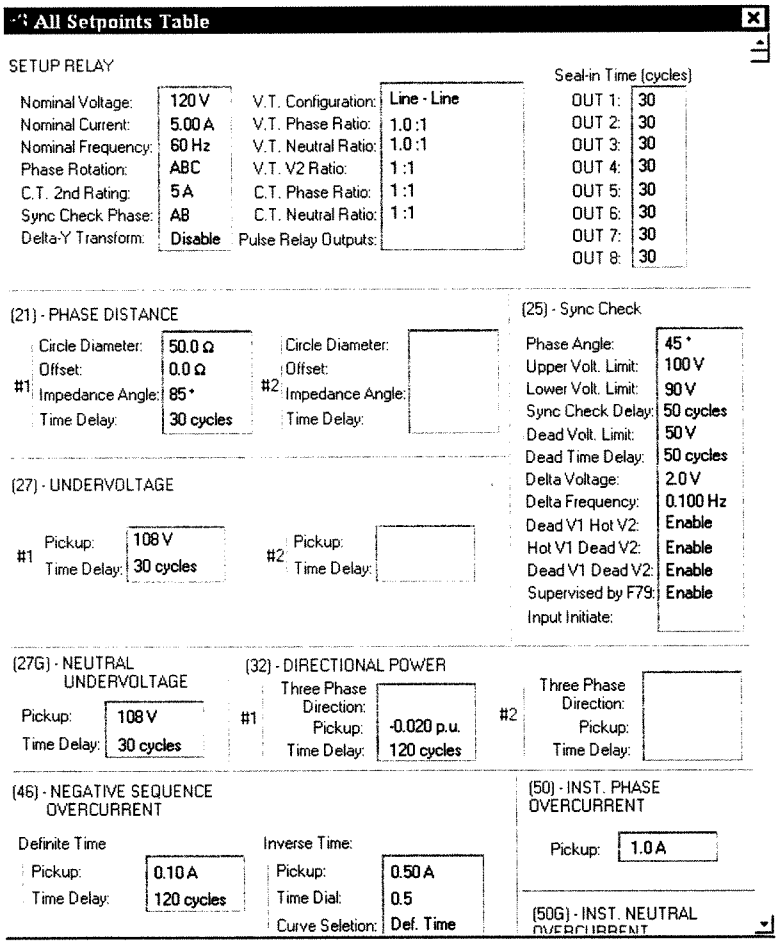


Figure 4-9 All Setpoints Table Dialog Box

Path: Relay menu / Setup submenu / Setpoints window/ Display All command button

JUMP HOTSPOTS

This window provides you with jump hotspots, identified by the hand icon, that take you to each relay dialog box and the Setup Relay dialog box. Exiting any of these dialog boxes will return you to the All Setpoints Table dialog box.

CONTROL MENU

Close Returns you to the Relay Setpoints dialog box.

Move Allows you to reposition the dialog box.

Choosing the **Configure** command button displays a dialog box (see Fig. 4-10), which contains a chart of programmed input and output contacts, in order to allow scrolling through all relay output and blocking input configurations. Both dialog boxes feature hotspots which allow the user to jump from a scrolling dialog box to an individual relay function dialog box and return to the scrolling dialog box again. All available parameters can be reviewed or changed when jumping to a relay configuration dialog box from either scrolling dialog box.

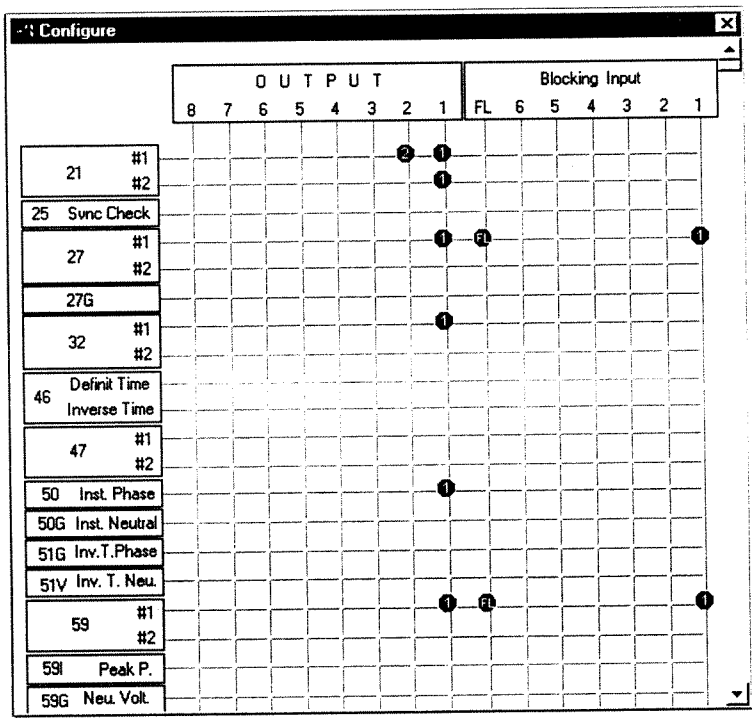


Figure 4-10 Configure Dialog Box

Path: Relay menu / Setup submenu / Setpoints window/ Configure command button

JUMP HOTSPOTS

This window provides you with jump hotspots, identified by the hand icon, that take you to each relay dialog box. Exiting any of these dialog boxes will return you to the Configure dialog box.

CONTROL MENU

Close Returns you to the Relay Setpoints dialog box.

Move Allows you to reposition the dialog box.

The **Set Date/Time** command (see Figure 4-11) allows system date and time to be set, or system clock to be stopped. This dialog box also displays an LED mimic to identify when the Sync Check is in use (preventing date/time from being changed by user).

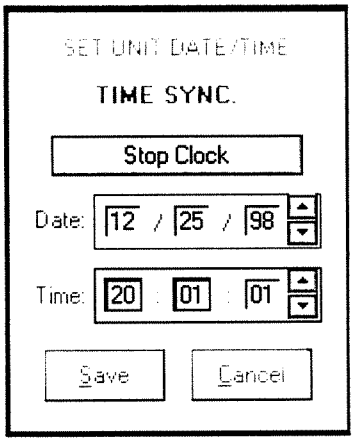


Figure 4-11 Unit Date/Time Dialog Box

Path: Relay menu/ Setup submenu/ Set Date/Time Command
There is a blue Time Sync LED mimic on this dialog box (the LED is displayed as different shading on a monochrome monitor). When this LED is blue, the relay is synchronized with the IRIG-B signal and the Time field is grayed out, indicating that this field can't be changed. But the Date field can be changed (by editing and pressing **Save**).

When the LED is *not* blue, the relay is not time-synchronized and therefore, both the Date and Time fields can be changed.

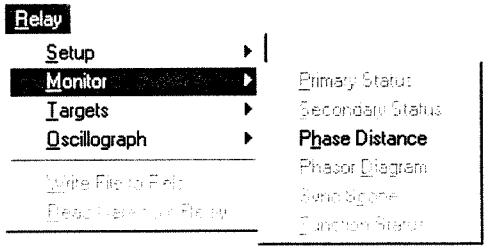
The time field in the dialog box is not updated continuously. The time at which the dialog box was opened is the time that is displayed and remains as such. This is true whether the relay is synchronized with the IRIG-B signal or not.

COMMAND BUTTONS

Stop Clock This toggles between start/stop, the relay clock. 'Stop' pauses, 'Start' resumes.

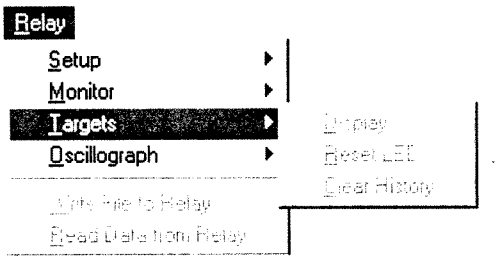
Cancel Returns you to the IPScom® main window. Any changes to the displayed information is lost.

The **Monitor** submenu provides access for reviewing the present status of the M-3520's measured and calculated values, other real-time parameters and conditions as well as examining real-time and historical demand metering information (see Section 4.4, Checkout Status/Metering). A cascading menu appears, providing several command options as shown below.



The **Targets** submenu provides three command options: **Display**, **Reset LED**, and **Clear**. The **Display** command displays the **Target** Dialog. This dialog box (see Figure 4-12) provides detailed data on target events, including time, date, function status, phase current values, and IN/OUT contact status at the time of trip. Individually recorded events may be selected within the dialog box and saved into a text file, or be printed out with optional added comments. The **Reset LED** is similar to pushing the **Target Reset** button on the relay's front panel, resetting current target(s) displayed on the relay. This command does not reset any target history.

The **Clear** command clears all stored target data.



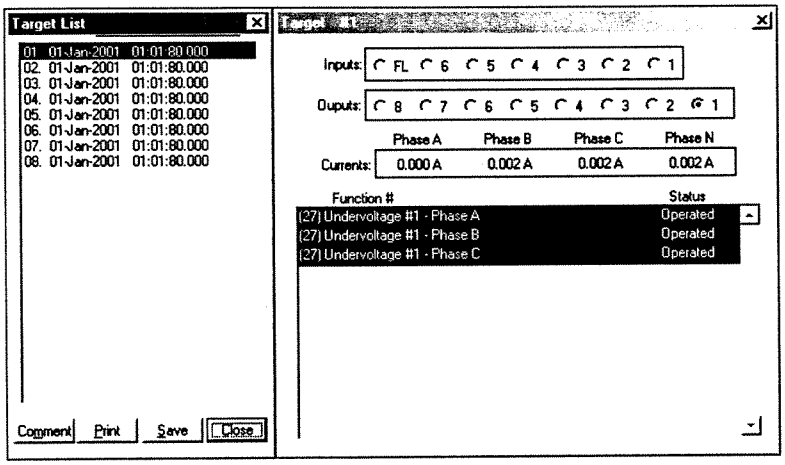


Figure 4-12 Target Dialog Box

Path: Relay menu / Targets submenu / Display command

COMMAND BUTTONS

Comment	Opens comment dialog box for annotation.
Print	Prints out selected target information, with comment.
Save	Saves selected target information, with comment, as a text file.
Close	Exits the currently displayed dialog box.

The **Oscillograph** submenu allows user to store data on selected parameters for review and plotting at a later time. The **Setup** command allows the user to set the number of partitions and triggering designations to be made. The **Retrieve** command downloads and stores collected data to a file; **Trigger** allows the manual triggering of the recorder; **Clear** erases the existing record. Run the optional M-3801A IPSplot® Oscillograph Analysis Software program to view the downloaded oscillograph files.

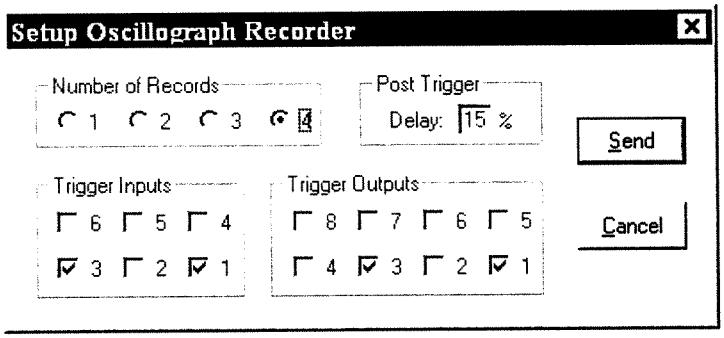
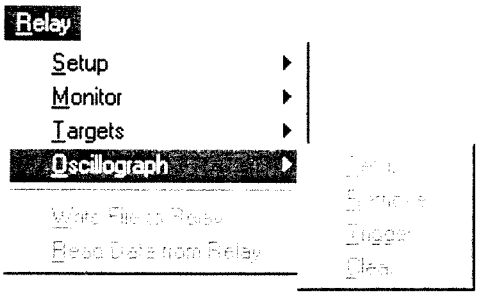
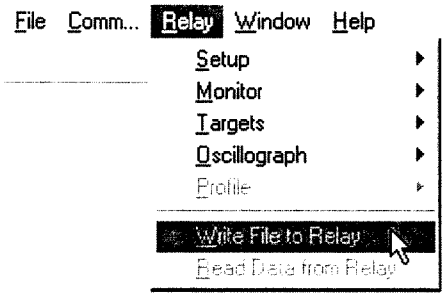


Figure 4-13 Setup Oscillograph Recorder

Path: Relay/Oscillograph/Setup

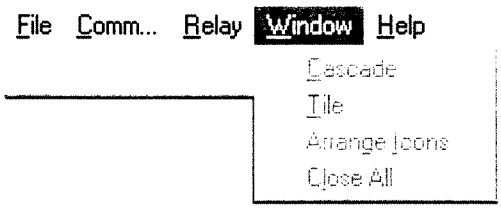


The **Write File To Relay** submenu is used to write the data to the M-3520 relay. The **Read Data From Relay** submenu is used to retrieve the data from the relay to the computer for display.



Window Menu

The **Window** menu enables the positioning and arrangement of any all IPScom® windows so that there is better access to available functions. This feature allows the display of several windows at the same time. Clicking on an inactive window activates that window.



Help Menu

The **Help** menu will enable the user to access information about any IPScom menus or commands. **Contents** and **Using Help** commands are currently unavailable, and will display as greyed out.

The **About...** screen displays IPScom version and development information.

Profile Info allows the user to view or make notations for the relay setpoint data files.

4.3 Cautions

System and IPScom® Compatibility

Every attempt has been made to maintain compatibility with previous software versions. In some cases (most notably with older protection systems), compatibility cannot be maintained. If there is any question about compatibility, contact Beckwith Electric.

System Priority

System conflicts will not occur, as local commands initiated from the front panel receive priority recognition. While the unit is in local mode, communication via the serial ports is suspended. IPScom displays an error message to indicate this fact.

Time and Date Stamping

Time and date stamping of events is only as useful as the validity of the unit's internal clock. Under the **Relay** menu, the **Set Date/TIme** command allows you to manually set the unit's clock.

Echo Cancel

The **Echo Cancel** check box, under the **Comm** menu, should only be used when several relays are connected via a fiber optic loop network. Otherwise, echo cancel must *not* be selected or communication will be prevented.

Serial Port Connections

If the serial port is connected to something other than a modem, and an IPScom modem command is executed, the results are unpredictable. In some cases, the computer may have to be reset.

4.4 Checkout Status/Metering

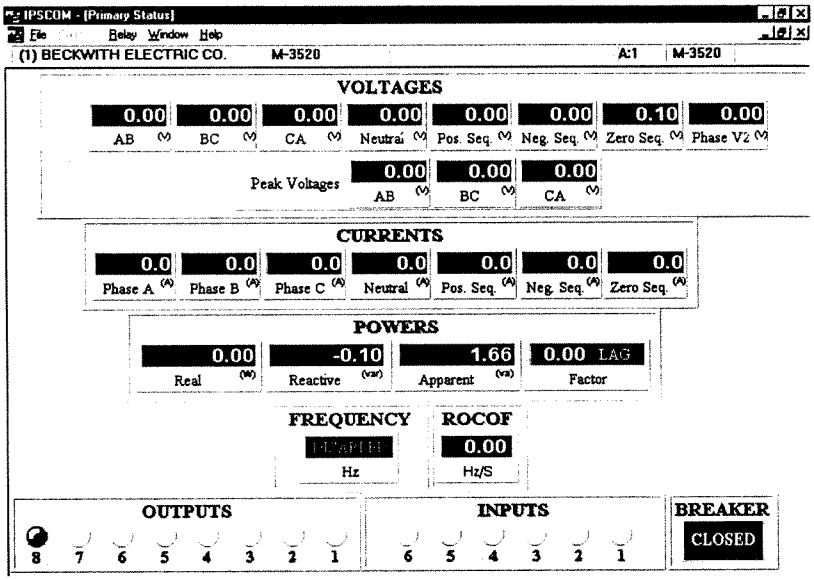


Figure 4-14 Primary Status Dialog Box

Path: Relay menu/Monitor submenu/ Primary Status window

These are calculated values based on the VT and CT inputs.

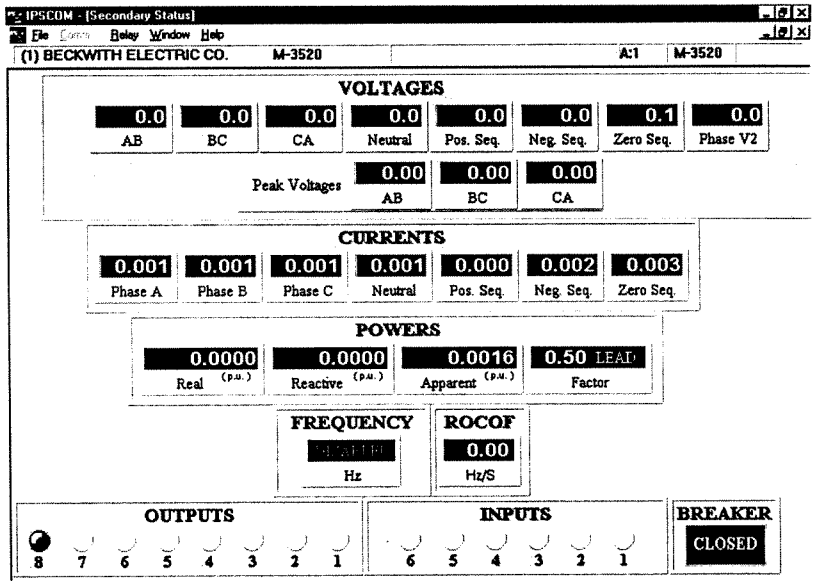


Figure 4-15 Secondary Status Dialog Box

Path: Relay menu / Monitor submenu / Secondary Status window

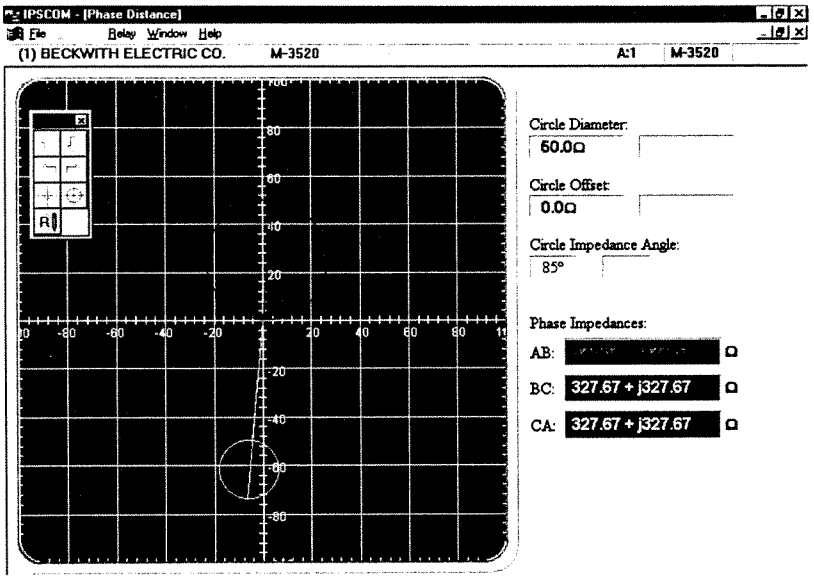


Figure 4-16 Phase Distance Dialog Box

Path: Relay menu / Monitor submenu / Phase Distance window

PHASE DISTANCE CONTROL BUTTONS

- Move up the scope window
- Move down the scope window
- Move the scope window to the left
- Move the scope window to the right
- Zoom In
- Zoom Out
- Refresh

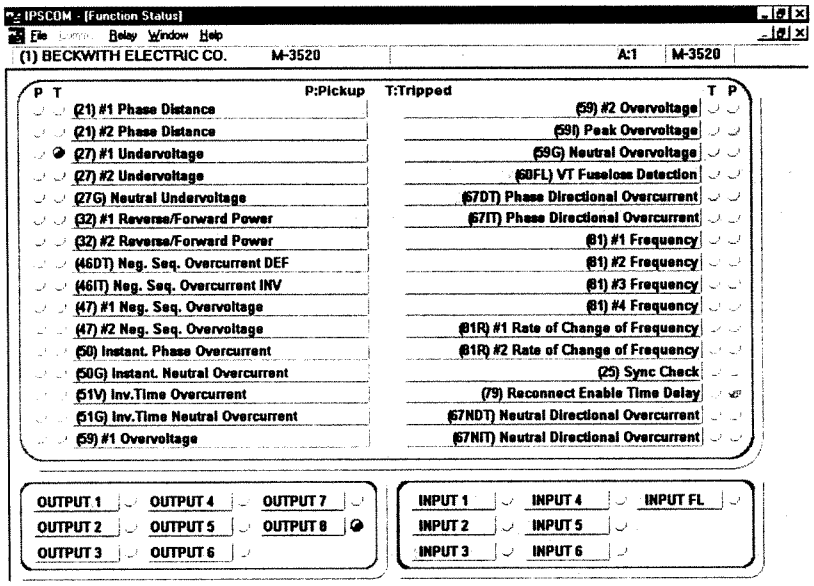


Figure 4-17 Function Status Dialog Box

Path: Relay menu / Monitor submenu / Function Status window

COMMAND BUTTONS

Close Exits the currently displayed dialog box.

