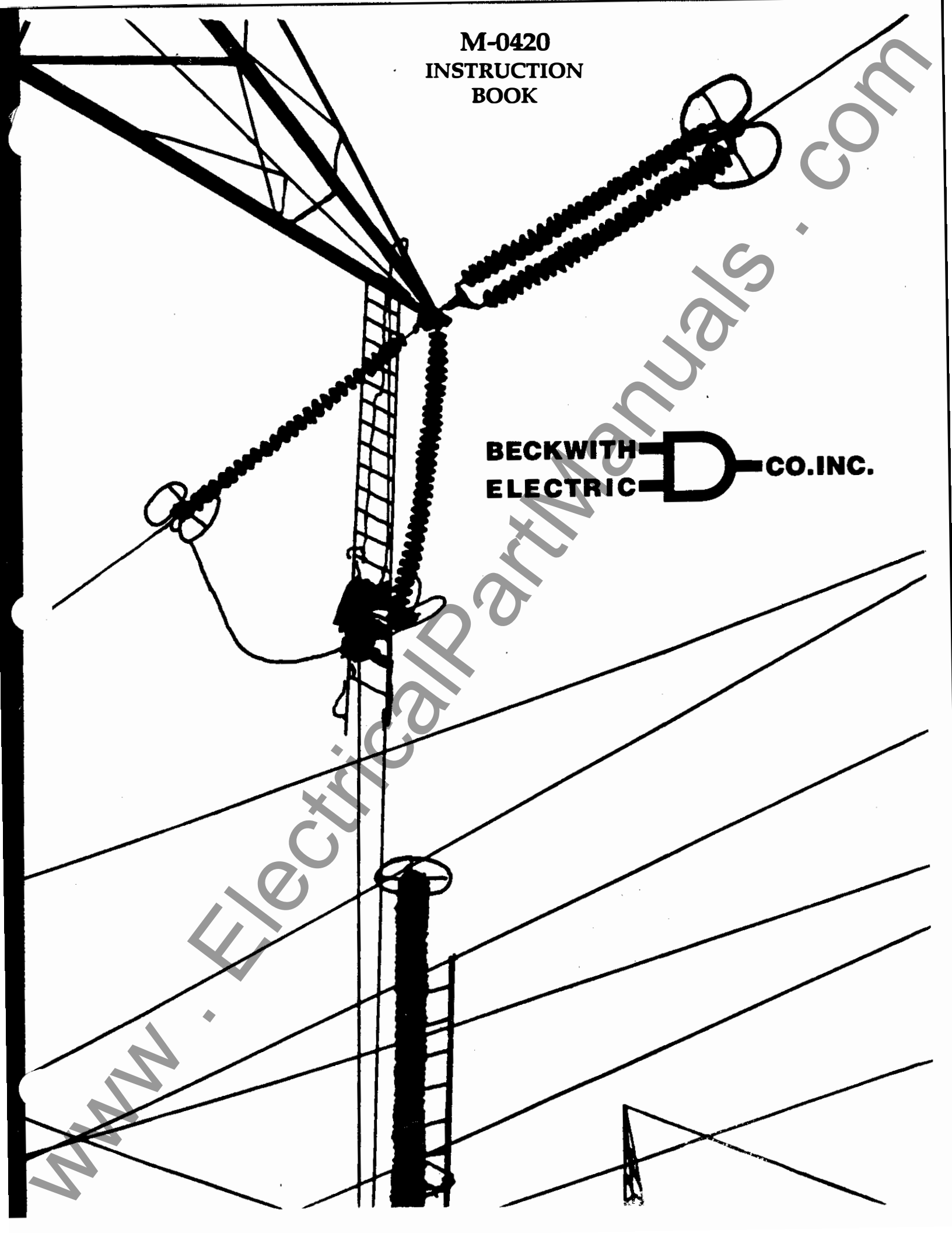


M-0420
INSTRUCTION
BOOK