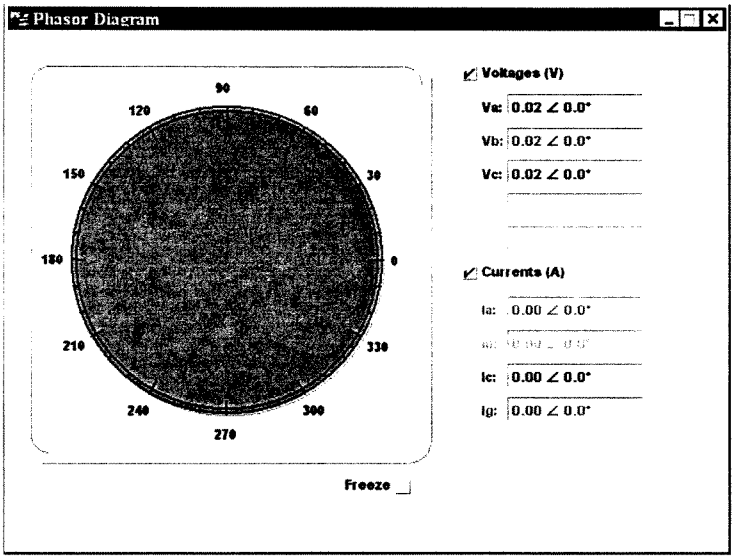


Figure 4-18 Phasor Diagram

Path: Relay menu/Monitor submenu/Phasor Diagram

☑ **COMMAND BOXES**

Voltage – Select to display voltage signals.

Currents – Select to display current signals

Freeze – When checked, visible data will not be updated.

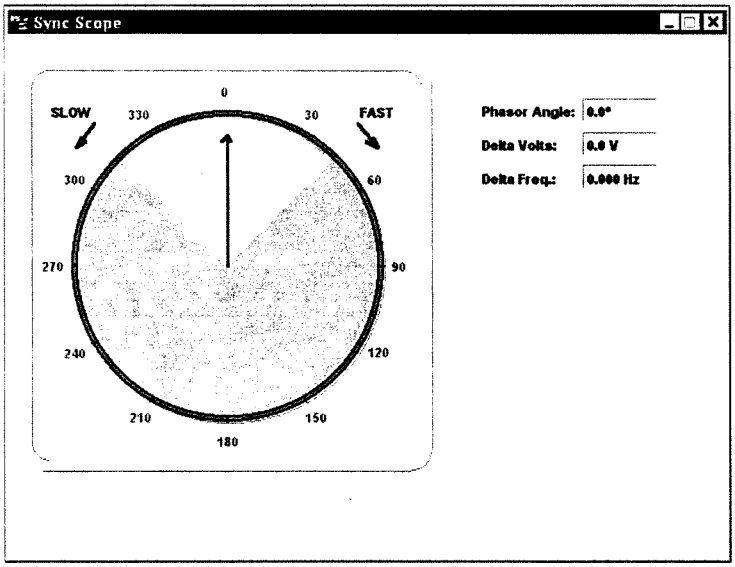


Figure 4-19 Sync Scope Screen

Path: Relay menu/Monitor submenu/Sync Scope

4.5 Keyboard Shortcuts

Keyboard Shortcuts

SYSTEM KEYS

These keys can be used within Windows and IPScom®.

Alt-Tab	To switch between applications.
Ctrl-Esc	To open Task List dialog box.
Ctrl-Tab	To switch between windows.
Arrow Keys	To select an application or group icon.
First Character of Name	To select application or group icon.
Enter	To open selected group or run selected application.

MENU KEYS

These keys enable you to select menus and choose commands.

Alt or F10	To select or cancel selection of the Setup menu on the menu bar..
Left Arrow, Right Arrow	To move between menus.
Up Arrow, Down Arrow	To move between commands.
A character key	To choose the menu or command. The underlined character matches the one you type.
Enter	To choose the selected menu name or command.
Esc	To cancel the selected menu name, or to close the open menu.

DIALOG BOX KEYS

These keys are useful when working in a dialog box.

Alt-a character key	To move to the option or group whose underlined letter or number matches the one you type.
Arrow Keys	To move highlighted selections within list boxes.
Alt-Down Arrow	To open a list.
Spacebar	To select an item or cancel a selection in a list. Also to select or clear a check box.
Enter	To carry out a command.
Esc or Alt-F4	To close a dialog box without completing the command.

Table 4-1 Windows Keyboard Shortcuts

4.6 IPSutil™ Communications Software

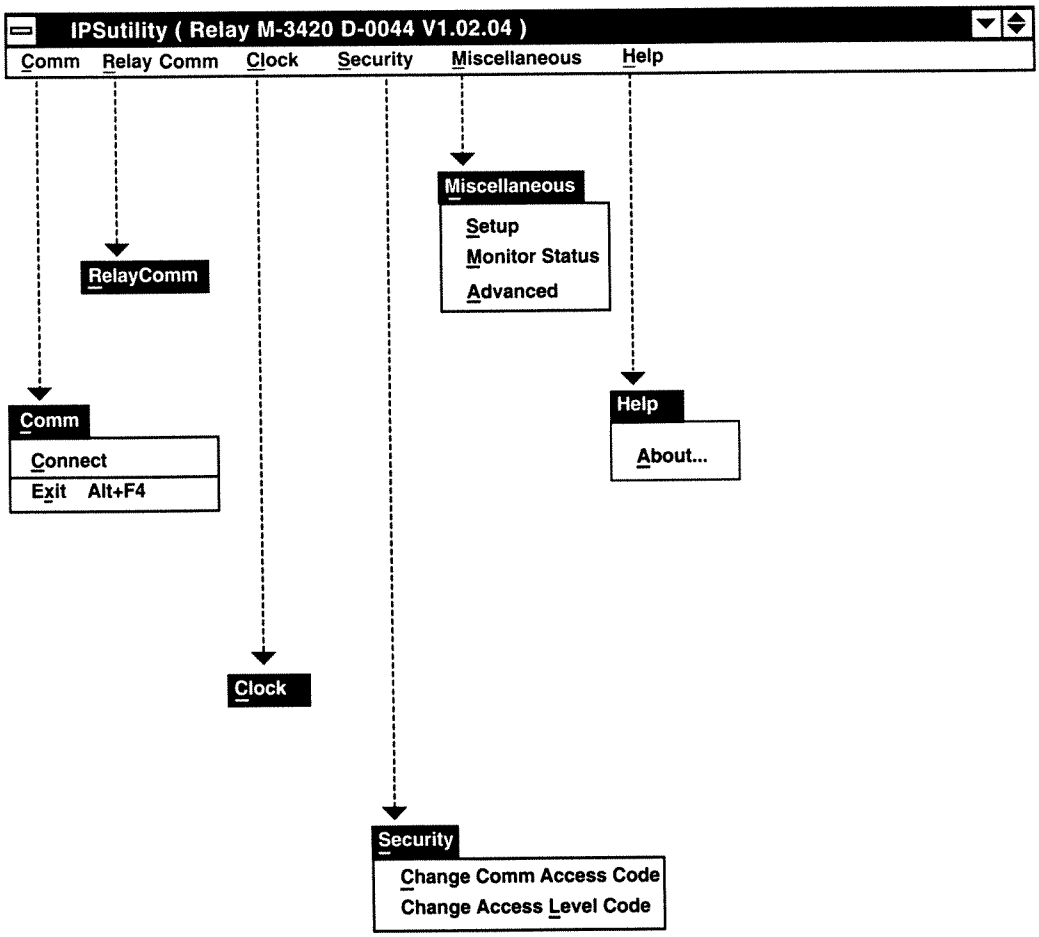


Figure 4-20 IPSutil Main Menu Flow

M-3890 IPSutil™

The M-3890 IPSutil Communication software package provides communication with the Beckwith Integrated Protection System® (IPS) for setting up the relays. Its main purpose is to aid in setting up IPS relays that are ordered without the optional front panel HMI interface.

● WARNING: The IPScom® and IPSutil programs are distributed on the same disk. The IPSutil program has the capability of overriding the security parameters set in the relay. It is recommended that you remove the IPSutil program from the IPScom disk and file it separately in a safe place, to be used by authorized people. For convenience, Beckwith Electric has distributed both programs on the same disk.

Installation and Setup

IPSutil runs with the Microsoft® Windows operating system, version 3.1 or above, and is available in the following IBM PC-compatible format:

- one 3.5" double-sided, high-density (DS/HD 1.44 Mb) disk

Hardware Requirements

IPSutil will run on any IBM PC-compatible computer that provides at least the following:

- 8 Mb of RAM
- Microsoft Windows 95 or later
- one 3.5" double-sided, high-density (DS/HD 1.44 Mb) disk drive
- one serial (RS-232) communication port
- VGA monitor
- Mouse or pointing device

Installation

An installation utility has been provided as a part of IPScom and IPSutil programs. After installation, the IPSutil can be run from the hard drive by choosing IPSUTIL.EXE.

System Setup

Connect a null modem cable from COM1 of the relay to the PC serial port. IPSutil supports COM1 port direct connection only. Modem connection is not supported. IPSutil program is not supported through COM2 or COM3 ports of the relay.

Overview

IPSutil helps in setting up IPS relays which were ordered without the optional front panel HMI interface. Units delivered without HMI's are shipped with a set of factory default settings for various parameters that the end user may wish to change. While the utility program is directed to users that do not have HMI, users of HMI-provided relays can also use IPSutil to set various parameters. When the IPSutil is started, a warning window appears (See Figure 4-21).

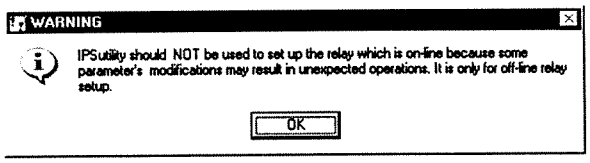


Figure 4-21 Warning Message

After you accept the warning, you can access the IPSutil main menu. The following sections describe each IPSutil menu items.

Comm Menu

The **Comm** menu allows you to make connections to the relay. This is the first command you must use to access the unit. After you click the **Connect** submenu item, the Communications dialog box appears (See Figure 4-22).

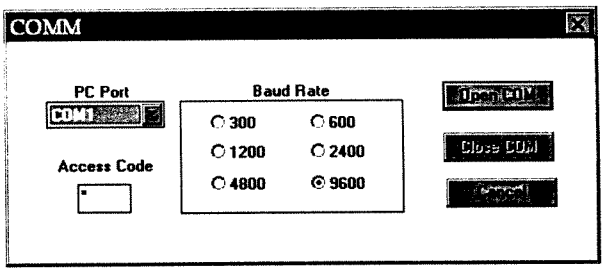
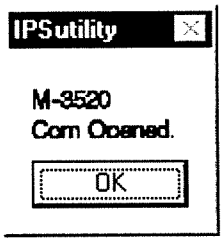


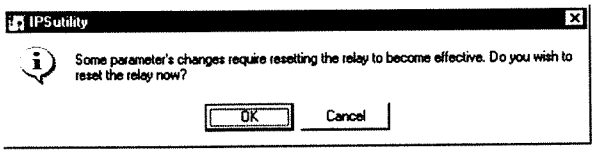
Figure 4-22 Communications Dialog Box

- Select the correct PC communication port where the null modem cable is connected for the relay.
- Select the baud rate of the relay. Factory default is 9600 baud.
- Select the access code resident in the relay. Factory default is 9999.
- Click "Open com" button.

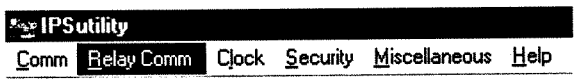
The following message window will appear showing COM opened. Now, the title bar will display the relay model and the software version.



The **Exit** submenu allows you to quit IPSutil™. If the relay was connected, this submenu disconnects the relay. When the relay was connected, if you have made any changes for some parameters (for example, baud rate, phase rotation) the following message window appears.



Relay Comm



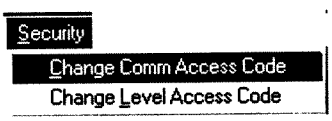
When **Relay Comm** menu is selected, the **Relay Comm Port Settings** dialog box appears (See Figure 4-22). It allows you to set the relay communication ports COM1 or COM2/COM3 baud rate. For COM2/COM3, it allows you to set the protocol and dead synch time. Additionally, for COM2 and COM3, if you select MODBUS protocol, the dialog box allows you to enable the parity option.

■ **NOTE:** If COM1 baud rate is changed and the relay is reset, the new baud rate must be used to communicate with COM1

Clock

When the **Clock** menu is selected, the **Set Unit Date/Time** dialog box appears, allowing the user to start or stop the clock in the relay, and change the date or time (See Figure 4-25).

Security Menu



The **Security** Menu allows you to set the communication access code and the level access codes for the relay.

The **Change Comm Access Code** allows you to assign new communication access code to the relay. The range of the access code is 1 to 9999. Note that the access code 9999 is a factory default. See Figure 4-26.

■ **NOTE:** Setting the access code to 9999 disables security.

The **Change Level Access Code** allows you to assign three different levels of access code for the relay functions accessibility. The range of the level access code is 1 to 9999. See Figure 4-27.

▲ **CAUTION**: This submenu allows you to change the relay level access codes.

Miscellaneous Menu

The **Miscellaneous** menu allows you to set and monitor some of the relay parameters.

The **Setup** submenu allows you to change the users Logo information, test outputs, assign communication address and user control number, phase rotation, **OK** LED flash mode in the relay. Note that the highest number used for the communication address is 255 and the highest control number allowed is 9999. See Figure 4-24.

The **Monitor Status** submenu allows you to monitor and clear the error code counters, monitor the check sums, and to view inputs test status. Note that powerloss counter cannot be cleared.

The **Advanced** command is reserved for factory use only, and will display as "greyed out".

Help Menu

Under **Help**, the **About...** submenu provides you the information on the IPSUtil version numbers.

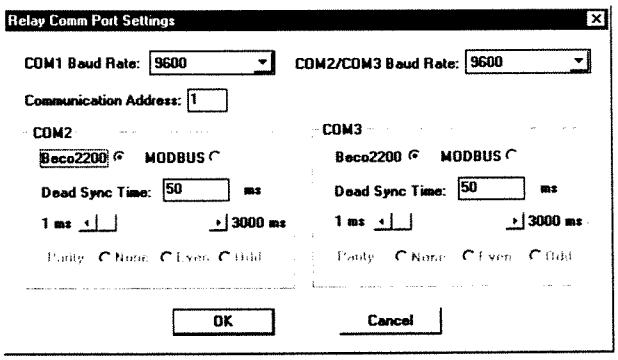


Figure 4-23 Relay Comm Port Settings

COMMAND BUTTONS

OK Sends the currently displayed information to the relay.

Cancel Returns you to the IPSutil main window. Any changes to the displayed information is lost.

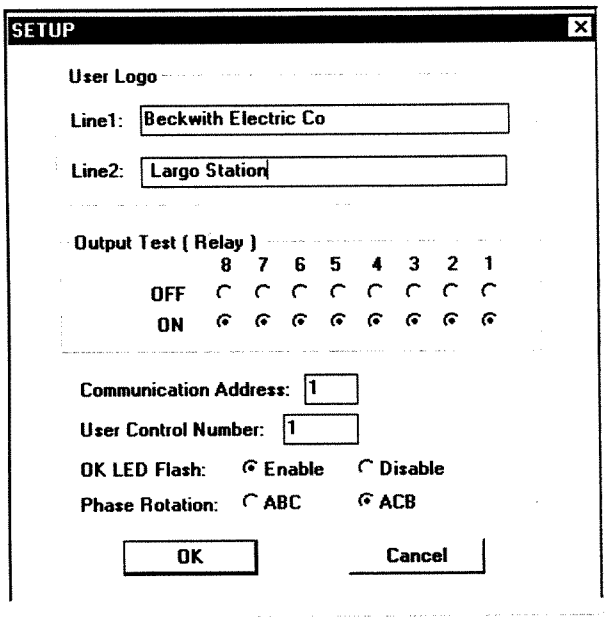


Figure 4-24 Setup Dialog Box

COMMAND BUTTONS

OK Sends the currently displayed information to the relay.

Cancel Returns you to the IPSutil main window. Any changes to the displayed information is lost.

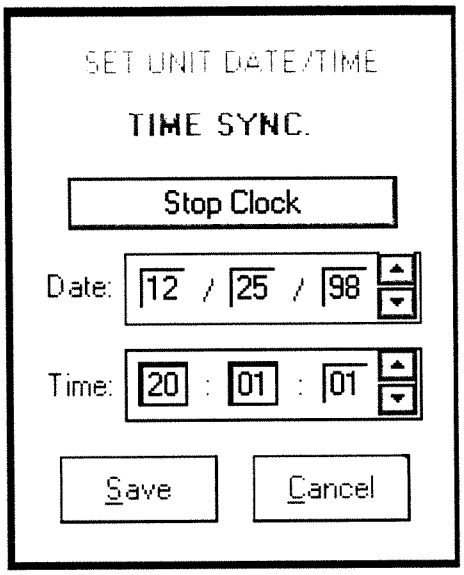


Figure 4-25 Unit Date/Time Dialog Box

COMMAND BUTTONS

Stop Clock This toggles between start/stop the clock of the relay. The 'Stop' stops the clock in the relay. The 'Start' resumes the clock in the relay.

Save When connected to the protection system, the date and time information on the display is sent to the relay.

Cancel Returns you to the IPSutil main window. Any changes to the displayed information is lost.

There is a blue Time Sync LED mimic on this dialog box (the LED is displayed as different shading on a monochrome monitor). When this LED is blue, the relay is synchronized with the IRIG-B signal and the Time field is grayed out, indicating that this field can't be changed. But the Date field can be changed (by editing and pressing **Save**).

When the LED is *not* blue, the relay is not time-synchronized and therefore, both the Date and Time fields can be changed.

The time field in the dialog box is not updated continuously. The time at which the dialog box was opened is the time that is displayed and remains as such. This is true whether the relay is synchronized with the IRIG-B signal or not. IPSutil is fully Y2K compliant.

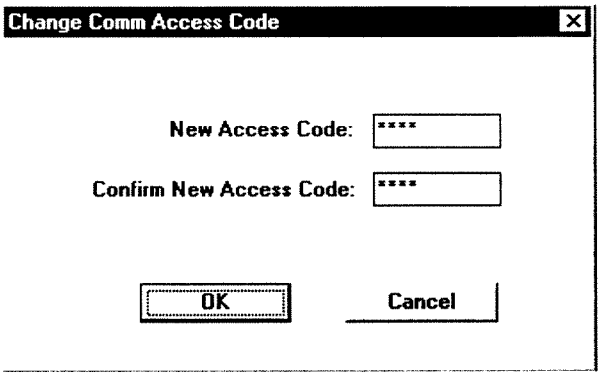


Figure 4-26 Change Communication Access Code Dialog Box

COMMAND BUTTONS

OK Sends the currently displayed information to the relay.

Cancel Returns you to the IPSutil™ main window. Any changes to the displayed information is lost.

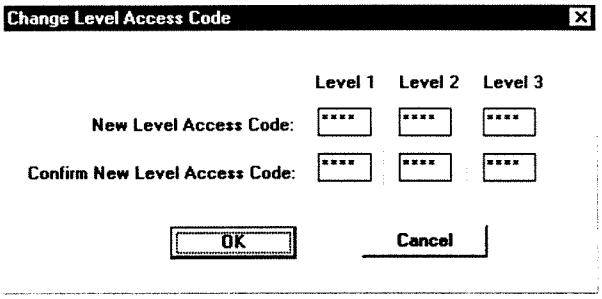


Figure 4-27 Change Level Access Code Dialog Box

COMMAND BUTTONS

OK Sends the currently displayed information to the relay.

Cancel Returns you to the IPSutil main window. Any changes to the displayed information is lost.

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5 Installation

5.1 General Information

■ **NOTE:** Prior to installation of the equipment, it is essential to review the contents of this manual to locate important data that may be of importance during installation procedures. The following is a quick review of the contents in the chapters of this manual.

It is suggested that terminal connections illustrated herein be transferred to station one-line wiring and three-line connection diagrams, station panel drawings and station DC wiring schematics.

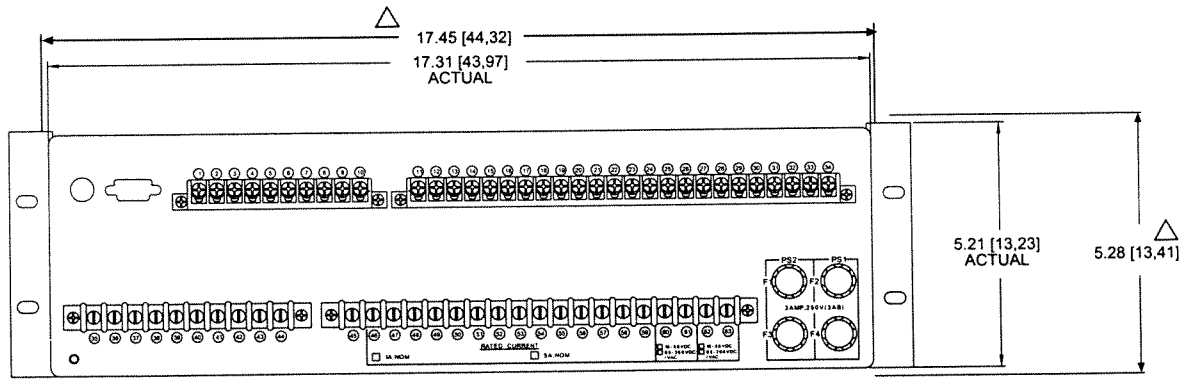
If during the commissioning of the relay, additional tests are desired, refer to Chapter 6, **Testing**.

The operation of the M-3520 Intertie Protection Relay, including the initial setup procedure, is described in Chapter 3, **Operation (Front Panel)**. If the relay is not provided with an HMI module, refer to Chapter 4, **Operation (Computer).**

Section 3.1, Front Panel Controls, describes the front panel controls, and Section 3.2, Initial Setup Procedure/Settings describe the HMI setup procedure. The procedures contain specific instructions for entering the communications data, unit setup data, configure relay data, individual setpoints and time settings for each function, and oscillograph recorder setup information. A similar setup can be performed using IPScom® and IPSutil™ software packages.

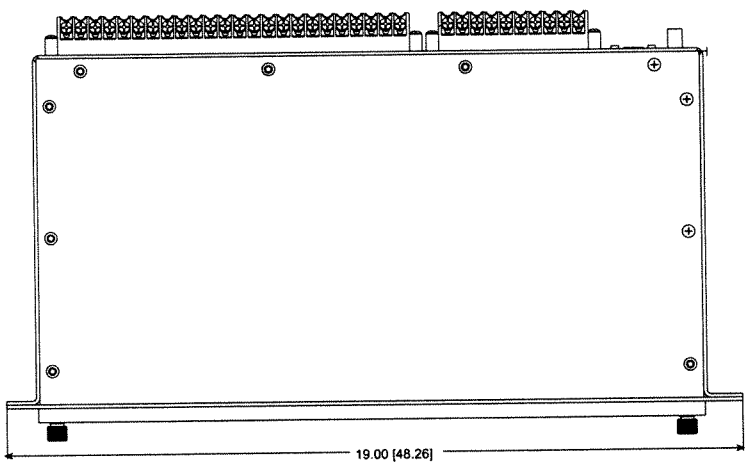
5.2 Mechanical/Physical Dimensions

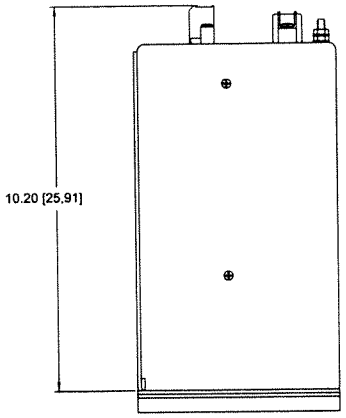
Figures 5-1 through 5-4 contain physical dimensions that may be required for mounting the unit to a rack.

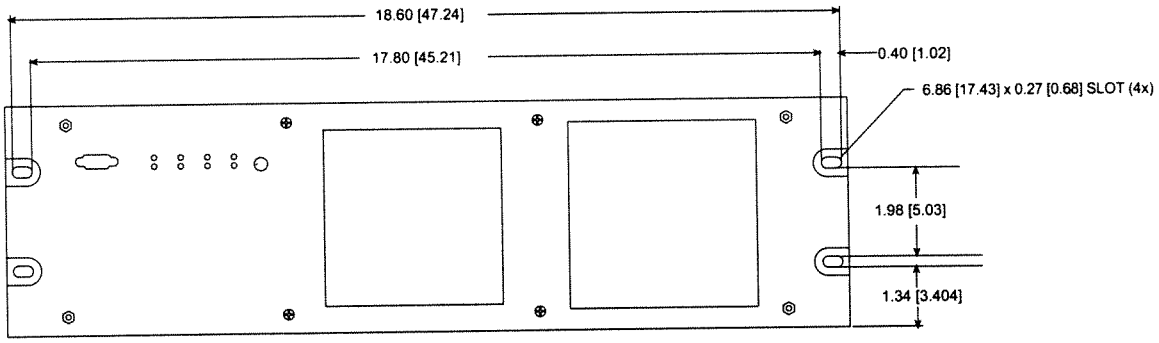


REAR VIEW

△ RECOMMENDED CUTOUT WHEN RELAY IS NOT USED AS STANDARD RACK MOUNT



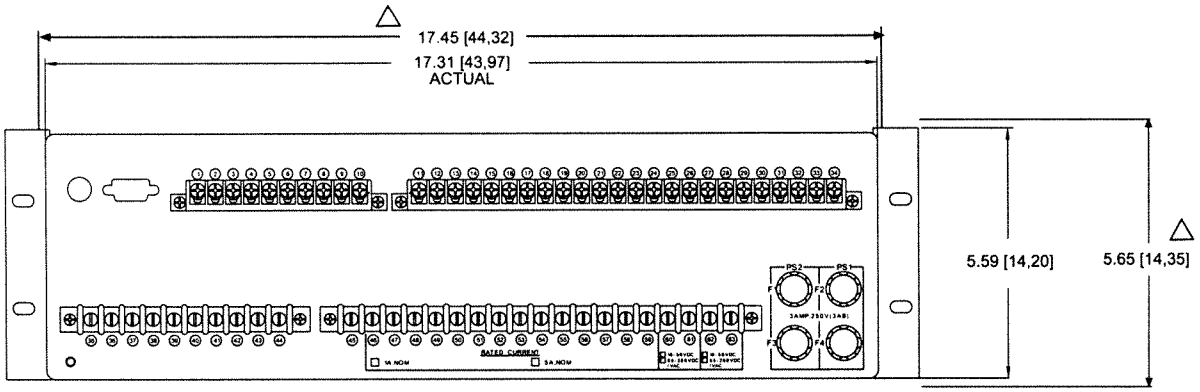




Horizontal Mount Chassis

■ **NOTE**: Dimensions in parentheses are in centimeters.

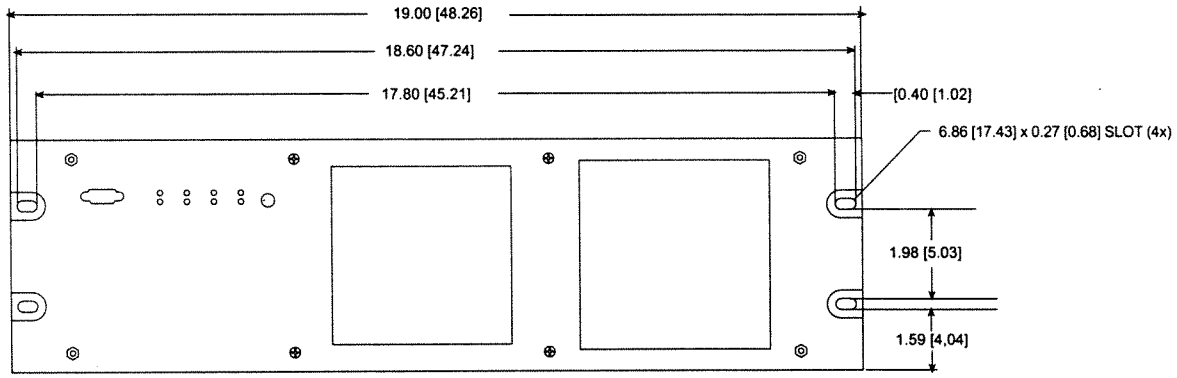
Figure 5-1 M-3520 Mounting Dimensions – Horitzonal Chassis



REAR VIEW

△ RECOMMENDED CUTOUT WHEN RELAY IS NOT USED AS STANDARD RACK MOUNT

■ **NOTE:** Dimensions in parentheses are in centimeters.



Vertical Mount Chassis

Figure 5-2 M-3520 Mounting Dimensions – Vertical Chassis

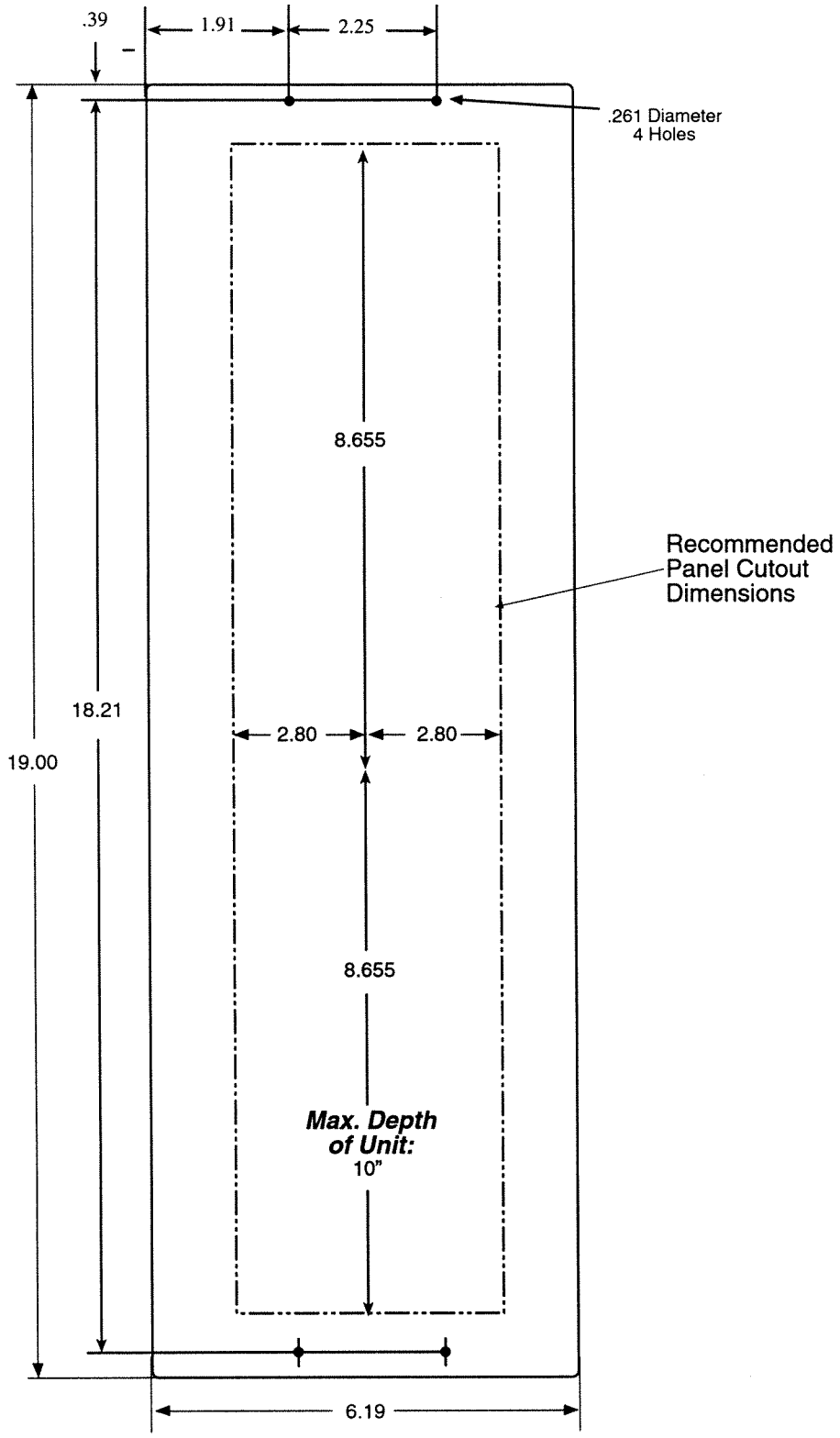


Figure 5-3 (H2) Mounting Dimensions

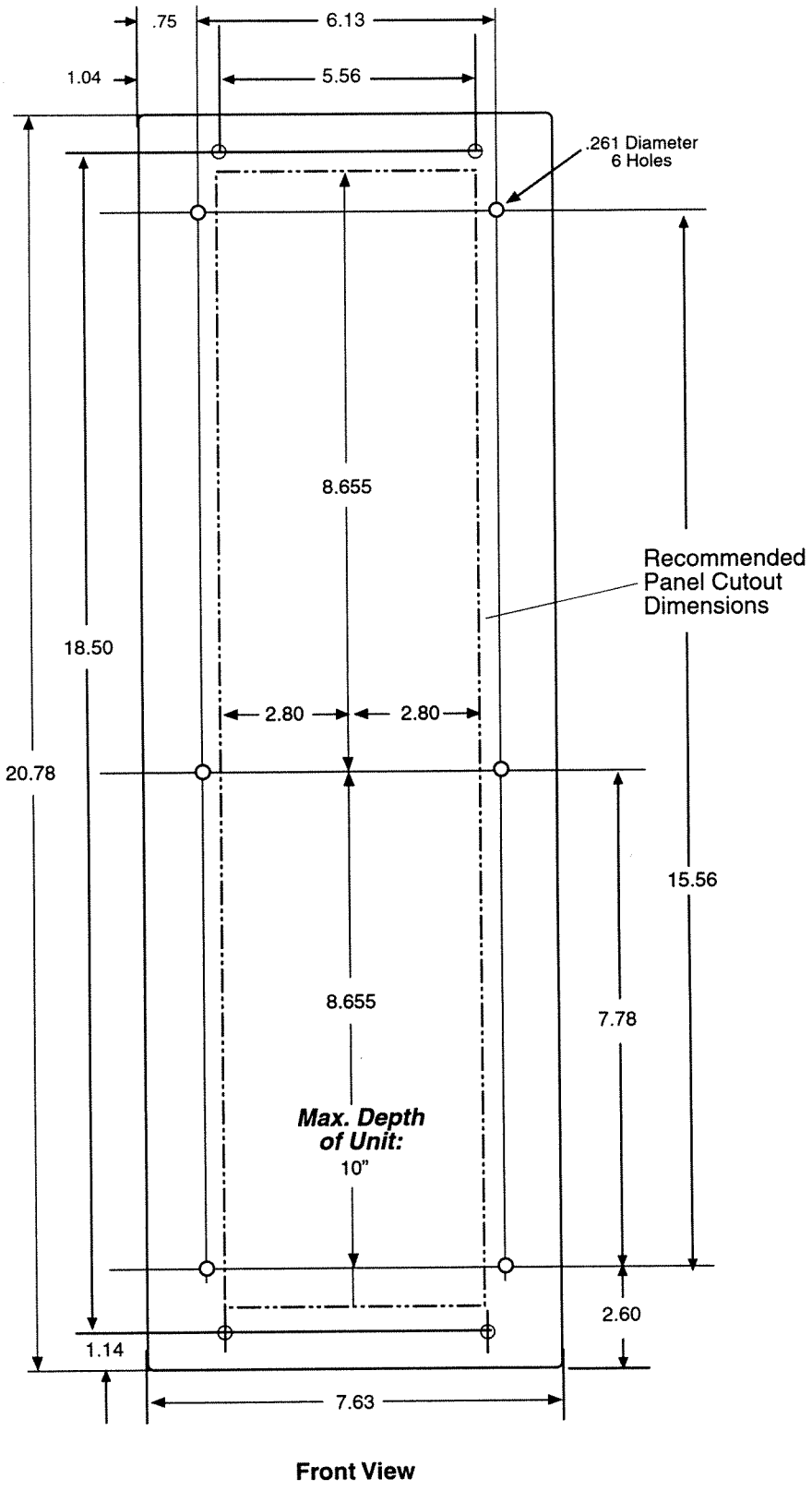


Figure 5-4 (H3) Mounting Dimensions for GE L-2 Cabinet

5.3 External Connections

Figure 5-5 provides an explicit view of all the external contacts, communications points, and power fuses of the M-3520 Intertie Protection Relay.