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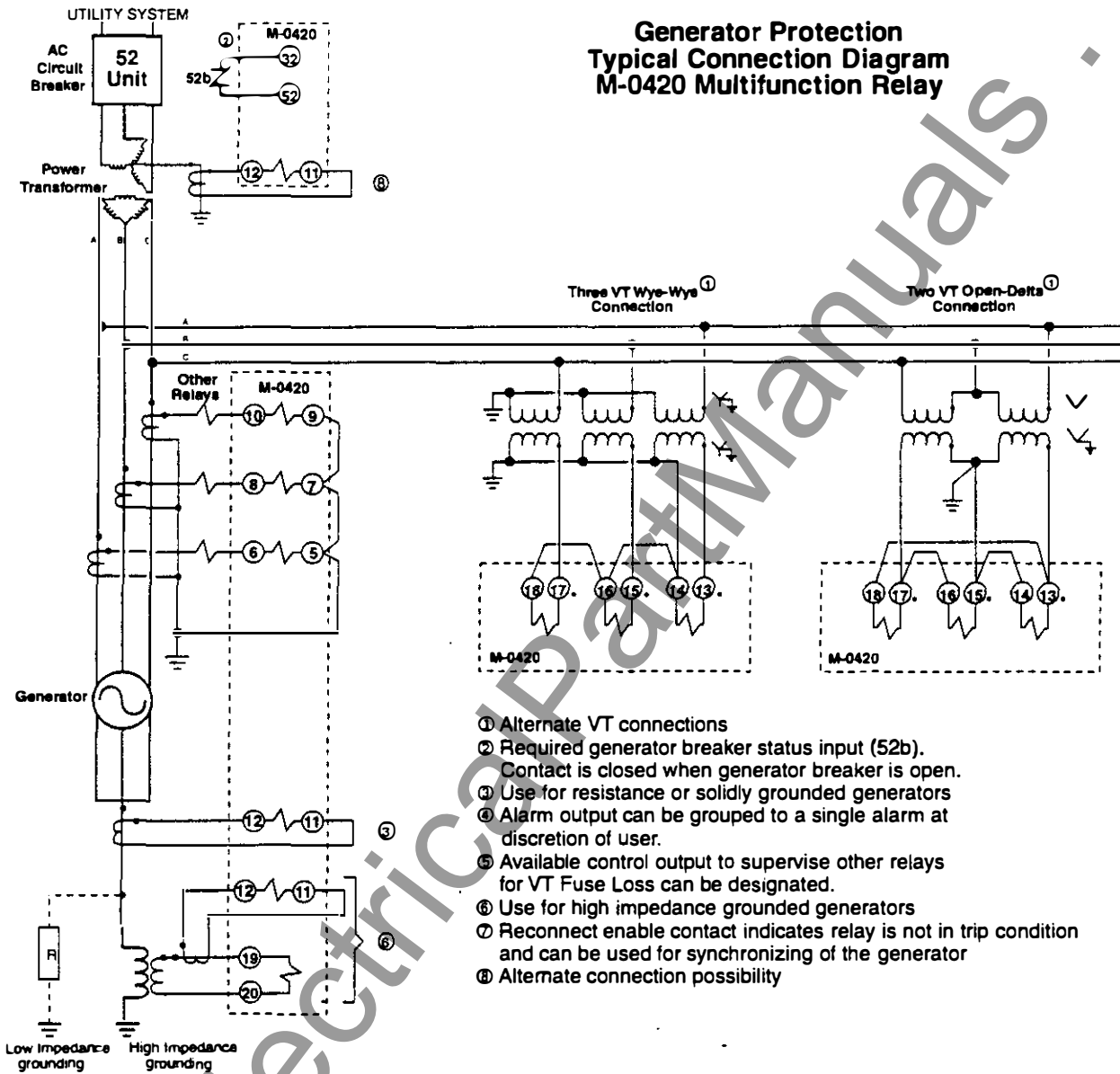