■ **NOTES**: Output contacts #1 through #4 are high-speed operation contacts. To fulfill UL and CSA requirements, terminal block connections must be made with No. 12 AWG solid or stranded copper wire inserted in an AMP #324915 or equivalent. The screws attaching the connector must be tightened to 8-inch pounds torque. Only dry contacts may be connected to **INPUTS** (terminals 5 through 10, with 11 common), because these contact inputs are internally wetted.

▲ **CAUTION:** Application of external voltages to the INPUT terminals may result in damage to the unit.

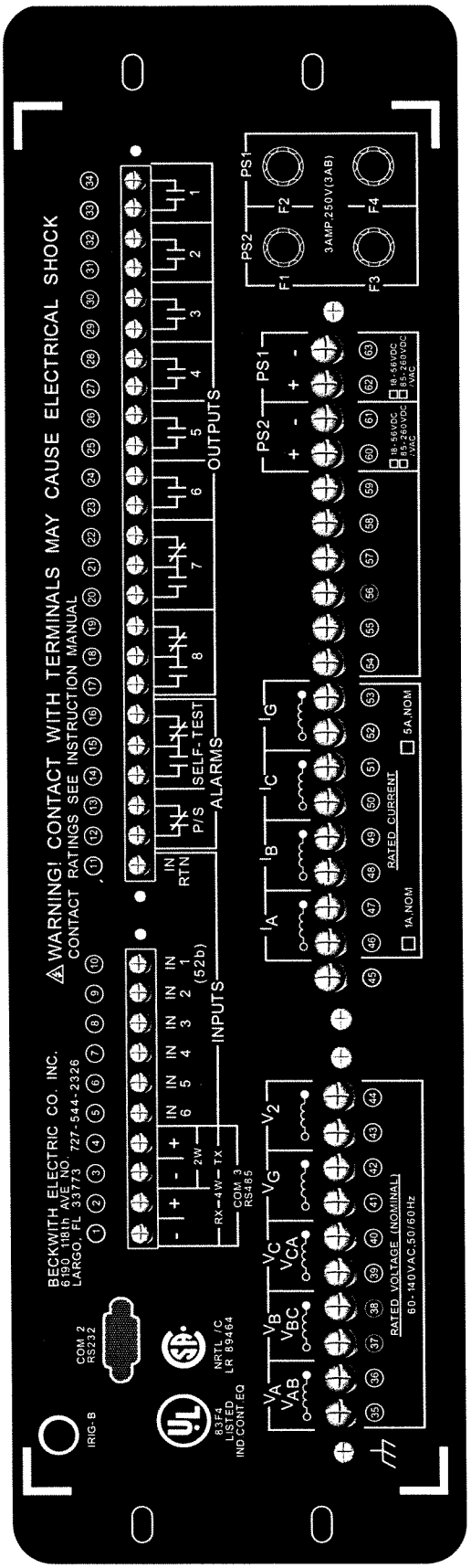


Figure 5-5 External Connections

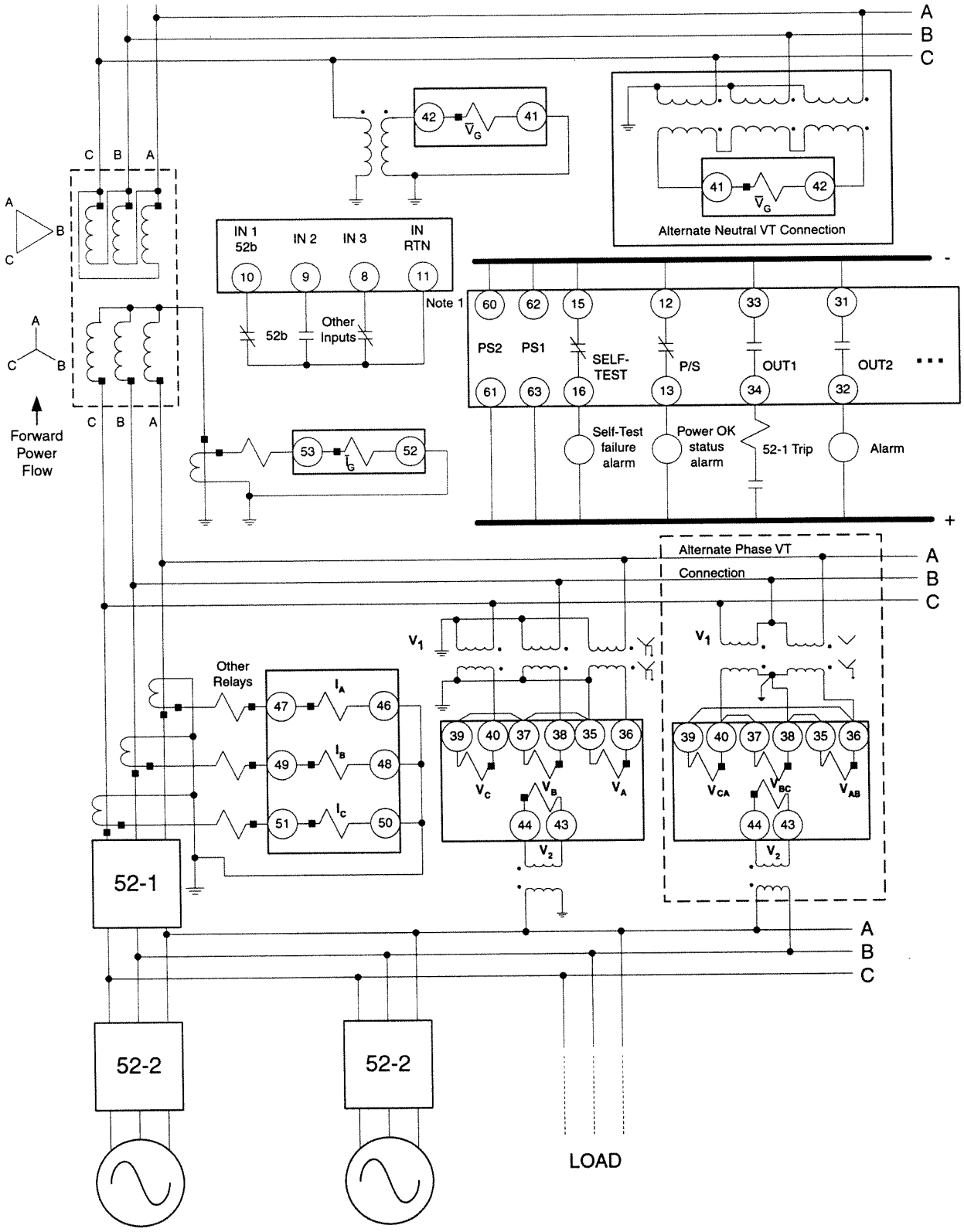


Figure 5-6 Three-Line Connection Diagram

5.4 Commissioning Checkout

During field commissioning, perform the following procedure to ensure that the CT and VT connections are correct.

1. On the keypad, press **ENTER**. After a short delay, the unit should display:

```
VOLTAGE RELAY
VOLT curr freq pwr →
```

2. Press the right arrow button until the unit displays:

```
STATUS
← config sys STAT →
```

3. Press **ENTER**. The unit should display:

```
VOLTAGE STATUS
VOLT curr freq powr →
```

4. Press **ENTER** to display the phase voltages. The unit should display either V_A V_B, V_C, for line-to-ground connections or V_{AB}, V_{BC}, V_{CA}, for line-to-line connections). Use a voltmeter to compare these actual measurements. If there is a discrepancy, check for loose connections to the rear terminal block of the unit.

```
PHASE VOLTAGE
AB=____ BC=___ CA=_____
```

5. Press **ENTER** to display the peak phase voltage.

```
PEAK PHASE VOLTAGE (PU)
AB=___ BC=____ CA=_____
```

6. Press **ENTER** to display the neutral voltage. Neutral voltage should be V_N=0 Volts

```
NEUTRAL VOLTAGE
_______ Volts
```

7. Press **ENTER** to display V2 phase voltage.

```
PHASE VOLTAGE (V2)
_______ Volts
```

8. Press **ENTER** to display positive sequence voltage. The positive sequence voltage should be $V_{POS} \approx V_A \approx V_B \approx B_C \approx$ or $V_{AB} \approx V_{BC} \approx V_{CA}$.

```
POS SEQUENCE VOLTAGE
_________ Volts
```

9. Press **ENTER** to display negative sequence voltage. The negative sequence voltage should be $V_{NEG} \approx 0$.

```
NEG SEQUENCE VOLTAGE
_________ Volts
```

10. Press ENTER to display zero sequence voltage. The zero sequence voltage should be $V_{ZERO} \approx 0$.

```
ZERO SEQUENCE VOLTAGE
_________ Volts
```

■ **NOTE:** If negative sequence voltage shows a high value and positive sequence voltage is close to zero, the phase sequence may be incorrect. Proper phasing must be achieved to obtain proper readings. If phase sequence is incorrect, frequency related functions will not operate properly and the **FREQUENCY STATUS** menu will read **DISABLED**.

If positive, negative and zero sequence voltages are all present, check the polarities of VT connections and correct the connections to obtain proper polarities.

11. Press **EXIT**. The unit will display:

```
VOLTAGE STATUS
VOLT curr freq powr →
```

12. Press the right arrow once, so that the unit displays:

```
CURRENT STATUS
volt CURR freq powr →
```

13. Press **ENTER** to display line currents (I_A, I_B, I_C). Compare these currents with the measured values using a meter. If there is a discrepancy, check the CT connections to the rear terminal block of the unit. The unit should display:

```
PHASE CURRENT
A=____ B=____  C=_____
```

14. Press **ENTER** for the unit to display neutral current. The neutral current should be near zero amperes.

```
NEUTRAL CURRENT
_______ Amps
```

15. Press **ENTER** for the unit to display positive sequence current. The positive sequence current should be $I_{POS} \approx I_A \approx I_B \approx I_C$.

```
POS SEQUENCE CURRENT
_______ Amps
```

16. Press **ENTER** for the unit to display negative sequence currents. Negative sequence current should be near zero amperes.

```
NEG SEQUENCE CURRENT
_______ Amps
```

17. Press **ENTER** for the unit to display the zero sequence currents. The zero sequence should be $I_{ZERO} \approx 0.00$. If there is a significant amount of negative or zero sequence (greater than 25% of I_A, I_B, or I_C) then either the phase sequence or the polarities are incorrect. Modify connections to obtain proper phase sequence and polarity.

```
ZERO SEQUENCE CURRENT
_______ Amps
```

18. Press **EXIT** for the unit to display :

```
CURRENT STATUS
volt CURR freq powr →
```

19. Press right arrow button once so that unit displays:

```
FREQUENCY STATUS
volt curr FREQ powr →
```

20. Press **ENTER** to display the nominal system frequency:

```
FREQUENCY BUS 1
60.00 Hz
```

21. Press **ENTER** for the unit to display the rate of change frequency:

```
RATE OF CHANGE FREQUENCY
_____ Hz/Sec
```

22. Press **EXIT** for the unit to display

```
FREQUENCY STATUS
volt curr FREQ powr →
```

23. Press right arrow button once so that unit displays:

```
POWER STATUS
volt curr freq POWR →
```

24. Press **ENTER** to display real power and verify the correct polarity. The polarity should be positive for forward power and negative for reverse power. If the readings do not agree with actual conditions, check the polarities of the three low end CT's and /or the PT's and the CT and PT ratios.

```
REAL POWER
_____ PU    _____ W
```

25. Repeat steps for the remaining metering quantities.

```
REACTIVE POWER
_______ PU _______ VAr
```

```
APPARENT POWER
_______ PU _______ VA
```

```
POWER FACTOR
_______ Lag/Lead
```

5.5 Circuit Board Switches and Jumpers

DIP JUMPER	POSITION	DESCRIPTION
J60	AB	Connects CD signal to COM 2 pin 1 *
	BC	Connects +15V to COM 2 pin 1
J61	Inserted	Connects -15V to COM 2 pin 9
	Removed	Disconnects COM 2 pin 9 *
J58	AB	Receiver continuously enabled
	BC	Receiver disabled while transmitting*
J46	AB	COM 3 shares Baud rate with COM 1
	BC	COM 3 shares Baud rate with COM2*
J5	AB	Demodulated IRIG-B signal TTL Pin 6
	BC	Modulated IRIG-B signal BNC *

* Default setting

Table 5-1 Jumper Settings

SWITCH POSITIONS				DESCRIPTION
1	2	3	4	**Switches should not be changed while power is applied to unit.**
U	X	X	X	Up for dual Pwr Supply, down for single.
	X			Not functional on M-3520
X	X	U	U	Run Mode
X	X	U	D	Factory Use Only
X	X	D	U	Initialize access codes and communication parameters to default values*.
X	X	D	D	Calibrate*, **

*Power down, set switch, then power up. After power up, the RELAY OK LED light remains off and DIAG LED will light when operation has been satisfactorily completed.

** Power down, adjust, connect reference inputs, power up.

Table 5-2 Switch Positions

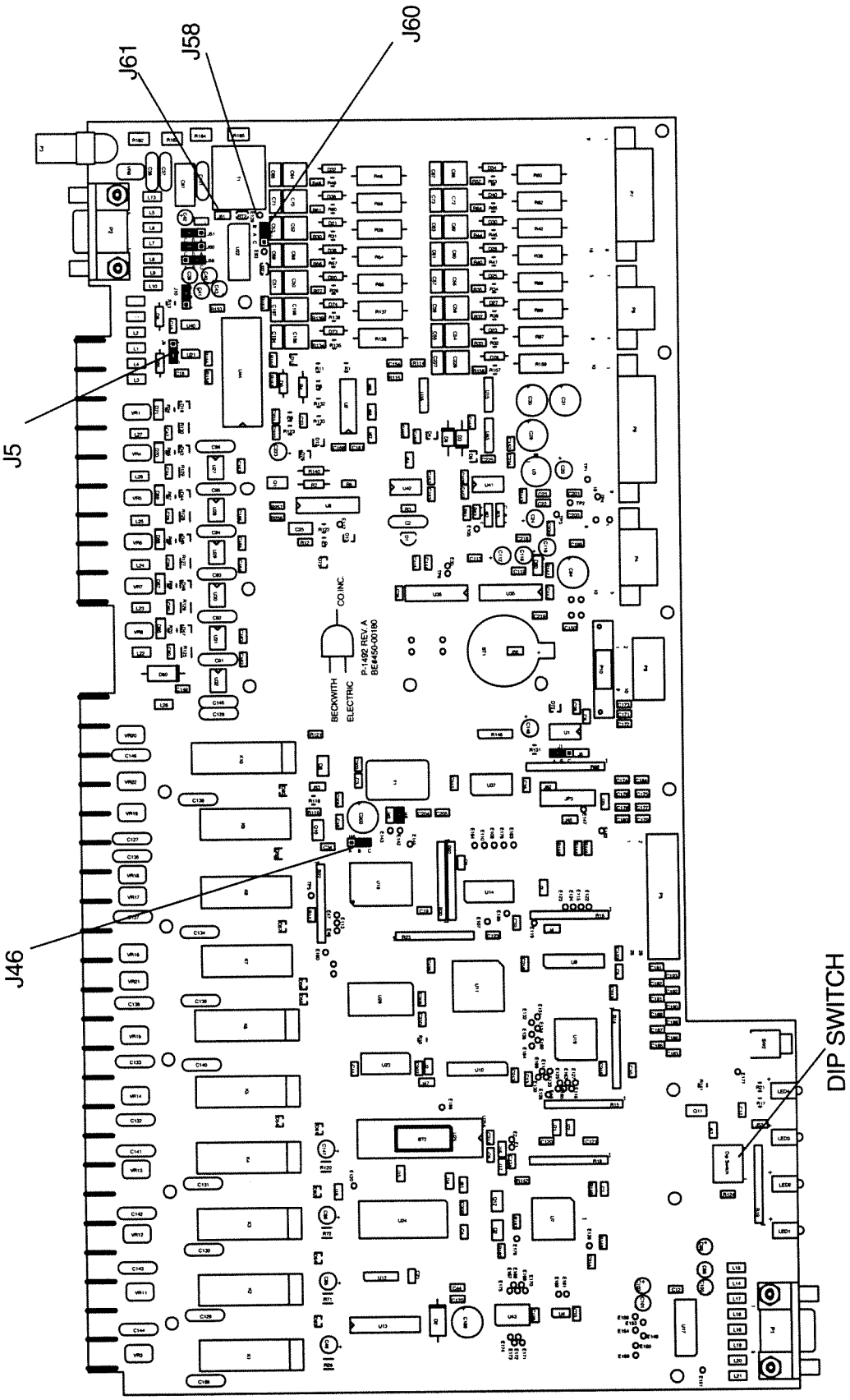


Figure 5-7 M-3520 Circuit Board

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6 Testing

6.1 Equipment and Test Setup

The M-3520 Intertie Protection Relay has been calibrated and fully tested at the factory. If calibration is necessary because of component replacement, follow the Auto-Calibration Procedure described in Section 6.3.

Automatic Calibration

■ **NOTE**: If necessary, refer to Figures 6-2, 6-3, and 5-4 for reference to the **HMI** and **TARGETS** controls and LEDs, and rear connections.

Required Equipment

The following equipment is required to carry out the test procedures:

- Two Digital Multi-meters (DMM) with a 10 Amp current range. These are not required if using a Pulsar Universal Test System.
- One power supply for the relay, capable of supplying 120 Vac or 125 Vdc for units with high voltage power supplies, or 24 Vdc for units with Low Voltage power supplies.
- One 3-phase voltage source capable of 0 to 250 Vac. (Pulsar Universal Test System or equivalent.)
- One 3-phase current source capable of 0 to 25 Amps. (Pulsar Universal Test System or equivalent.)
- Electronic timer with a minimum accuracy of 8 msec. (Pulsar Universal Test System or equivalent.)

■ **NOTE:** A single-phase frequency tester may be used:

48 to 59.99 Hz for 60 Hz units

38 to 49.99 Hz for 50 Hz units

Equipment Setup

▲ **CAUTION:** The proper voltage range for the relay is clearly marked underneath each of the power supply inputs.

1. Connect power to the relay's power input terminals 62 and 63. The M-3520 may be configured with a high voltage power supply with a nominal voltage input of 110/120 /230/240 Vac or 110/125/220/250 Vdc. The relay is also available with a low voltage power supply with nominal voltage input of 24/48 Vdc, and a redundant power supply, which is available as an option
2. Connect the voltage and current inputs for each test procedure according to the configuration included with each test description and follow the outlined steps. It is recommended to disable any functions that may operate while performing tests on a particular function.
3. Table 6-1 identifies the functions to disable.