ADDENDA

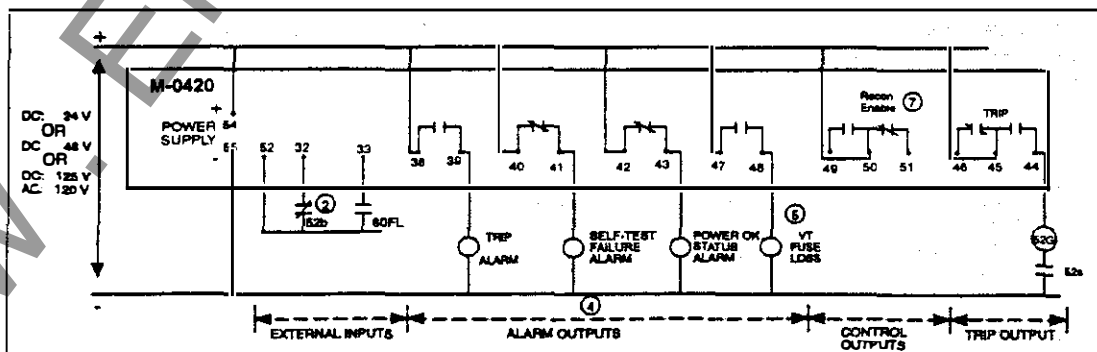
M-0420 INSTRUCTION BOOK

This page contains additional information when referring to Figure 2-2 on page 2-6 and Figure 2-5 on page 2-9.

Generator Protection Typical Connection Diagram M-0420 Multifunction Relay



Example of Control / Output Connections



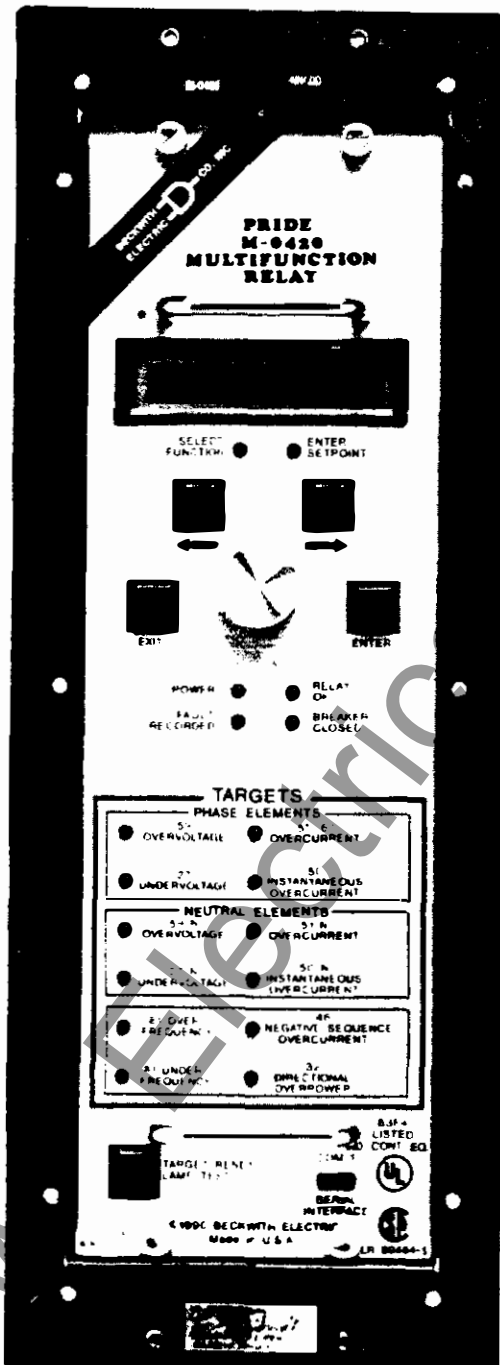
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D-co. INC.

PRIDE[®] Multifunction Relay M-0420

Multifunction Relay for Generator or Intertie Protection



- Protects a generator or its parallel interconnection from voltage, frequency, overcurrent, and directional power disturbances.
- Enables reconnect when protective parameters have been within limits for an adjustable time period.
- Uses waveform sampling and digital signal processing for accurate measurement of system parameters.
- Provides easy-to-use 2-line-by-24-character Liquid Crystal Display for local access to relay functions.
- Provides capability for local and remote metering of phase, neutral, and sequence voltages and currents; real and reactive power; power factor; and frequency.
- Provides time-tagged trip target information for the five most recent trips.
- Includes two RS-232C serial communication ports to connect SCADA interface and external PC running the optional M-0429 BECOCOM[™] Communications Software package.
- Includes capability for capturing 96 cycles of fault data for display with the optional M-0428 BECO PLOT[™] Fault Data Analysis Software package.
- Optional directional overcurrent function.
- Draw-out case construction.
- UL Listed; CSA Certified.

RELAY FUNCTIONS

Device Number	Function	Setpoint Ranges	Increment	Initial Setting†	Accuracy	
59 3Φ	RMS Overvoltage, 3-Phase					
	Magnitude #1, #2	10 – 200 V	1.0 V	132 V	±0.5 V	
	Time Delay #1, #2	1 – 8160 cycles	1.0 cycle	30 cycles	±1 cycle	
59N	RMS Overvoltage, Neutral Circuit or Zero Sequence*					
	Magnitude #1, #2	10 – 200 V	1.0 V	150 V	±0.5 V	
	Time Delay #1, #2	1 – 8160 cycles	1.0 cycle	30 cycles	±1 cycle	
*59N responds to fundamental frequency component only.						
59I 3Φ	Peak Overvoltage*					
	Magnitude #1, #2	1.05 – 1.50 pu	0.01 pu	1.10 pu	±0.03 pu**	
	Time Delay #1, #2	1 – 8160 cycles	1.0 cycle	30 cycles	±1 cycle	
*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.						
27 3Φ	RMS Undervoltage, 3-Phase					
	Magnitude #1, #2	10 – 200 V	1.0 V	108 V	±0.5 V	
	Time Delay #1, #2	1 – 8160 cycles	1.0 cycle	30 cycles	±1 cycle	
27N	RMS Undervoltage, Neutral Circuit or Zero Sequence*					
	Magnitude #1, #2	10 – 200 V	1.0 V	60 V	±0.5 V	
	Time Delay #1, #2	1 – 8160 cycles	1.0 cycle	30 cycles	±1 cycle	
*27N responds to fundamental frequency component only.						
81O	Over Frequency					
	Magnitude #1, #2	60.05 – 63.00 Hz (50.05 – 53.00 Hz)	0.05 Hz	60.50 Hz	±0.02 Hz*	
	Time Delay #1, #2	2 – 8160 cycles	1.0 cycle	30 cycles	±1 cycle	
*The accuracy is based on 3 Φ voltage inputs in the range of 57 to 63 Hz; outside this range, the accuracy is ±0.1 Hz.						
81U	Under Frequency					
	Magnitude #1, #2	53.00 – 59.95 Hz (43.00 – 49.95 Hz)	0.05 Hz	59.50 Hz	±0.02 Hz*	
	Time Delay #1, #2	2 – 8160 cycles	1.0 cycle	30 cycles	±1 cycle	
*The accuracy is based on 3 Φ voltage inputs in the range of 57 to 63 Hz; outside this range, the accuracy is ±0.1 Hz.						
50 3Φ	Instantaneous Overcurrent, 3-Phase					
	Magnitude	1.0 – 240.0 A*	0.1 A	10.0 A	±3%**	
	Trip Time Response	2 cycles max.				
*Not to exceed 20 times the maximum of the range into which the 3-phase overcurrent tapsetting chosen for 51V falls. **±3% or ±3% of the maximum of the tap setting range chosen for 51V, whichever is greater.						
50N	Instantaneous Overcurrent, Neutral					
	Magnitude	1.0 – 240.0 A*	0.1 A	10.0 A	±3%**	
	Trip Time Response	2 cycles max.				
*Not to exceed 20 times the maximum of the range into which the neutral overcurrent tapsetting chosen for 51N falls. **±3% or ±3% of the maximum of the tap setting range chosen for 51V, whichever is greater.						
51V 3Φ	Inverse Time Overcurrent, 3-Phase, with Voltage Control or Voltage Restraint*					
	Characteristic Curve	Definite time/Inverse Very Inverse/Extremely Inverse		Very Inverse		
	Tap Setting	0.50 – 1.45 A 1.50 – 2.90 A 3.00 – 5.80 A 6.00 – 12.00 A	0.05 A 0.10 A 0.20 A 0.50 A	6.0 A		
	Time Dial Setting	0.5 – 11.0	0.1	5.0	±3% or ±1 cycle**	
	Voltage Control (VC) or	10 – 200 V (0.08 – 1.67 pu)	1 V	132 V (1.10 pu)	±0.5 V	
	Voltage Restraint (VR)	Linear Restraint				
*The 51V element can be controlled optionally by the directional element (67). **The accuracy of the operating time is ±3% or ±1 cycle, whichever is greater; ±5% or ±2 cycles with Linear Restraint.						