FUNCTION BEING TESTED	FUNCTION TO DISABLE																		
	21	25	27	27G	32	46	47	50	50G	51V	51G	59	59I	59G	60FL	67	67N	79	81	81R
21	■														✓					
25		■	✓				✓					✓	✓						✓	
27		✓	■												✓					
27G				■										✓						
32			✓		■			✓		✓		✓	✓		✓					
46						■		✓		✓										
47						✓	■													
50								■		✓										
50G									■		✓									
51V								✓		■						✓				
51G											■									
59												■			✓					
59I												✓	■							
59G				✓										■						
60FL			✓		✓										■					
67					✓		✓	✓		✓		✓				■				
67N					✓		✓	✓		✓		✓					■			
79																		■		
81												✓							■	✓
81R												✓							✓	■

Table 6-1 Functions to Disable When Testing

6.2 Diagnostic Test Procedures

The diagnostic procedures perform basic functional tests to verify the operation of the relay's front panel controls, LEDs, input and outputs, and communication ports. These tests are performed in diagnostic mode, which is entered in the following manner:

■ **NOTE:** The Diagnostic Mode is intended for bench testing the relay only. Do not use the diagnostic mode in relays that are installed in an active protection scheme.

For units with the optional HMI panel:

1. Press **ENTER** to begin main menu.
2. Press the right arrow button until **SETUP UNIT** appears in the top line of the display.
3. Press **ENTER** to access the **SETUP UNIT** menu.
4. Press the right arrow button until **DIAGNOSTIC MODE** appears in the display.
5. Press **ENTER**. A reset warning appears:

```
PROCESSOR WILL RESET!
ENTER KEY TO CONTINUE
```

● **WARNING: ALL RELAY FUNCTIONS AND PROTECTION WILL BE INOPERATIVE WHILE THE RELAY IS IN DIAGNOSTIC MODE**

6. Press **ENTER**. Unit will now reset and **DIAGNOSTIC MODE** will be temporarily displayed, followed by **OUTPUT TEST** (RELAY). This is the beginning of the diagnostic menu.

7. When testing in **DIAGNOSTIC MODE** is complete, press **EXIT** until the following message appears:

```
PRESS EXIT TO
EXIT DIAGNOSTIC MODE
```

8. Press **EXIT** again to exit **DIAGNOSTIC MODE**. The relay will reset and normal running mode will resume.

■ **NOTE**: Pressing any button other than **EXIT** will return the user to **DIAGNOSTIC MODE.**

Output Test (Relay)

The first step in testing the operation of the function outputs is to confirm the positions of the outputs in the unoperated or **OFF** position. This can be accomplished by connecting a DMM across the appropriate contacts and confirming open or closed contacts. The de-energized or **OFF** positions for each output is listed in Table 6-2, Output Contacts

RELAY/OUTPUT NUMBER	NORMALLY OPEN CONTACT*		NORMALLY CLOSED CONTACTS*	
1	33	34	N/A	N/A
2	31	32	N/A	N/A
3	29	30	N/A	N/A
4	27	28	N/A	N/A
5	25	26	N/A	N/A
6	23	24	N/A	N/A
7	21	20	21	22
8	18	17	18	19
9 (Self-Test)	15	14	15	16
10 (Power Supply)	13	12	N/A	N/A

**"Normal" position of the contact corresponds to the OFF or de-energized state of the relay*

Table 6-2 Output Contacts

For units with optional HMI panel:

Enter Diagnostic Mode as previously outlined. Following completion of testing, the output contacts, can be turned **ON** in the following manner:

1. Press **ENTER**. The following is displayed:

```
RELAY NUMBER
      1
```

2. Press **ENTER**. The following is displayed:

```
RELAY NUMBER 1
      OFF on
```

3. Use the right button to highlight **ON** in uppercase letters, which signifies selection. The following is displayed:

```
RELAY NUMBER 1
      off ON
```

4. Press **ENTER**. **Output Relay #1** will energize. The following is displayed:

```
RELAY NUMBER
            1
```

5. Choose output numbers 2–8 by using the up and down arrow buttons to turn all relays or outputs to the energized or **ON** position. When each output is turned on, the appropriate **OUTPUT** LED turns on and stays on.

6. Use the DMM to verify the position of the output contacts in the "operate" or **ON** position. The readings should be the opposite of the initial reading above. All outputs should be returned to their initial de-energized or **OFF** positions. The **OUTPUT** LED's will extinguish when each output is turned off.

7. If Output Relay testing is complete, press **EXIT** to return to the **DIAGNOSTIC MODE** menu.

Input Test (Status)

The **INPUT TEST** menu enables the user to determine the status of the individual status inputs.

For units with optional HMI panel:

Each input can be selected by its number using the up and down buttons. The status of the input will then be displayed.

INPUT NUMBER	RETURN TERMINAL	INPUT NUMBER
1 (52b)	11	10
2	11	9
3	11	8
4	11	7
5	11	6
6	11	5

Table 6-3 Input Contacts

1. When **OUTPUT TEST (RELAY)** is displayed press the right arrow to display the following:

```
INPUT TEST
output INPUT led target →
```

2. Press **ENTER**. The following is displayed:

```
INPUT NUMBER
          1
```

3. Press **ENTER**. The following is displayed:

```
INPUT NUMBER 1
CIRCUIT OPEN
```

4. Connect **IN RTN**, terminal #11, to IN1, terminal #10.

5. Alternatively, if the input in step 4 above is being used in this application and external wiring is complete, the actual external status input contact can be manually closed. This will test the input contact operation *and* the external wiring to the input contacts. The following is immediately displayed:

```
INPUT NUMBER 1
CIRCUIT CLOSED
```

6. Disconnect **IN RTN**, terminal #11, from **IN1**, terminal #10. The following is immediately displayed:

```
INPUT NUMBER 1
CIRCUIT OPEN
```

7. Press **ENTER**. The following is displayed:

```
INPUT NUMBER
      1
```

8. Use the up button to go to the next input. Repeat the procedure using the contacts as shown in Table 6-3, Input Contacts.

9. When finished, press **EXIT** to return to the **DIAGNOSTIC MODE** menu.

Status LED Test

The **STATUS LED TEST** menu enables the user to check the front panel LED's Individually.

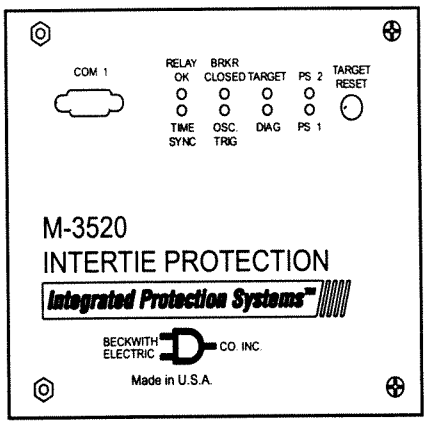


Figure 6-1 Status LED Panel

For units with the optional HMI panel:

1. When **INPUT TESTS (STATUS)** is displayed, press the right arrow button until the following is displayed:

```
STATUS LED TEST
output input LED target →
```

2. Press **ENTER**. LED #1, **RELAY OK**, illuminates and the following is displayed:

```
STATUS LED TEST
LED NUMBER 1 = ON
```

3. Repeat step 2 for each of the 5 remaining LED's shown in Figure 6-1. The PS1 and PS2 LED's are not subject to this test.

4. When **STATUS LED** testing is complete, press **EXIT** to return to **DIAGNOSTIC MODE**.

Target LED Test

■ **NOTE:** This test is not applicable to units that are not equipped with the M-3915 Target Module.

The **TARGET LED TEST** menu allows the user to check the M-3915 Target Module LEDs individually.

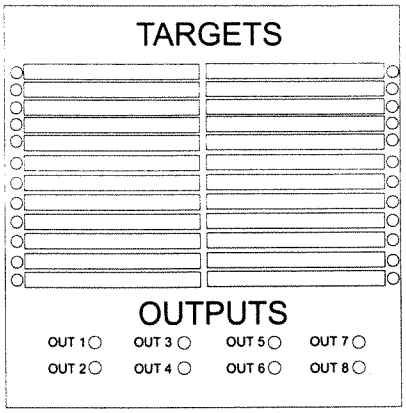


Figure 6-2 M-3915 Target Module

For units with the optional HMI panel:

1. When **STATUS LED TEST** is displayed, press the right button until the following is displayed:

```
TARGET LED TEST
output input LED target →
```

2. Press **ENTER**. Target LED #1 illuminates and the following is displayed:

```
TARGET LED TEST
LED NUMBER 1 = ON
```

3. Repeat step 2 for each of the remaining target and output LED's shown in Figure 6-2.
4. When **TARGET LED** testing is complete, press **EXIT** to return to **DIAGNOSTIC MODE**.

Expanded I/O Test

This function is not implemented at this time.

Button Test

■ **NOTE:** This test is only applicable to units that are equipped with the M-3931 HMI Module.

The **BUTTON TEST** menu selection allows the user to check the M-3931 HMI Module Keypad. As each button is pressed, its name is displayed.

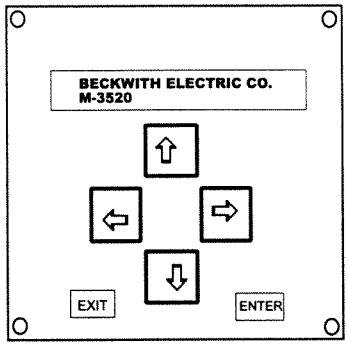


Figure 6-3 M-3931 Human-Machine Interface Module

1. When the **TARGET LED TEST** is displayed, press the right button until the following is displayed:

```
BUTTON TEST
← ex_io BUTTON disp →
```

2. Press and hold **ENTER**. The following is displayed:

```
BUTTON TEST
ENTER
```

3. Release **ENTER**. The following is displayed:

```
BUTTON TEST
      0
```

4. Repeat this test for each of the buttons on the keypad and the **TARGET RESET** button.
5. Press **EXIT** to exit from test.

■ **NOTE:** The **EXIT** button should be tested last. Notice the word **EXIT** is displayed temporarily before the test sequence is terminated.

Display Test

■ **NOTE:** This test is only applicable to units that are equipped with the M-3931 HMI Module.

The **DISPLAY TEST** menu selection enables the user to check the alphanumeric display. This test cycles through varying test patterns until the **EXIT** button is pressed.

1. When **BUTTON TEST** is displayed, press the right arrow button until the following is displayed:

```
SCREEN TEST
← ex_io button DISP →
```

2. Press **ENTER**. The unit will display a sequence of test characters until the **EXIT** button is pressed.
3. After the test has cycled completely through the characters, press **EXIT** to return to the **DIAGNOSTIC MODE** menu.

Communication Tests

■ **NOTE:** These tests are only applicable to units that are equipped with the M-3931 HMI Module.

COM1 and COM2 Test

The **COM1** and **COM2 LOOPBACK TESTS** allow the user to test the front and rear RS-232C ports for proper operation. These tests require the use of a loop-back plug (see Figure 6-4).

The loop-back plug consists of a DB9P connector, with pin 2 connected to pin 3 and pin 7 connected to pin 8.

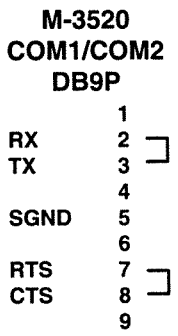


Figure 6-4 COM1/COM2 Loopback Plug

1. When **DISPLAY TEST** is displayed, press the right arrow button until the following is displayed:

```
COM1 LOOPBACK TEST
← COM1 com2 com3 com3 →
```

2. Press **ENTER**. The following is displayed:

```
COM1 LOOPBACK TEST
CONNECT LOOPBACK PLUG
```

3. Connect the loopback plug to **COM1**.
4. Press **ENTER**. The following is displayed:

```
COM1 LOOPBACK TEST
      19200 PASS...
```

5. Press **ENTER** to test each of the baud rates. When all baud rates have been tested, press **ENTER**. The following is displayed:

```
COM1 LOOPBACK TEST
       -DONE-
```

6. Press the right arrow until the following is displayed:

```
COM2 LOOPBACK TEST
← com1 COM2 com3 com3 →
```

7. Repeat steps 2-5 to test **COM2**.

COM3 Test (2-Wire)

The **COM3 ECHO TEST 2WIRE** allows the user to test the RS-485 rear terminal connections for proper operation.

■ **NOTE:** This test requires a PC with an RS-485 converter and terminal emulator software installed.

1. When **COM3 LOOPBACK TEST 4WIRE** is displayed, press the right arrow button until the following is displayed:

```
COM3 ECHO TEST 2WIRE
← com1 com2 com3 COM3 →
```

2. Press **ENTER**. The following is displayed:

```
COM3 ECHO TEST 2WIRE
IDLING....9600, N, 8, 1
```

3. On the rear of the unit, connect a PC to the relay at terminals 3 (-) and 4 (+) via RS-485 converter set for 2 wire operation. See Figure 6-5 for diagram.

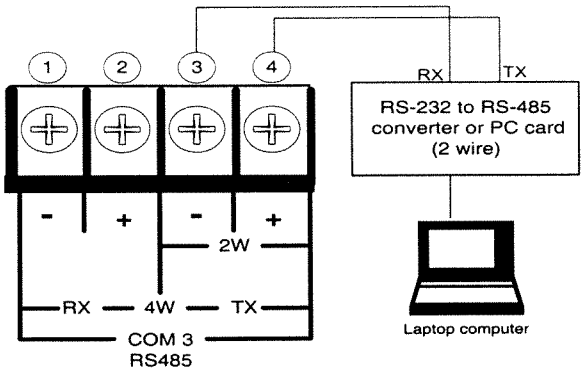


Figure 6-5 RS-485 2-Wire Testing

4. Set the following PC communications parameters:

Baud Rate	9600
Parity	None
Data Bits	8
Stop Bits	1
Duplex	Half

5. Open the terminal emulator program on the PC and open the COM port for the RS-485 converter.
6. Press a key on the PC keyboard. Verify that the character pressed shows temporarily on the display of the relay and appears on the PC monitor.
7. When communications has been verified, press **EXIT**. The following is displayed:

```
COM3 ECHO TEST 2WIRE
      -DONE-
```

8. Close the COM port on the PC and exit the terminal emulator program.

COM3 Test (4-Wire)

■ **NOTE:** This test is only applicable to units that have the RS-485 4-Wire option installed.

The **COM3 LOOPBACK TEST 4WIRE** allows the user to test the RS-485 rear terminal connections for proper operation.

1. When **DISPLAY TEST** is displayed, press the right button until the following is displayed:

```
COM3 LOOPBACK TEST 4WIRE
← com1 com2 COM3 com →
```

2. Press **ENTER**. The following is displayed:

```
COM3 LOOPBACK TEST 4 WIRE
CONNECT LOOPBACK PLUG
```

3. On the rear of the unit, connect a jumper from terminal 1 to terminal 3 and from terminal 2 to terminal 4. See Figure 6-6 for diagram.

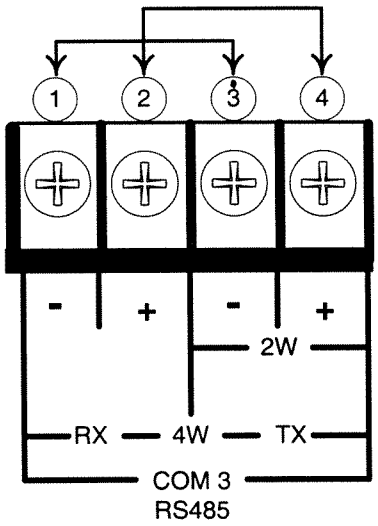


Figure 6-6 RS-485 4-Wire Testing

4. Press **ENTER**. The following is displayed:

```
COM3 LOOPBACK TEST
      19200 PASS...
```

5. Press **ENTER** to test each of the baud rates. When all baud rates have been tested, press **ENTER**. The following is displayed:

```
COM3 LOOPBACK TEST
      -DONE-
```

Clock Test

1. When **COM3 ECHO TEST 4WIRE** is displayed, press the right arrow button until the following is displayed:

```
CLOCK TEST
← CLOCK led cal factory
```

2. Press **ENTER**. A display similar to the following is shown:

```
CLOCK TEST
03-JAN-1998 09:00:00.000
```

3. Press **ENTER** again to toggle the clock. If the clock is running, it will stop. If clock has stopped, it will start. The clock stop case is shown below.

```
CLOCK TEST
      -CLOCK START-
```

4. Press **ENTER** and verify the relay clock is running. A display similar to the following is shown with the seconds counting:

```
CLOCK TEST
03-JAN-1998 09:0035.000
```

5. Press **ENTER** again to stop the clock. The following is displayed:

```
CLOCK TEST
-CLOCK STOP-
```

6. Press **ENTER** and verify the relay clock is stopped. A display similar to the following is shown with the seconds stopped:

```
CLOCK TEST
03-JAN-1998 09:01:80.000
```

■ **NOTE:** When the relay clock is stopped the seconds will be displayed as 80. If the unit is removed from service or is to be without power for long periods of time, the clock should be stopped to preserve battery life.

7. Repeat steps 2 and 3 to restart the clock.

Flash Relay OK LED

The **Flash Relay OK LED** function is provided to enabled or disable the flashing of the **Relay OK LED**. This function only has effect while the relay is in normal operating mode and will not be noticed while in **Diagnostic Mode**.

The operation of this function may be tested by completing the following steps:

1. When **CLOCK TEST** is displayed, press the right arrow button until the following is displayed:

```
FLASH RELAY OK LED
← clock LED cal factory
```

2. Press **ENTER**. The following is displayed:

```
FLASH RELAY OK LED
off     ON
```

■ **NOTE:** Please be advised that programming the **OK** LED to remain on indefinitely is not recommended. It is possible that the LED OK would remain lit even if the relay failed.

Factory Use Only

This function is provided to allow access by factory personnel.

```
FACTORY USE ONLY
← clock led cal FACTORY
```

6.3 Automatic Calibration

The relay has been fully calibrated at the factory. There is no need to recalibrate the unit prior to installation. Recalibration is only necessary if a component was changed.

For units with the optional M-3931 HMI:

● WARNING: ALL RELAY FUNCTIONS AND PROTECTION WILL BE INOPERATIVE WHILE THE RELAY IS IN DIAGNOSTIC MODE

1. Navigate to the **Auto Calibration** function in the **Diagnostic Mode** menu. The following is displayed:

```
AUTO CALIBRATION
← clock led CAL factory
```

2. Press **ENTER**. The following is displayed:

```
CONNECT REFERENCE INPUTS
PRESS ENTER TO CALIBRATE
```

3. Connect all voltage inputs in parallel (V_A= V_B=V_C= V_2) and apply 120.00 (±0.01) VAC ∠0°. See Figure 6-7.
4. Connect all current inputs in series (I_A=I_B=I_C=I_N) and apply 5.00 (±0.01) Amps ∠0°. See Figure 6-8. For 1 Amp CT models, use 1.0 (±0.01) Amps ∠0°.
5. Press **ENTER** to start calibration. This process takes less than 5 seconds. The unit will display the following while the automatic calibration is in progress:

```
AUTO CALIBRATION
      -WAIT-
```

6. When the unit has completed calibration, the following will be displayed:

```
AUTO CALIBRATION
      -DONE-
```

7. The calibration can be checked by using the **Monitor Status** menu, see Section 3.3, **Check-out Status/Metering**.

For units without the optional M-3931 HMI:

It is possible to auto-calibrate Intertie Protection Relays that are not equipped with the optional M-3931 HMI. The procedure is similar to HMI equipped units:

1. Power down unit.
2. Refer to Figure 6-8 and place unit in calibrate mode by configuring the proper dip switches.
3. Connect all voltage inputs in parallel.
4. Connect all current inputs in series.
5. Power up unit.
6. **DIAG** LED will light when operation is complete.
7. Power down unit and return dip switches to normal position.