RELAY FUNCTIONS

Device Number	Function	Setpoint Ranges	Increment	Initial Setting†	Accuracy	
*Inverse Time Overcurrent, Neutral						
51N	Characteristic Curve	Definite time Inverse Very Inverse Extremely Inverse		Very Inverse		
	Tap Setting	0.50 – 1.45 A 1.50 – 2.90 A 3.00 – 5.80 A 6.00 – 12.00 A	0.05 A 0.10 A 0.20 A 0.50 A	6.0 A		
	Time Dial Setting	0.5 – 11.0	0.1	5.0	±3% or ±1 cycle*	
	*The accuracy of the operating time is ±3% or ±1 cycle, whichever is greater.					
Negative Sequence Overcurrent						
46	Tap Setting	1.0 – 5.0 A	0.1 A	5.0 A		
	Pickup as % of Tap Setting	5 – 100%	1%	50%	±0.5% of 5A	
	Time Dial Setting ($K = I_2^{2t}$)	1 – 95	1	25	±3% or ±1 cycle**	
	Definite Maximum Time to Trip	600 – 60,000 cycles	5 cycles	10,000	±2 cycles	
*Reset Characteristic: 4 minutes, linear, from threshold of trip.						
**The accuracy of the operating time is ±3% or ±1 cycle, whichever is greater.						
Phase Directional Overcurrent (Optional)						
67	The directional overcurrent element can be programmed (by dipswitch) to respond only to three-phase faults or faults on any phase.					
	3Φ	Overcurrent Element				
		Magnitude	1 – 240* A	0.1 A	10.0 A	±3%**
		Time Delay***	1 – 8160 cycles	1.0 cycle	30 cycles	
		Directional Element				
		Maximum Sensitivity (Torque) Angle (MSA)	0° – 359°	1°	85°	
		Sensitivity at MSA	0.5 VA (positive sequence)			
		Prefault Memory	8 cycles (positive sequence voltage)			
		Polarizing Quantities:	Positive sequence voltage and positive sequence current.			
		* Not to exceed 20 times the maximum tap setting of the range into which the 3-phase overcurrent tap setting chosen for 51V falls.				
		** ±3% or ±3% of the maximum of the tap setting range chosen for 51V, whichever is greater.				
		*** High Speed setting has no intentional delay; response time = 0.75 ± 0.5 cycle.				
Directional Power, 3-Phase						
32	3Φ	Forward Power Flow Mag.	0.02 – 3.0 pu*	0.01 pu	3.0 pu	±0.01 pu
		Time Delay	1 – 8160 cycles	1.0 cycle	30 cycles	±1 cycle
		Reverse Power Flow Mag.	0.02 – 3.0 pu*	0.01 pu	3.0 pu	±0.01 pu
		Time Delay**	1 – 8160 cycles	1.0 cycle	30 cycles	±1 cycle
*1 pu = 1800 W with Line-to-Neutral inputs and 1039 W with Line-to-Line inputs.						
**High Speed setting has no intentional delay; response time = 0.75 ± 0.5 cycle.						
Reconnect Time Delay						
79		Reconnect (Close) Relay	1 – 8160 cycles	1.0 cycle	60 cycles	±1 cycle

† **Initial Setting:** The value is in setpoint memory until reprogrammed by operator; functions with two setpoints have only setpoint #1 enabled as shipped from the factory. The voltage control/voltage restraint functions on 51 V are disabled as shipped from the factory.

NOTES:

- ① All times specified in cycles are equivalent to 16.67 ms for 60 Hz and 20 ms for 50 Hz.
- ② For all functions except 51V, 51N, and 46, the time delay set via the front panel includes the one cycle response time of the relay signal processing and logic (two cycles for 81O/U). For functions 51V, 51N, and 46, an additional one-cycle relay response time should be added to the operating time obtained from the inverse time curves in the Instruction Book.

CALCULATIONS

Current and Voltage RMS Values: User selectable via dipswitch to be calculated from fundamental frequency only or to include harmonic content. Fundamental frequency phasors of sampled voltage and current signals are obtained by using the Discrete Fourier Transform algorithm. (Voltages and currents are sampled 16 times per cycle.)

Power Factor: Calculated correctly as watts/volt-amperes. Does not use the common simplifying assumption of voltage and current zero-cross criteria.

Reverse Power Flow: User-selectable to be based on total three-phase power or on power reversal of any one phase (when VT inputs are connected phase-to-ground).

V.T. Fuse-Loss detection: VT fuse-loss condition is detected using positive and negative sequence components of voltages and currents.

POWER INPUT OPTIONS

- Nominal 120 V ac, 50/60 Hz or nominal 125 V dc. Operates properly from 90 V ac to 145 V ac and from 90 V dc to 160 V dc. Withstands 240 V ac for 1 second. Burden 24 VA.
- Nominal 48 V dc. Operates properly from 35 V dc to 60 V dc. Burden 24 VA.
- Nominal 24 V dc. Operates properly from 18 V dc to 36 V dc. Burden 24 VA.

SENSING INPUTS

Four Voltage Inputs: Nominal 120 V ac/69 V ac, 50/60 Hz. Will withstand maximum continuous voltage of 180 V. Source voltages may be line-to-ground or line-to-line connected. Voltage transformer burden less than 0.2 VA.

Four Current Inputs: Nominal 5.0 A, 50/60 Hz; nominal 1.0 A optional for neutral circuit. Will withstand maximum continuous current of 10 A. Current transformer burden less than 0.05 VA @ 5A.

STATUS INPUTS

Breaker Status Input, 52b

External V.T. Fuse Loss Input, 60 F.L. Input

OUTPUT CONTACTS

- | | |
|----------------------|--------------------------|
| 1. Trip* | 4. Trip Annunciate |
| 2. Reconnect Enable* | 5. Power OK Status Alarm |
| 3. V.T. Fuse Loss* | 6. Self-Test Alarm |

**Rated per C37.90-1989, § 6.7.1 (make 30 A for 0.2 sec); in addition, carry 8 A, break 6 A @ 120 V ac, break 0.1 A @ 125 V dc, inductive break 0.1 A.*

LED INDICATORS

The **POWER LED** will remain on as long as power is applied to the unit and the power supply is operating properly. The **RELAY OK LED** reveals proper cycling of the microcomputer, and the **FAULT RECORDED** and **BREAKER CLOSED** LEDs indicate the status of those functions. The LEDs marked **TARGETS** will remain off when conditions are within limits. Appropriate LEDs will light when an over- or under-limit condition occurs, and will remain lighted until reset.

COMMUNICATION PORTS

Two optically isolated RS-232C communication ports.

SOFTWARE FEATURES

Front Panel Controls and Display

The M-0420 provides easy-to-use, menu-driven access to all functions via the front-panel controls and the 2-line-by-24-character Liquid Crystal Display. Software functions include the following:

- Individual relay functions can be enabled or disabled.
- User-selectable for generator or intertie applications.
- Trip logic can be selected for generator or intertie protection.
- User-definable access codes allow three levels of security.
- Time-tagged trip target information for the five most recent trips.
- User-selectable V.T. fuse loss detection. Under user selection, the functions 27, 51V, 32R, and 67 can individually be disabled during VT fuse-loss conditions. In addition, an external VT fuse-loss input (60 F.L. input) can be used to supplement the internal VT fuse-loss detection.
- Metering of 3 Φ voltages (RMS and peak), neutral voltage (RMS), 3 Φ currents (RMS), Neutral Current (RMS), Sequence Voltages (positive, negative, zero), Negative Sequence Current, Real and Reactive Power, Power Factor, and Frequency.

Communications Capabilities

The two RS-232 communication ports provide access to all M-0420 features—including metering and programming of all functions—via direct connection or modem for any IBM PC-compatible personal computer running the M-0429 BECOCOM™ software package.

Fault-Recording and Analysis

The M-0420 provides up to 96 cycles of fault waveform data. This data can be downloaded via the M-0429 BECOCOM™ Communications Software package for analysis with the M-0428 BECOPLOT™ Fault Data Analysis software.

DIELECTRIC AND SURGE WITHSTAND CAPABILITY

Voltage and current inputs are electrically isolated from each other, from other circuits and from ground. Power input and output circuits withstand 3536 V dc (Hi-pot) to chassis or instrument ground for one minute. (Communication circuits will withstand 1414 V dc for one minute.) The relay meets the requirements of the ANSI/IEEE C37.90-1989 Standard for Relays and Relay Systems Associated with Electric Power Apparatus.