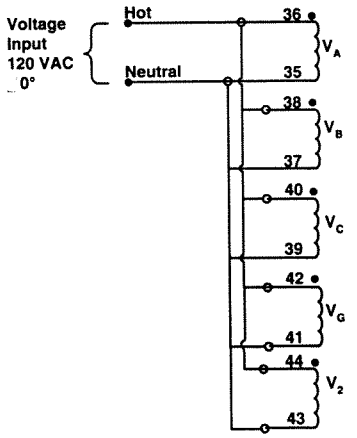


Figure 6-7 Voltage Calibration Configuration

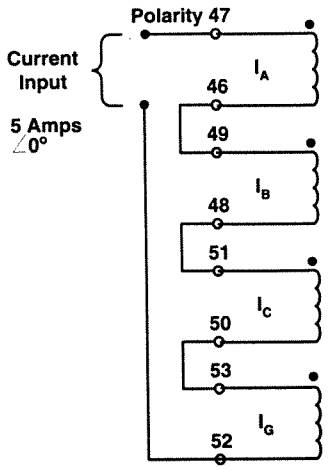


Figure 6-8 Current Calibration Configuration

6.4 Input Configurations

The phase angles shown here represent leading angles as positive and lagging angles as negative. Some manufacturers of test equipment use lagging angles as positive, in which case V_B=120 VAC∠120° and V_C=120 VAC ∠240°. Other voltage and current phase angles should be adjusted in the same manner.

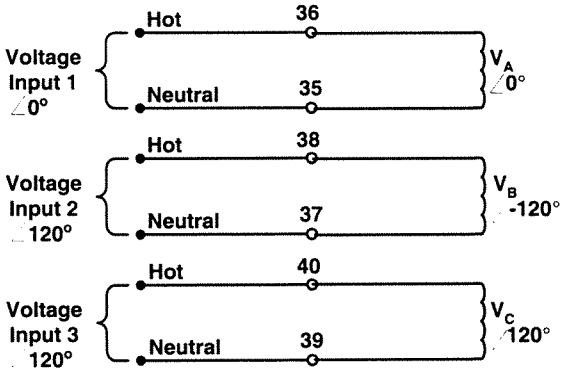


Figure 6-9 Voltage Inputs, Configuration V1

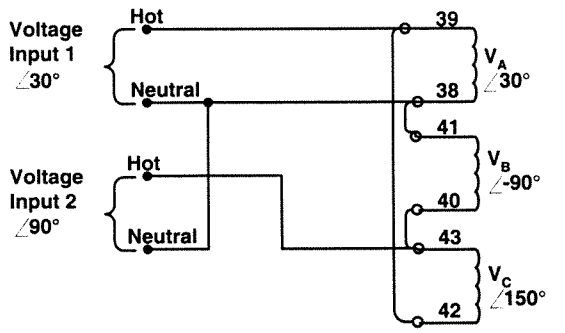


Figure 6-10 Voltage Inputs, Configuration V2

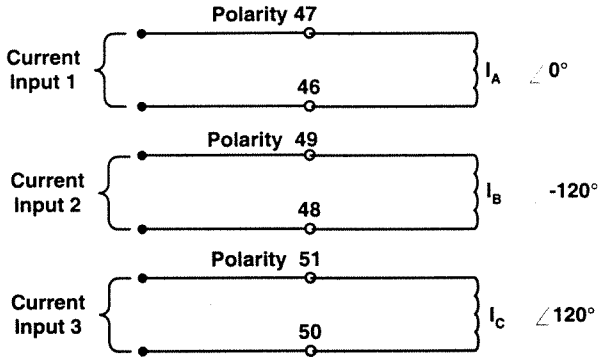


Figure 6-11 Current Inputs, Configuration C1

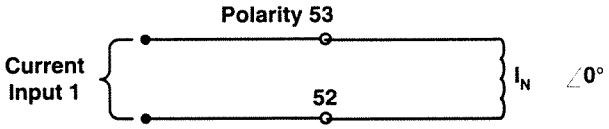


Figure 6-12 Current Inputs, Configuration C2

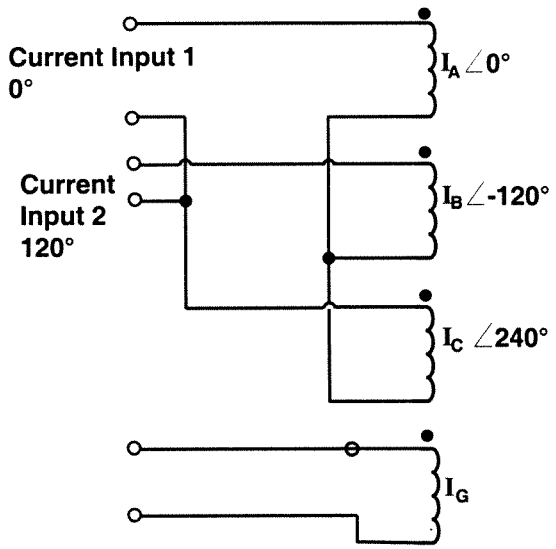


Figure 6-13 Current Inputs, Configuration C3

6.5 Functional Test Procedures

This section details the test quantities, inputs and procedures for testing each function of the M-3520 Intertie Protection Relay. The purpose is to confirm the function's designated output operation, the accuracy of the magnitude pickup settings, and the accuracy of time delay settings. Whereas the first test described, **"Power On Self Test,"** does not require electrical quantity inputs, all other functional tests require inputs, and the necessary connection configurations as specified in the test procedure.

In all test descriptions, a process for calculating input quantities to test the actual settings of the function will be given if needed. In many test cases, it will be necessary to disable other functions not being tested at the time. This action is to prevent the operation of multiple functions with one set of input quantities that could cause confusion of operation of outputs or timers. The complete description of the method to disable or enable functions may be found in detail in Section 3.2, Configure Relay Data, or Chapter 4, **Operation (Computer)**. The complete description of the method to install setting quantities is found in detail in Section 3.2, Setpoints and Time Settings.

It is desirable to *record and confirm* the actual settings of the individual functions of the relay before beginning test procedures. Use the **FUNCTIONAL CONFIGURATION RECORD FORM** and the **SETPOINT AND TIMING RECORD FORM** found in Appendix A for recording settings.

The tests are described in this section in ascending function number order as in Chapter 2, **Application**. Depending on which functions are to be tested at a given time, an order may be determined with the aid of Table 6-1, Functions to Disable When Testing. This may result in fewer changes in connections and disable and enable operations.

During the lifetime of the relay, testing of individual functions due to changes in application settings will be more likely than an overall testing routine. An index of the individual test procedures is illustrated at the beginning of this chapter.

■ **NOTE:** Care must be taken to reset or re-enable any functions that have been changed from the intended application settings when the test procedures are complete. When a function is re-enabled, both output arrangements and blocking input designations must be reestablished.

It may be desirable to program all test settings in an alternate profile, or to save the relay settings in IPScom® to preserve a particular setup.

Many options for test sequences and methods are possible. As an example, the operation of the output contacts can be tested along with the operation of the LED's in the Diagnostic Test Procedures. The operation of the output contacts may also be confirmed with the LED and function operation during Functional Test Procedures, Section 6.5, if desired.

If timer quantities are to be checked, the timer must be activated by the appropriate output contacts. The contact pin numbers are enumerated in Table 6-2 , Output Contacts.

It is suggested that copies of the following be made for easy referral during test procedures:

- Input Configurations - page 6-11
- Output Test (Relay)- page 6-4
- Relay Configuration Table - page A-2
- Setpoint & Time Record Form - pages A-8, 9

21 Phase Distance (#1 or #2) Line to Line

VOLTAGE INPUTS: Configuration V1

CURRENT INPUTS: Configuration C1

TEST SETTINGS:	**Diameter**	**C**	**ohms**	**(0.1 to 100)**
	1 Amp CT Rating			**(0.5 to 500.0)**
	Offset	**O**	**ohms**	**(–100 to 100)**
	5 Amp CT Rating			**(–500.0 to 500.0)**
	Impedance Angle	**A**	**degrees**	**(0 to 90)**
	Time Delay	**D**	**cycles**	**(1 to 8160)**
	Programmed Outputs	**Z**	**output**	**(1 to 8)**
	Function 60FL, 21 (1 or 2)		**Disable**	
	Delta-Y Transform		**Disable**	

■ **NOTE:** It would be efficient to disable the function with the higher "reach" (Diameter plus Offset) setting first (*lower current*), and test the lower reach setting operation, since the higher reach setting operation can be tested without disabling the lower setting.

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect input in Configuration V1 and C1 as designated above. Refer to Section 6.1, Equipment/Test Setup for configurations.
4. The level of current at which operation is to be expected for an individual setting is as follows:
   a. Define "reach" as **R** ohms = (**C** ohms + **O** ohms) offset, **O**, usually set at zero ohms.
   b. Define "current" as **I** = ((Selected Voltage / $\sqrt{3}$) $\div$ **R** ohms). The voltage level may be selected based on the desired test current level.
5. Pickup Test: Set the three-phase voltages to the Selected Voltage value from step 4. Set the phase angle between the voltage and current inputs at (**A** –30°) degrees from setting above. Hold the **TARGET RESET** button in and slowly increase the three-phase currents until the appropriate **PHASE DISTANCE 21** LED light goes on, or the pickup indicator operates on the computer target screen. The level should be equal to **I** calculated in step 4 with the resulting impedance ±0.1 ohms or 5%. Release the **TARGET RESET** button and decrease the **INPUT CURRENTS**, and **OUTPUT** LEDs will go out. Press **TARGET RESET** button to remove targets.
6. Time Test: With output contacts connected to the timer, apply approximately 110% of the current (**I**) found in step 4, and start timing. The contacts will close after **D** cycles within –1 to +3 cycles or 1%.
7. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this configuration.

21 Phase Distance (#1 or #2) Line to Ground

VOLTAGE INPUTS: Configuration V1

CURRENT INPUTS: Configuration C1

TEST SETTINGS:	**Diameter**	**C**	**ohms**	**(0.1 to 100)**
	1 Amp CT Rating			**(0.5 to 500.0)**
	Offset	**O**	**ohms**	**(–100 to 100)**
	5 Amp CT Rating			**(–500.0 to 500.0)**
	Impedance Angle	**A**	**Degrees**	**(0 to 90)**
	Time Delay	**D**	**cycles**	**(1 to 8160)**
	Programmed Outputs	**Z**	**output**	**(1 to 8)**
	VT Configuration		**Line-Ground**	
	Function 60FL, 21 (1 or 2)		**Disable**	
	Delta-Y Transform		**Disable**	

■ **NOTE:** It would be efficient to disable the function with the higher "reach" (Diameter plus Offset) setting first (lower current), and test the lower reach setting operation, since the higher reach setting operation can be tested without disabling the lower setting.

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect input in Configuration V1 and C1 as designated above. Refer to Section 6.1, Equipment/Test Setup for configurations.
4. The level of current at which operation is to be expected for an individual setting is as follows:
   a. Define "reach" as **R** ohms = (**C** ohms + **O** ohms) offset, **O**, usually set at zero ohms.
   b. Define "current" as **I** = ((Selected Voltage)I**R** ohms). The voltage level may be selected based on the desired test current level
5. Pickup Test: Set the three-phase voltages to the Selected Voltage value from step 4. Set the phase angle between the voltage and current inputs at (**A**) degrees from setting above. Hold the **TARGET RESET** button in and slowly increase the three-phase currents on the input until the appropriate **PHASE DISTANCE 21** LED light goes on, or the pickup indicator operates on the computer target screen. The level should be equal to **I** calculated in step 4 with the resulting impedance ±0.1 ohms or 5%. Release the **TARGET RESET** button and decrease the **INPUT CURRENTS**, and **OUTPUT** LEDs will go out. Press **TARGET RESET** button to remove targets.
6. Time Test: With output contacts connected to the timer, apply approximately 110% of the current (**I**) found in step 4, and start timing. The contacts will close after **D** cycles within –1 to +3 cycles or 1%.
7. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this configuration.

25 Sync Check

VOLTAGE INPUTS: See Below

CURRENT INPUTS: None

TEST SETTINGS:

79 Supervise 25	Disable		
Phase Angle Limit	PA	Degrees	(0 to 90)
Voltage Limits			
Upper Limit	UL	Volts	(100 to 140)
Lower Limit	LL	Volts	(90 to 120)
Sync Check Delay	SD	Cycles	(1 to 8160)
Delta Volt	DV	Volts	(1.0 to 50.0)
Delta Freq	DF	Hz	(0.001 to 0.500)
Dead V1	See Below		
Dead V2	See Below		
Dead V1 & V2	See Below		
Dead Input Enable	DIN	Input	(1 to 6)
Dead Delay	DD	Cycles	(1 to 8160)
Programmed Outputs	Z	Output	(1 to 8)
Function 27 #1, #2	Disable		
Function 47 #1, #2	Disable		
Functions 59, 59I	Disable		
Function 81 #1,2,3,4	Disable		

■ **NOTE**: The 25 function requires only one phase voltage and V2 for testing in the Line-to-Ground configuration. The phase voltage used for reference may be selected through the **System Setup** menu. The following tests will reference the phase voltage as V1, although any phase may be used for testing. Line-to-Line testing will follow the same procedures, with V1 representing the proper Line-to-Line phase input. Each test below can be performed using any of the three phases as a reference.

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedures.
2. Confirm settings to be tested.
3. Phase Angle Limit Test: Apply Nominal Voltage to V1 and V2, and establish a phase angle difference of more than **PA** +5°. Hold the **TARGET RESET** button in and slowly decrease the phase angle difference until Output **Z** LED operates or the pickup indicator operates on the computer target screen. The angle difference should be equal to **PA** ±1°. Release the **TARGET RESET** button and increase the angle difference, and the **OUTPUT** LED will go out.
4. Upper Voltage Limit Test: Apply voltage 5V higher than **UL** to both V1 and V2. Hold the **TARGET RESET** button in and slowly decrease the voltage on V1 until Output **Z** LED operates, or the pickup indicator operates on the computer target screen. The voltage should be equal to **UL** ±0.5V or ±0.5%. Release the **TARGET RESET** button and increase the voltage and the **OUTPUT** LED will go out. If desired, repeat the test using V2.
5. Lower Voltage Limit Test: Apply voltage 5V lower than **LL** to both V1 and V2. Hold the **TARGET RESET** button in and slowly increase the voltage on V1 until Output **Z** LED operates, or the pickup indicator operates on the computer target screen. The voltage level should be equal to **LL** ±0.5V or ±0.5%. Relase the **TARGET RESET** button and decrease the voltage, and the **OUTPUT** LED will go out. If desired, repeat the test using V2.

6. Sync Check Time Delay Test: Apply Nominal Voltage to V1 and V2, and establish a phase angle difference of more than **PA** +5°. With the output contacts connected to a timer, remove the phase angle difference and start timing. The contacts will close after **SD** cycles within –1 to +3 cycles or ±1%.

7. Delta Voltage Test: Set the Upper and Lower Voltage limits to their maximum and minimum values, respectively. Set V2 to 140 V and V1 to 80 V. Hold the **TARGET RESET** button in and slowly increase the voltage on V1 until Output **Z** LED operates, or the pickup indicator operates on the computer target screen. The voltage difference should be equal to ±0.5 V. Release the **TARGET RESET** button, and decrease the voltage, and the **OUTPUT** LED will go out. If desired, repeat the test using V2 with V1 at 140 volts.

8. Delta Frequency Test: Set V1 and V2 to Nominal Voltage, and set the frequency of V1 to 0.05 lower than Nominal Frequency–**DF**. Hold the **TARGET RESET** button in, and slowly increase the frequency of V1 until Output **Z** LED operates, or the pickup indicator operates on the computer target screen. The frequency difference level should be equal to **DF** ±0.0007 Hz or 5%. Release the **TARGET RESET** button and decrease the frequency, and the **OUTPUT** LED will go out. If desired, repeat the test using V2 with V1 at Nominal Frequency.

9. Dead Volt Limit Test:

   Dead V1 Test: Enable Dead V1 and disable Dead V2 (if enabled). Set V2 to Nominal Voltage, and V1 to **DVL** +5 V. Hold the **TARGET RESET** button in, and slowly decrease the voltage on V1 until Output **Z** LED operates, or the pickup indicator operates on the computer target screen. The voltage level should be equal to **DVL** ±0.5 V or ±5%. Release the **TARGET RESET** button and increase the voltage level and the **OUTPUT** LED will go out.

   Set V1 to Nominal Voltage, and decrease V2 below **DVL** and verify that the function does not operate.

   Dead V2 Test: Enable Dead V2 and disable Dead V1 (if enabled). Set V1 to Nominal Voltage, and V2 to **DVL** +5 V. Hold the **TARGET RESET** button in, and slowly decrease the voltage on V2 until Output **Z** LED operates, or the pickup indicator operates on the computer target screen. The voltage level should be equal to **DVL** ±0.5 V or ±5%. Release the **TARGET RESET** button and increase the voltage level and the **OUTPUT** LED will go out.

   Set V2 to Nominal Voltage, and decrease V1 below **DVL**, and verify that the function does not operate.

   Dead V1 and V2 Test: Enable Dead (V1 & V2) . Disable Dead (V1) and Dead (V2), if enabled. Set V1 and V2 to **DVL** +5 V. Hold the **TARGET RESET** button in, and slowly decrease the voltage on V1 and V2 until Output **Z** LED operates, or the pickup indicator operates on the computer target screen. The voltage level should be equal to **DVL** ±0.5 V or ±5%. Release the **TARGET RESET** button and increase the voltage level and the **OUTPUT** LED will go out.

   Set V1 to Nominal Voltage, decrease V2 below **DVL**, and verify that the function does not operate.

   Set V2 to Nominal Voltage, decrease V1 below **DVL**, and verify that the function does not operate.

10. Dead Input Enable Test: Select one of the Dead Inputs (**DIN**) and activate it. Repeat step 9, verify that the function operates as in step 9. Deactivate the **DIN** and repeat step 9 once more. Verify that the function does not operate. Disable Dead Input feature when this step is complete.

11. Dead Timer Test: Enable Dead V1 & V2. Disable Dead V1 and Dead V2 (if enabled). Set V1 and V2 to **DVL** +5 V. With output contacts connected to a timer, remove V1 and V2 and start timing. The contacts will close within –1 to +3 cycles or ±1%.

7. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

27 Undervoltage, 3 Phase (#1 or #2)

VOLTAGE INPUTS:	**Configuration V1**			
CURRENT INPUTS:	**None**			
TEST SETTINGS:	**Pickup**	**P**	**Volts**	**(5 to 180)**
	Time Delay	**D**	**Cycles**	**(1 to 8160)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 60FL		**Disable**	
	Function 27#1 or #2		**Disable**	
	Function 25		**Disable**	

■ **NOTE**: If 27#1 and 27#2 have different pickup settings, it would be efficient to disable the one with the higher setting first and test the lower setting operation, since the higher setting operation could then be tested without disabling the lower.