NOTES: *Due to the use of transient suppression capacitors from many inputs to chassis, Hi-pot testing must be conducted with a dc voltage.*

Input and output circuits are protected against system transients. The M-0420 will pass all requirements of ANSI/IEEE C37.90.1-1989, defining oscillatory and fast transient capability.

▲ CAUTION: Digital Data Circuits (RS-232 communication ports) are excluded by Beckwith Electric from passing ANSI/IEEE C37.90.1-1989. The use of fiber optic communication lines is suggested to avoid any question of surge-withstand capability.

The relay performs properly when subjected to an RF field of 20 V/m at popular VHF and UHF communication frequencies.

ENVIRONMENTAL

Temperature: Stated accuracies are maintained from -20°C to $+70^{\circ}\text{C}$.

Humidity: Stated accuracies are maintained at up to 90% relative humidity (non-condensing).

Fungus Resistance: A conformal printed circuit board coating inhibits fungus growth.

INDUSTRIAL CERTIFICATIONS

UL Listed; CSA Certified.

N.S.T.A. Certification: Tested and certified to Project 1-A category by the National Safe Transit Association for immunity to standard shipping and handling stresses.

PHYSICAL

Mounting: The unit is designed as a drawout case for semi-flush panel mounting. It will mount directly in a panel prepared for an ABB (formerly Westinghouse) FT-41 or General Electric L-2 housing. A transparent cover is included.

Size: 20-13/16" high x 7-5/8" wide x 14-1/8" deep (52.8 x 19.4 x 35.9 cm).

Approximate Weight: 40 lb (18.2 kg).

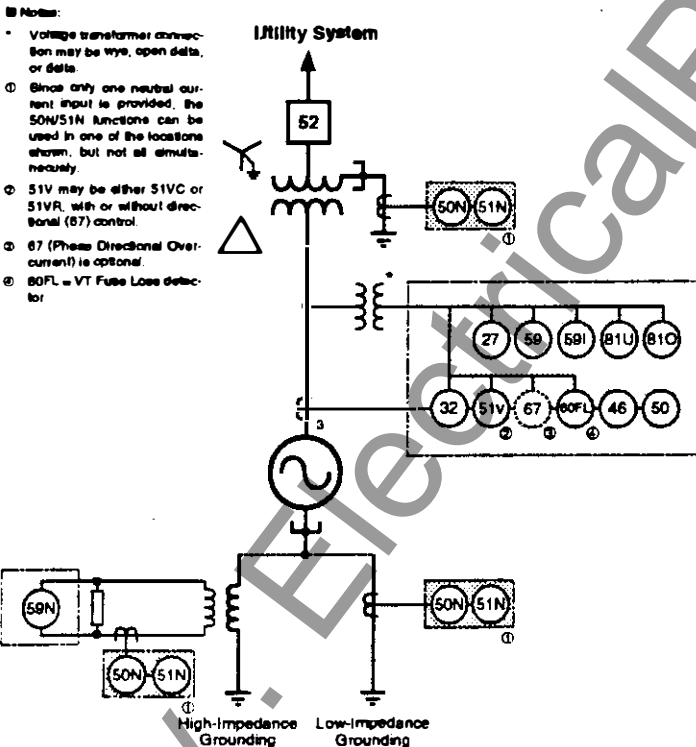
Approximate Shipping Weight: 46 lb (20.9 kg).