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedures.
2. Confirm settings to be tested.
3. Connect voltage input in Configuration V1 designated previously. Refer to Section 6.1, Equipment/Test Setup, for configuration. Set at Nominal Voltage.
4. Pickup Test: Hold the **TARGET RESET** button in and slowly decrease the input voltage on phase A until the **UNDERVOLTAGE 27** LED illuminates, or the pickup indicator operates on the computer target screen. The level should be equal to **P** volts ±0.5V or ±5%. Release the **TARGET RESET** button and increase the input to the nominal voltage and the **OUTPUT** LED will extinguish. Press **TARGET RESET** button to remove targets.
5. Time Test: With output contacts connected to the timer, apply (**P**-1) Volts and begin timing. The contacts will close after **D** cycles within –1 or +3 cycles or ±1%.
6. Test phases B and C by repeating steps 4 and 5.
7. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

27G Undervoltage, Neutral

VOLTAGE INPUTS: See Below

CURRENT INPUTS: None

TEST SETTINGS:	**Pickup**	**P**	**volts**	**(5 to 180)**
	Time Delay	**D**	**cycles**	**(1 to 8160)**
	Programmed Outputs	**Z**	**OUT**	**(1 to 8)**
	Function 59G	**Disable**		

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedures.
2. Confirm settings to be tested.
3. Connect voltage input to V_G, terminals 41 & 42. Set at 105% of Pickup **P**.
4. Pickup Test: Hold the **TARGET RESET** button in and slowly decrease the neutral voltage until **Neutral Undervoltage 27G** LED illuminates, or the pickup indicator operates on the computer target screen. The level should be equal to **P** volts ±0.5V or ±5%. Release the **TARGET RESET** button and increase the input to the nominal voltage and the **OUTPUT** LED will extinguish. Press **TARGET RESET** button to remove targets.
5. Time Test: With output contacts connected to the timer, apply (**P**-1) Volts and begin timing. The contacts will close after **D** cycles within −1 or +3 cycles or ±1%.
6. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

32 Reverse/Forward Power, #1, #2 (Line to Ground)

VOLTAGE INPUTS: Configuration V1

CURRENT INPUTS: Configuration C1

TEST SETTINGS:	**Pickup**	**P**	**PU**	**(-3.000 to +3.000)**
	Time Delay	**D**	**Cycles**	**(1 to 8160)**
	Three-Phase Detect		**See Below**	
	Programmed Outputs	**Z**	**OUT**	**(1 to 8)**
	Function 60FL		**Disable**	
	Function 32 #1 or #2		**Disable**	
	VT Configuration		**Line-Ground**	

■ **NOTE**: It would be efficient to disable the function with the lower pickup setting first and test the higher setting operation, since the lower setting operation can be tested without disabling the higher setting.

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect inputs in Configuration V1 and C1 designated above. Refer to Section 6.1, Equipment/Test Setup for configurations.
4. The level of current at which operation is to be expected for an individual power setting is as follows: Multiply the PU pickup value (**P** above) by the **Nominal Current** previously input to the relay. This value is described in Section 2.2, Configuration and is recorded on the COMMUNICATION & UNIT SETUP RECORD FORM. The other value required for this test is on the same page and form and is described as the **Nominal Voltage**.
5. Three-Phase Detect Pickup Test: Enable Three-Phase Detection. Set the three phase voltages to the Nominal Voltage. Hold the **TARGET RESET** button in and slowly increase the three phase current (*for negative or reverse power flow direction, the phase angle of these currents are set at 180 degrees*). Increase the current until the **DIRECTIONAL POWER 32** LED light goes on, or the pickup indicator operates on the computer target screen. The level at which operation occurs will be equal to that calculated in step 4, ± 2% or ±0.002pu.
6. Single-Phase Pickup Test: Disable Three-Phase Detection. Repeat step number 5 using only one voltage and one current of the same phase.
7. Release the **TARGET RESET** button and decrease the current. The **OUTPUT** LEDs will go out. Press **TARGET RESET** button to remove targets.
8. Time Test: With output contacts connected to the timer, apply approximately 110% of the pickup current and start timing. The contacts will close after **D** cycles within +16 cycles, ±1%.
8. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this configuration.

32 Reverse/Forward Power, #1, #2 (Line to Line)

VOLTAGE INPUTS: Configuration V1

CURRENT INPUTS: Configuration C1

TEST SETTINGS:	**Pickup**	**P**	**PU**	**(-3.000 to +3.000)**
	Time Delay	**D**	**Cycles**	**(1 to 8160)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 60FL		**Disable**	
	Function 32 #1 or #2		**Disable**	
	VT Configuration		**Line-Line**	

■ **NOTE**: It would be efficient to disable the function with the lower pickup setting first and test the higher setting operation, since the lower setting operation can be tested without disabling the higher setting.

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect inputs in Configuration V1 and C1 designated above. Refer to Section 6.1, Equipment/Test Setup for configurations.
4. The level of current at which operation for an individual power setting is as follows: Multiply the PU pickup value (**P** above) by the **Nominal Current** previously input to the relay. This value is described in Section 2.2, Configuration and is recorded on the COMMUNICATION & UNIT SETUP RECORD FORM. The other value required for this test is on the same page and form and is described as the **Nominal Voltage**.
5. Pickup Test: Set the three phase voltage to the Nominal Voltage. Hold the **TARGET RESET** button in and slowly increase the three phase current (*for negative or reverse power flow direction, the phase angle of these currents are set at –210 degrees*). Increase the current until the **DIRECTIONAL POWER 32 #_** LED light goes on, or the pickup indicator operates on the computer target screen. The level of operation will be equal to that calculated in step 4, ± 2% or ±0.002pu.
6. Release the **TARGET RESET** button and decrease the current. The **OUTPUT** LEDs will go out. Press **TARGET RESET** button to remove targets.
7. Time Test: With output contacts connected to the timer, apply approximately 110% of the pickup current and start timing. The contacts will close after **D** cycles within +16 cycles, ±1%.
8. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this configuration.

46DT Negative Sequence Overcurrent Definite Time

VOLTAGE INPUTS: None

CURRENT INPUTS: Configuration C1 (MODIFIED)

TEST SETTINGS:	**Pickup**	**P**	**Amps**	**(0.10 to 20.00)**
	1 Amp CT Rating			**(0.02 to 4.00)**
	Time Delay	**D**	**Cycles**	**(1 to 8160)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 46 Inverse Time		**Disable**	
	Function 50		**Disable**	
	Function 51V		**Disable**	

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedures.
2. Confirm settings to be tested.
3. Connect inputs in Configuration C1 (MODIFIED) designated previously. Refer to Section 6.4, Input Configurations for configurations. The modification to C1 is to exchange Current source 2 and 3 connections. Configuration will be Phase B current from source 3 and Phase C current from source 2.

■ **NOTE**: For proper testing use current below 3 times CT rating.

4. Pickup Test: Hold the **TARGET RESET** button in and slowly increase the three-phase current until the **NEG SEQ O/C** LED illuminates or the pickup indicator operates on the computer screen The level of operation will be equal to Pickup Current **P** ±0.1 Amp (±0.02 for 1 Amp units) or ±3%, whichever is higher. Release the **TARGET RESET** button and decrease the three-phase current to a level below the Pickup Current **P** and the **OUTPUT** LED will extinguish. Press the **TARGET RESET** button to remove targets.
5. Time Test: With output contacts connected to the timer, apply three-phase current at least 1.1 times **P** and start timing. The operating time will be **D** cycles within –1 or +3 cycles or ±3%. Reduce applied current to 0 Amps
6. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

46IT Negative Sequence Overcurrent Inverse Time

VOLTAGE INPUTS:	**None**			
CURRENT INPUTS:	**Configuration C1 (MODIFIED)**			
TEST SETTINGS:	**Pickup**	**P**	**Amps**	**(0.5 to 5.00)**
	1 Amp CT Rating			**(0.1 to 1.00)**
	Standard Inverse Time Curves[1]:			
	Curve	**C**		**(1 to 4)**
	Time Dial	**TD**		**(0.5 to 11.0)**
	IEC Inverse Time Curves[1]:			
	IEC Curve	**C**		**(5 to 8)**
	IEC Time Dial	**TD**		**(0.05 to 1.10)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 46 Inverse Time		**Disable**	
	Function 50		**Disable**	
	Function 51V		**Disable**	

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedures.
2. Confirm settings to be tested.
3. Connect inputs in Configuration C1 (MODIFIED) designated previously. Refer to Section 6.4, Input Configurations for configurations. The modification to C1 is to exchange Current source 2 and 3 connections. Configuration will be Phase B current from source 3 and Phase C current from source 2.

■ **NOTE**: For proper testing use current below 3 times CT rating.

4. IEC Curve Testing: Test current level may be chosen as a multiple of any level within the Pickup (**P**) range. Calculate the operating time for the applied current and appropriate Time Dial (**TD**) setting from the table below. Choose 4 or 5 test levels and calculate the operating times for each.

   Standard Curve Testing: The operating time will be read from Appendix D, Negative Sequence Current Inverse Time Curves for the applied current and appropriate Time Dial (**TD**) setting. The curve portions extending to lower than **P** current values are inactive and can be ignored.

5. Time Test: With output contacts connected to the timer, apply currents equal to the multiple of the Inverse Time Pickup (**P**) chosen in Step 4, and start timing. The operating time will be as calculated in step 4, ±3 cycles or ±5%.

IEC Class A Standard Inverse	**IEC Class B** Very Inverse	**IEC Class C** Extremely Inverse	**IEC Class D** Long Time Inverse
$t = TD \times \left[\frac{0.14}{M^{0.02} - 1}\right]$	$t = TD \times \left[\frac{13.5}{M - 1}\right]$	$t = TD \times \left[\frac{80}{M^2 - 1}\right]$	$t = TD \times \left[\frac{120}{M - 1}\right]$
Curve 5	***Curve 6***	***Curve 7***	***Curve 8***

t = time in seconds TD = Time Dial setting M = current in multiples of pickup

6. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

[1]Either a Standard Curve or an IEC Curve must be selected.

47 Negative Sequence Overvoltage

VOLTAGE INPUTS:	**Configuration V1 (Modified)**			
CURRENT INPUTS:	**Configuration C1**			
TEST SETTINGS:	**Pickup**	**P**	**Volts**	**(5 to 180)**
	Time Delay	**D**	**Cycles**	**(1 to 8160)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 59		**Disable**	

■ **NOTE:** Although no current input is required for the testing of the 47 function, it is suggested that Nominal Current be applied to restrain the functions which use both voltage and current inputs for operation. If other functions operate during these tests they will need to also be disabled for the test and re-enabled after the tests are complete.

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. The modification of V1 connection to to exchange voltage source V2 and V3 connections. The resulting configuration will be Phase B voltage, supplied from voltage source 3, and Phase C voltage, supplied from voltage source 2.
4. Pickup Test: Apply 3-phase voltage 5 volts below pickup **(P)**. Hold the **TARGET RESET** button in and slowly increase the voltage applied until the **NEG SEQ OVERVOLTAGE** LED lights or the pickup indicator operates on the computer target screen. The level should be equal to **P** volts ±0.5 volts or ±5%. Release the **TARGET RESET** button and decrease applied voltage, and the **OUTPUT** LED will go out. Press the **TARGET RESET** button again to remove targets.
5. Time Test: Apply voltage 10% less than pickup (**P**) to all three phases. With output contacts connected to a timer, apply **P** + 10% volts and start timing. The contacts will close after **D** cycles, within –1 to +3 cycles or ±3%.
8. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this point.

50 Instantaneous Phase Overcurrent

VOLTAGE INPUTS:	**None**			
CURRENT INPUTS:	**Configuration C1**			
TEST SETTINGS:	**Pickup**	**P**	**Amps**	**(1.0 to 240.0)**
	1 Amp CT Rating			**(0.2 to 48.0)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 51V		**Disable**	

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedures.
2. Confirm settings to be tested.
3. Connect inputs in Configuration C1 designated previously. Refer to Section 6.4, Input Configurations, for configurations.
4. Pickup Test: Hold the **TARGET RESET** button in and slowly increase the Phase A current until the **50 INST PHASE O/C** LED illuminates or the pickup indicator operates on the computer target screen. The level of operation will be **P** Amps ±0.1 A (±0.02 A for 1 Amp units) or ±3%. Release the **TARGET RESET** button and decrease the current and the **OUTPUT** LED's will extinguish. Press **TARGET RESET** button to remove targets. This test may be repeated for each of the other phases.
5. Time Test: With output contact (**Z**) connected to the timer, apply current 5% above pickup (**P**) and start timing. The operating time will be under 4 cycles.
6. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

50G Instantaneous Overcurrent , Neutral

VOLTAGE INPUTS:	**None**			
CURRENT INPUTS:	**Configuration C2**			
TEST SETTINGS:	**Pickup**	**P**	**Amps**	**(0.5 to 240.0)**
	1 Amp CT Rating			**(0.1 to 48.0)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 51G		**Disable**	

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedures.
2. Confirm settings to be tested.
3. Connect inputs in Configuration C2 designated previously. Refer to Section 6.4, Input Configurations, for configurations.
4. Pickup Test: Hold the **TARGET RESET** button in and slowly increase the neutral current until the **50G INST NEUTRL O/C** LED illuminates or the pickup indicator operates on the computer target screen. The level of operation will be **P** Amps ±0.1A (±0.02 A for 1 Amp units) or ±3%. Release the **TARGET RESET** button and decrease the current and the **OUTPUT** LED's will extinguish. Press **TARGET RESET** button to remove targets.
5. Time Test: With output contact (**Z**) connected to the timer, apply current 5% above pickup (**P**) and start timing. The operating time will be under 4 cycles.
6. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

51V Inverse Time Overcurrent , Phase

VOLTAGE INPUTS:	**None**			
CURRENT INPUTS:	**C1**			
TEST SETTINGS:	**Pickup**	**P**	**Amps**	**(0.50 to 12.00)**
	1 Amp CT Rating			**(0.10 to 2.40)**
	Standard Inverse Time Curves: [1]			
	Curve	**C**		**(1 to 4)**
	Time Dial	**TD**		**(0.5 to 11.0)**
	IEC Inverse Time Curves: [1]			
	IEC Curve	**C**		**(5 to 8)**
	IEC Time Dial	**TD**		**(0.05 to 1.10)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 50, 67		**Disable**	

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedures.
2. Confirm settings to be tested.
3. Connect current inputs in Configuration C1 designated previously. Refer to Section 6.4, Input Configurations, for configurations.
4. Refer to Appendix D and Table 6-4. Calculate test times for levels represented on the graphs. It is suggested that 4 or 5 test levels be chosen.
5. Time Test: With output contacts connected to the timer, apply current used in calculations from step 4 and start timing. The operating time will be ±3 cycles or 5% of calculated time. Repeat this step for each test level chosen. The tested points verify the operation of this function.

IEC Class A Standard Inverse	**IEC Class B** Very Inverse	**IEC Class C** Extremely Inverse	**IEC Class D** Long Time Inverse
$t=TD \times \left[\frac{0.14}{M^{0.02}-1}\right]$	$t=TD \times \left[\frac{13.5}{M-1}\right]$	$t=TD \times \left[\frac{80}{M^{2}-1}\right]$	$t=TD \times \left[\frac{120}{M-1}\right]$
Curve 5	***Curve 6***	***Curve 7***	***Curve 8***

t = time in seconds TD = Time Dial setting M = current in multiples of pickup

6. Voltage Control Test: Input voltages at least 5% under the Voltage Control setting V.
   a. With output contacts connected to the timer, apply current equal to the chosen test level calculated in step 4 on phase A, and start timing. The operating time will be as read from the appropriate Inverse Curve Family and **K** (Time Dial) setting. Repeat this step for all test levels chosen. The curve portion extending to lower than 150% of **X** amps are inactive and can be ignored. The tested points verify the operating times of the function.
   b. The input voltage may be increased over the Voltage Control setting by at least 0.5 Volts, and the function will drop out.
7. Voltage Restraint Test: Input Nominal Voltages and test as in step 6 above (same current input values). Repeat step 6 above with reduced input voltage values and current reduced by an equivalent percentage as the voltage reduction.
8. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

[1] Either a Standard Curve or an IEC Curve must be selected.

51G Inverse Time Residual Overcurrent, Neutral

VOLTAGE INPUTS: None

CURRENT INPUTS: C2

TEST SETTINGS:	**Pickup**	**P**	**Amps**	**(0.25 to 12.00)**
	1 Amp CT Rating			**(0.05 to 2.40)**
	Standard Inverse Time Curves: [1]			
	Curve	**C**		**(1 to 4)**
	Time Dial	**TD**		**(0.5 to 11.0)**
	IEC Inverse Time Curves: [1]			
	IEC Curve	**C**		**(5 to 8)**
	IEC Time Dial	**TD**		**(0.05 to 1.10)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 51G		**Disable**	

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedures.
2. Confirm settings to be tested.
3. Connect current inputs in Configuration C2 designated previously. Refer to Section 6.4, Input Configurations, for configurations.
4. Refer to Appendix D and Table 6-6. Calculate test times for levels represented on the graphs. Choose 4 or 5 test levels and calculate test times for each.
5. Time Test: With output contacts connected to the timer, apply current used in calculations from step 4 and start timing. The operating time will be ±3 cycles or 5% of calculated time. Repeat this step for each test level chosen. The tested points verify the operation of this function.

IEC Class A Standard Inverse	**IEC Class B** Very Inverse	**IEC Class C** Extremely Inverse	**IEC Class D** Long Time Inverse
$t=TD \times \left[\frac{0.14}{M^{0.02}-1}\right]$	$t=TD \times \left[\frac{13.5}{M-1}\right]$	$t=TD \times \left[\frac{80}{M^{2}-1}\right]$	$t=TD \times \left[\frac{120}{M-1}\right]$
Curve 5	***Curve 6***	***Curve 7***	***Curve 8***

t = time in seconds TD = Time Dial setting M = current in multiples of pickup

6. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

[1] Either a Standard Curve or an IEC Curve must be selected.

59 Overvoltage, 3-Phase (#1 or #2)

VOLTAGE INPUTS: Configuration V1

CURRENT INPUTS: None

TEST SETTINGS:	**Pickup**	**P**	**Volts**	**(5 to 180)**
	Time Delay	**D**	**Cycles**	**(1 to 8160)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Functions 60FL		**Disable**	
	Function 59 #1 or #2		**Disable**	

■ **NOTE**: If 59 #1 and 59 #2 have different pickup settings, it would be efficient to disable the one with the lower setting first and test the higher setting operation, since the lower setting operation could then be tested without disabling the higher setting.

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect inputs in Configuration V1 designated above. Refer to Section 6.1, Equipment/Test Setup for configuration. Set Voltages to Nominal voltage
4. Pickup Test: Hold the **TARGET RESET** button in and slowly increase the input voltage on phase A until **59 PHASE OVERVOLTAGE** LED light goes on, or the pickup indicator operates on the computer target screen. The level should be equal to **P** volts ± 0.5 V or 5%. Release the **TARGET RESET** button and decrease the input voltages to nominal voltage and the **OUTPUT** LEDs will go out. Press **TARGET RESET** button to remove targets.
5. Time Test: With output contacts being connected to the timer, apply (**P**+1) Volts on phase A and start timing. The contacts will close after **D** cycles within –1 to +3 cycles or ± 1%.
6. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this point.

59I Peak Overvoltage, 3-Phase

VOLTAGE INPUTS:	**V1**			
CURRENT INPUTS:	**None**			
TEST SETTINGS:	**Pickup**	**P**[1]	**PU**	**(1.05 to 1.50)**
	Time Delay	**D**	**Cycles**	**(1 to 8160)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 59		**Disable**	

■ **NOTE:** If function 59 settings are greater than the 59I setting being tested, it is not necessary to disable.

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect inputs in Configuration V1 designated above. Refer to Section 6.1, Equipment/Test Setup for configuration. Set voltages to Nominal Voltage.
4. Pickup Test: Hold the **TARGET RESET** button in, and slowly increase the voltage applied to Phase A until the **59I PEAK OVERVOLTAGE** LED goes on or the pickup indicator operates on the computer target screen. The level should be equal to **P** PU ±0.3 PU. Release the **TARGET RESET** button and decrease the input voltage and the **OUTPUT** LEDs will go out. Press **TARGET RESET** button to remove targets. This test may be performed on each phase, if desired.
5. Time Test: With output contacts being connected to the timer, apply (**P**+5) Volts and start timing. The contacts will close after **D** cycles within –1 to +3 cycles.
6. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this point.

[1] *Accuracy of the function only applies to voltages below 180 Volts.*

59G Neutral Overvoltage

VOLTAGE INPUTS:	**See Below**			
CURRENT INPUTS:	**None**			
TEST SETTINGS:	**Pickup**	**P**	**Volts**	**(5 to 180)**
	Time Delay	**D**	**Cycles**	**(1 to 8160)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 27G	**Disable**		

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect voltage input to terminal numbers 41 and 42.
4. Pickup Test: Hold the **TARGET RESET** button in and slowly increase the input Neutral voltage until **59G NEUTRAL OVERVOLT** LED illuminates or the pickup indicator operates on the computer target screen. The level should be equal to **P** volts ± 0.5 V or 5%. Release the **TARGET RESET** button and decrease the input voltage and the **OUTPUT** LED's will extinguish. Press **TARGET RESET** button to remove targets.
5. Time Test: With output contacts being connected to the timer, apply **P**+1 volts and start timing. The contacts will close after **D** cycles within −1 to +3 cycles or 1%.
6. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

60 FL VT Fuse Loss Detection

VOLTAGE INPUTS:	**Configuration V1**			
CURRENT INPUTS:	**Configuration C1**			
TEST SETTINGS:	**Time Delay**	**D**	**Cycles**	**(1 to 8160)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 27, 32		**Disable**	

■ **NOTE:** It is necessary for "FL" to be designated as an initiating input (see Section 2.3 Setpoints and Time Settings, 60FL Fuse Loss) before this function can be tested.

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect inputs in Configuration V1 and C1 designated above. Refer to Section 6.1, Equipment/Test Setup for configurations.
4. Adjust the three-phase voltage source to nominal volts, and the three-phase current source to nominal current.
5. Time Test: With output contacts connected to the timer, remove the A phase voltage input and start timing. The operating time will be **Y** cycles within –1 to +3 cycles and the **60FL V.T. FUSE LOSS** LED and output **Z** LEDs will light, or the pickup indicator operates on the computer target screen.
6. Reconnect the phase A voltage and press **TARGET RESET** button to remove targets.
7. Repeat steps 5 and 6 for phases B and C.
8. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this configuration.

67DT Phase Directional Overcurrent, Definite Time

VOLTAGE INPUTS: V1

CURRENT INPUTS: C1

TEST SETTINGS:

Pickup	P	Amps	(1.0 to 240.0)
1 Amp			(0.2 to 48.0)
Directional	See Below		
Three Phase Detect	See Below		
Delay	D	Cycles	(1 to 8160)
MSA	MSA	Degrees	(0 to 359)
Programmed Outputs	Z	Output	(1 to 8)
Function 32		Disable	
Function 47 #1, #2		Disable	
Functions 50, 51V, 59		Disable	
Functions 67IT, 67NDT, 67NIT		Disable	

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect inputs in Configuration V1 and C1 designated above. Refer to Section 6.1, Equipment/Test Setup for configurations.
4. Single-Phase Pickup Test: Disable Directional and Three-Phase Detect features, if enabled. Apply Nominal Voltage to all three phases. Apply current 10% less than pickup (**P**) to all three phases. Hold the **TARGET RESET** button in and slowly increase the current applied to phase A until the **DIR PHASE DEF TIME O/C** LED lights, or the pickup indicator operates on the computer target screen. The level should be equal to **P** amps ±0.1 Amps or ± 3%. Release the **TARGET RESET** button and decrease phase A current and the **OUTPUT** LED will go out. Press the **TARGET RESET** button again to remove targets. If desired, repeat this test for both phase B and C currents.
5. Three-Phase Pickup Test: Enable the Three-Phase Detect feature and perform test #4 again to verify that the relay does not operate. Reset targets and apply Nominal Voltage to all three phases. Apply current 10% less than pickup (**P**) to all three phases. Hold the **TARGET RESET** button in and slowly increase the current applied to all phases until the **DIR PHASE DEF TIME O/C** LED lights, or the pickup indicator operates on the computer target screen. The level should be equal to **P** amps ±0.1 Amps or ± 3%. Release the **TARGET RESET** button and decrease the applied current and the **OUTPUT** LED will go out.
6. Directional Test: Reset targets and apply Nominal Voltage to all three phases. Set the current angle to an angle more than 100° from **MSA**. Apply current 10% more than pickup (**P**) to all three phases. Hold the **TARGET RESET** button in and slowly swing the angle of the currents applied toward **MSA** until the **DIR PHASE DEF TIME O/C** LED lights, or the pickup indicator operates on the computer target screen. The angle should be equal to **A** –90° or +90°, depending to which side of **MSA** the current has been set. Release the **TARGET RESET** button and swing the current angle away from **MSA**, and the **OUTPUT** LED will go out.
7. Timer Test: Disable the Directional and Three-Phase Detect features, if enabled. Apply Nominal Voltage to all three phases. Apply current 10% less than pickup (**P**) to all three phases. With output contacts connected to a timer, apply **P**+10% Amps and start timing. The contacts will close after **D** cycles within –1 to +3 cycles or ±3%.
8. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this point.

67IT Directional Overcurrent, Inverse Time

VOLTAGE INPUTS: V1

CURRENT INPUTS: C1

TEST SETTINGS: Pickup	P	Amps	(0.5 to 12.0)
1 Amp			(0.1 to 2.4)
Directional		See Below	
Standard Inverse Time Curves[1]			
Curve	C		(1 to 4)
Time Dial	TD		(0.5 to 1.1)
IEC Inverse Time Curves[1]			
Curve	C		(5 to 8)
IEC Time Dial	TD		(0.05 to 11.0)
MSA	MSA	Degrees	(0 to 359)
Programmed Outputs	Z	Output	(1 to 8)
Function 32	Disable		
Function 47 #1, #2	Disable		
Functions 50, 51V, 59	Disable		
Functions 67NIT	Disable		
Function 67NDT	Disable		

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect voltage input to terminal numbers 44 and 45.
4. Pickup Test: Refer to Appendix D, **Inverse Time Curves** and the table below in order to calculate test times for levels represented on the graphs. It is suggested that 4 or 5 test levels be chosen.
5. Time Test: With output contacts being connected to the timer, apply input current used in calculations from step 4 to all 3 phases and start timing. The operating time will be ±3 cycles or ±5% of the calculated time. Repeat this step for each test level chosen. The points tested verify the operation of this function.

IEC Class A Standard Inverse	**IEC Class B** Very Inverse	**IEC Class C** Extremely Inverse	**IEC Class D** Long Time Inverse
$t=TD \times \left[\frac{0.14}{M^{0.02}-1}\right]$	$t=TD \times \left[\frac{13.5}{M-1}\right]$	$t=TD \times \left[\frac{80}{M^{2}-1}\right]$	$t=TD \times \left[\frac{120}{M-1}\right]$
Curve 5	***Curve 6***	***Curve 7***	***Curve 8***

t = time in seconds TD = Time Dial setting M = current in multiples of pickup

6. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this point.

[1]Either a Standard Curve or an IEC Curve must be selected.

67NDT Neutral Directional Overcurrent, Definite Time

VOLTAGE INPUTS:	**See Below**			
CURRENT INPUTS:	**See Below**			
TEST SETTINGS:	**Pickup**	**P**	**Amps**	**(0.50 to 240.0)**
	1 Amp			**(0.1 to 48.0)**
	Directional	**See Below**		
	Time Delay	**D**	**Cycles**	**(1 to 8160)**
	MSA ✣	**MSA**	**Degrees**	**(0 to 359)**
	Polarization Type ✣			**(1 to 5)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 32	**Disable**		
	Function 47 #1, #2	**Disable**		
	Functions 50, 51V, 59	**Disable**		
	Functions 67IT, 67NIT	**Disable**		

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Enable directional feature and connect inputs as listed in table below, for the polarization type selected for testing.

   ■ **NOTE**: This feature is designed for use with the Line-to-Ground VT configuration.

POLARIZATION TYPE	SETUP
1	Voltage Phases A, B, and C placed in parallel, and current phases A, B, and C placed in series.
2	Neutral voltage; current phases A, B, and C placed in series.
3	Balanced 3-phase voltages with full negative sequence and apply phase A current only.
4	Neutral current; current phases A, B, and C placed in series. This polarization type does not use Maximum Sensitivity Angle (MSA) feature, which is set at zero.
5	Either voltage phases A, B, and C in parallel, or neutral current in the trip region in reference to $3I_{zero}$ will give trip condition (see type 1 or 4).

4. Pickup Test: Apply Nominal Voltage to all three phases. Apply current 10% less than pickup (**P ÷ 3**) to all three phases. Hold the **TARGET RESET** button in and slowly increase the current applied to all phases in the above table, until the **RES DIR DEF TIME O/C** LED lights, or the pickup indicator operates on the computer target screen. The level should be equal to **P ÷ 3 Amps** ±0.1A or ±3%. Release the **TARGET RESET** button and decrease the applied current, and the **OUTPUT** LED will go out.

✣ *These settings are in a separate menu labeled Neutral Dir Setup.*

5. Directional Test: Enable directional feature. Reset targets and apply Nominal Voltage to all three phases. Set the current angle to an angle more than 100° from **MSA**. Apply current 10% more than **P** ÷ 3, (**for type 3, use P**) to all three phases. Hold the **Target Reset** button in and slowly swing the angle of the currents applied towards the **MSA** until the **RES DIR DEF TIME O/C** LED lights, or the pickup indicator operates on the computer target screen. The angle should be equal to A –90° or +90°, depending to which side of **MSA** the current has been set. Release the **TARGET RESET** button and swing the current angle away from the **MSA**, and the **OUTPUT** LED will go out.

   ■ **NOTE**: MSA is not used in type 4.

6. Time Delay Test: Disable the Directional and Three-Phase Detect features, if enabled. Apply Nominal Voltage to all three phases. Apply current 10% less than **P** ÷ 3, (**for type 3, use P**) to all three phases. With output contacts connected to a timer, apply **P**+10% Amps, and start timing. The contacts will close after **D** cycles within –1 to +3 cycles or ± 3%.

7. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this point.

67NIT Neutral Directional Overcurrent, Inverse Time

VOLTAGE INPUTS:	**See Below**			
CURRENT INPUTS:	**See Below**			
TEST SETTINGS:	**Pickup**	**P**	**Amps**	**(0.50 to 240.0)**
	1 Amp			**(0.1 to 48.0)**
	Directional	**See Below**		
	Standard Inverse Time Curves[1]			
	Curve	**C**		**(1 to 4)**
	Time Dial	**TD**		**(0.05 to 11.0)**
	IEC Inverse Time Curves[1]			
	Curve	**C**		**(5 to 8)**
	Time Dial	**TD**		**(0.05 to 1.10)**
	MSA✣	**MSA**	**Output**	**(0 to 359)**
	Polarization Type✣			**(1 to 5)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 32	**Disable**		
	Function 47 #1, #2	**Disable**		
	Functions 50, 51V, 59	**Disable**		
	Functions 67IT, 67NDT	**Disable**		

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Enable directional feature and connect inputs as listed in table below for the polarization type selected for testing:

POLARIZATION TYPE	SETUP
1	Voltage Phases A, B, and C placed in parallel, and current phases A, B, and C placed in series.
2	Neutral voltage; current phases A, B, and C placed in series.
3	Balanced 3-phase voltages with full negative sequence and apply phase A current only.
4	Neutral current; current phases A, B, and C placed in series. This polarization type does not use Maximum Sensitivity Angle (MSA) feature, which is set at zero.
5	Either voltage phases A, B, and C in parallel, or neutral current in the trip region in reference to $3I_{zero}$ will give trip condition (see type 1 or 4).

4. Refer to Appendix D, **Inverse Time Curves**, and IEC table below to calculate test times for levels represented on the graphs. It is suggested that 4 or 5 test levels be chosen.

✣ *These settings are in a separate menu labeled Neutral Dir Setup.*

[1]Either a Standard Curve or an IEC Curve must be selected.

5. Time Delay Test: Apply Nominal Voltage to voltage inputs, if any, as listed in table above. With output contacts connected to a timer, apply input current used in calculations from step 4 to current phases specified in table above, and start timing. The operating time will be ±3 cycles or ±5% of the calculated time. Repeat this step for each test level chosen. The points tested verify the operation of this function.

IEC Class A Standard Inverse	**IEC Class B** Very Inverse	**IEC Class C** Extremely Inverse	**IEC Class D** Long Time Inverse
$t=TD \times \left[\frac{0.14}{M^{0.02}-1}\right]$	$t=TD \times \left[\frac{13.5}{M-1}\right]$	$t=TD \times \left[\frac{80}{M^2-1}\right]$	$t=TD \times \left[\frac{120}{M-1}\right]$
Curve 5	***Curve 6***	***Curve 7***	***Curve 8***

t = time in seconds TD = Time Dial setting M = current in multiples of pickup

6. Directional Test: Enable directional feature. Reset targets and apply Nominal Voltage to all three phases. Set the current angle to an angle more than 100° from **MSA**. Apply current 10% more than **P** ÷ 3, (**for type 3, use P**) to all three phases. Hold the **Target Reset** button in and slowly swing the angle of the currents applied towards the **MSA** until the **RES DIR DEF TIME O/C** LED lights, or the pickup indicator operates on the computer target screen. The angle should be equal to **A** –90° or +90°, depending to which side of **MSA** the current has been set. Release the **TARGET RESET** button and swing the current angle away from the **MSA**, and the **OUTPUT** LED will go out.

   ■ **NOTE**: MSA is not used in type 4.

7. If testing is complete, enable any functions disabled for this test. If other tests are to be completed, check the proper functions to disable for the next test and proceed from this point.

81 Frequency (#1, #2, #3, or #4)

VOLTAGE INPUTS:	**Configuration V1**			
CURRENT INPUTS:	**None**			
TEST SETTINGS:	**Pickup**	**P**	**Hz**	**(50.00 to 67.00)**
	50 Hz Relay			**(40.00 to 57.00)**
	Time Delay	**D**	**Cycles**	**(2 to 65,500)**
	Programmed Outputs	**Z**	**Output**	**(1 to 8)**
	Function 81 (#1, #2)		**Disable**	

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect inputs in Configuration V1 designated previously. Refer to Section 6.4, Input Configurations for configuration.
4. Pickup Test: Set the voltages to the Nominal Frequency. Hold the **TARGET RESET** button in and slowly decrease the frequency on the input voltage(s) until the **81 FREQUENCY** LED illuminates or the pickup indicator operates on the computer target screen. The level of operation will be equal to **P** Hz ±0.02 Hz from 57 to 63 (47 to 53), otherwise the accuracy is ±0.1 Hz. Return to nominal input frequency and the **OUTPUT** LED's will extinguish. Press **TARGET RESET** button to remove targets.
5. Time Test: With output contacts being connected to the timer, apply **P** ±0.5 Hz and start timing. The operating time will be **D** cycles within –2 to +3 cycles or ±1%.
6. Complete the testing for the remaining 81 functions by repeating steps 4 and 5, above.
7. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

81R Rate of Change of Frequency (#1, #2)

VOLTAGE INPUTS: V1

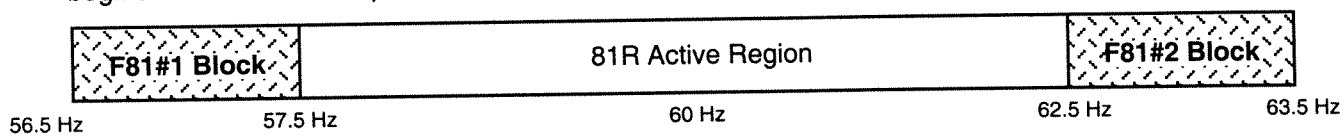
CURRENT INPUTS: None

TEST SETTINGS:

Pickup	P	Hz/s	(0.10 to 20.00)
Delay	D	Cycles	(1 to 8160)
Negative Sequence Voltage Inhibit	N	%	(0 to 99)
Programmed Outputs	Z	Output	(1 to 8)
Function 59		Disable	
Function 81	See Below		

■ **NOTE**: Testing of the 81R function requires a 3-phase voltage source capable of smoothly sweeping the frequency of all voltages at a variable rate, continuously.

1. Disable functions as shown. Refer to Section 3.2, Configure Relay Data, for procedure.
2. Confirm settings to be tested.
3. Connect inputs in Configuration V1 designated previously. Refer to Section 6.4, Input Configurations for configuration.
4. It is recommended that the 81 function be used to establish a window of operation for the 81R function which is smaller than the actual sweep range of the frequncy applied. This is accomplished by enabling 81#1 to pickup at a frequency 1 Hz higher than the minimum frequency of the ramp, and assign a unique output. Set 81#2 to pickup 1 Hz lower than the maximum frequency of the ramp, and assign a unique output (see figure below). The frequencies given are suggested for testing rates below 10 Hz/S. Higher rates will require consideration of the capabilities of the test equipment involved. Conncet both of these outputs to an input with jumpers, and set the 81R function to block on this input. Set the time delays and seal-in times of the 81 functions to minimum. This will result in an operational window that is free of erroneous Hz/S measurements when the voltage source begins or ends the sweep.



Using this setup, it is important to remember that the 81 elements being used will be operating in the 81R blocking regions, and the 81R contact operation must be distinguished from the 81 contacts.

5. Pickup Test: Apply Nominal Voltage to all three phases. Calculate the time for the pickup setting and apply a sweep rate 25% less than the pickup (**P**) to all three phases.

   Hold the **TARGET RESET** button in and slowly decrease the sweep time until the **RATE OF CHANGE FREQ** LED lights, or the pickup indicator operates on the computer target screen. The level should be equal to **P** ± 0.05 Hz/S or ±5 %. Release the **TARGET RESET** button, and increase the sweep time, and the **OUTPUT** LED will go out.

6. Negative Sequence Voltage Inhibit Test: Reset targets and apply Nominal Voltage to all three phases at a sweep rate 25% above **P**. Verify that the **RATE OF CHANGE FREQ** LED lights, or the pickup indicator operates on the computer target screen. Swing the phase angle of a phase voltage and monitor the positive and negative sequence voltage levels. The **81R OUTPUT** should reset when the negative sequence voltage is **N**% ±0.5% of the positive sequence voltage.
7. Timer Test: Reset targets and apply Nominal Voltage to all three phases at a sweep rate 25% below **P**. With output contacts connected to a timer, apply a sweep rate 25% above **P** and start timing. The contacts will close after **D** cycles within –1 to +3 cycles, or ±3 %.
8. If testing is complete, enable any functions disabled for this test. If further testing is desired, check the proper functions to disable for the next test and continue from this point.

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