WARRANTY

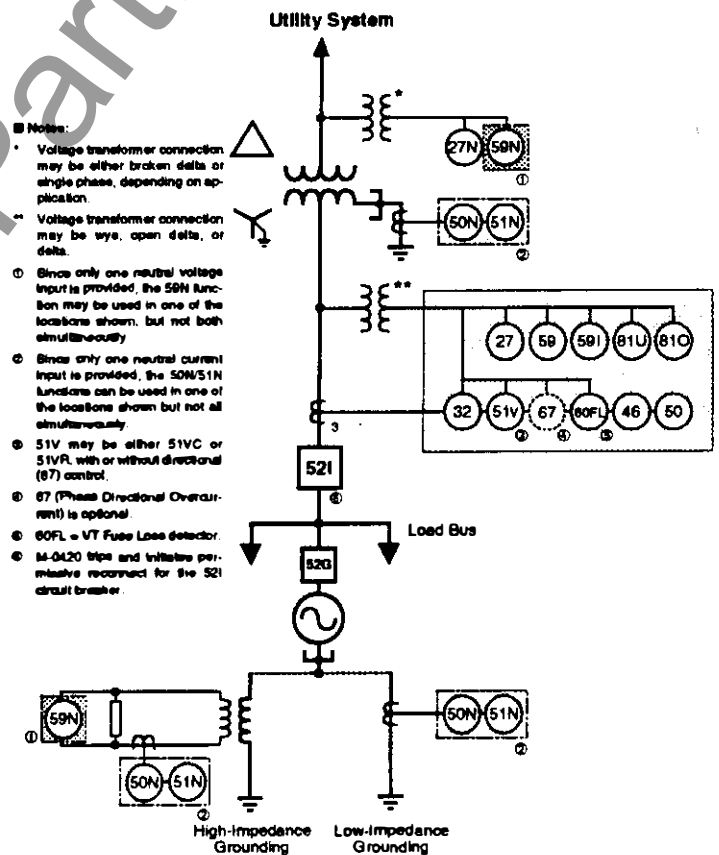
The PRIDE[®] M-0420 Multifunction Relay is covered by a two-year warranty from date of shipment.

PATENT

U.S. Patent 5,117,175



M-0420 Generator Protection Application



M-0420 Intertie Protection Application

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● WARNING

DANGEROUS VOLTAGES, CAPABLE OF CAUSING DEATH OR SERIOUS INJURY, ARE PRESENT ON THE EXTERNAL TERMINALS AND INSIDE THIS EQUIPMENT. USE EXTREME CAUTION AND FOLLOW ALL SAFETY RULES WHEN HANDLING, TESTING OR ADJUSTING THE EQUIPMENT. HOWEVER, THESE INTERNAL VOLTAGE LEVELS ARE NO GREATER THAN THE VOLTAGES APPLIED TO THE EXTERNAL TERMINALS.

● PERSONNEL SAFETY PRECAUTIONS

The following general rules and other specific warnings throughout the manual must be followed during application, test or repair of this equipment. Failure to do so will violate standards for safety in the design, manufacture and intended use of the product. Qualified personnel should be the only ones who operate and maintain this equipment. Beckwith Electric Co., Inc. assumes no liability for the customer's failure to comply with these requirements.

ALWAYS GROUND THE EQUIPMENT

To avoid possible shock hazard, the chassis must be connected to an electrical ground. When servicing equipment in a test area, the chassis must be attached to a separate ground since it is not grounded by external connections.

DO NOT OPERATE IN AN EXPLOSIVE ENVIRONMENT

Do not operate this equipment in the presence of flammable or explosive gases or fumes. To do so would risk a possible fire or explosion.

KEEP AWAY FROM LIVE CIRCUITS

Operating personnel must not remove the cover or expose the printed circuit board while power is applied. In no case may components be replaced with power applied. In some instances, dangerous voltages may exist even when power is disconnected. To avoid electrical shock, always disconnect power and discharge circuits before working on the unit.

EXERCISE CARE DURING INSTALLATION, OPERATION AND MAINTENANCE PROCEDURES

The equipment described in this manual contains voltages high enough to cause serious injury or death. Only qualified personnel should install, operate, test and maintain this equipment. Be sure that all personnel safety procedures are carefully followed. Exercise due care when operating or servicing alone.

DO NOT MODIFY EQUIPMENT

Do not perform any unauthorized modifications on this instrument. Return of the unit to a Beckwith Electric repair facility is preferred. If authorized modifications are to be attempted, be sure to follow replacement procedures carefully to assure that safety features are maintained.

▲ PRODUCT CAUTIONS

Before attempting any test, calibration or maintenance procedure, personnel must be completely familiar with the particular circuitry of this unit and have an adequate understanding of field effect devices. If a component is found to be defective, always follow replacement procedures carefully to assure safety features are maintained. Always replace components with those of equal or better quality as shown in the Parts List of the Instruction Book.

AVOID STATIC CHARGE

If this unit contains MOS circuitry, it can be damaged by improper test or rework procedures. Care should be taken to avoid static charge on work surfaces and service personnel.

USE CAUTION WHEN MEASURING RESISTANCES

Any attempt to measure resistances between points on the printed circuit board, unless otherwise noted in the Instruction Book, is likely to cause damage to the unit.

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Patent, Warranty and Indemnification

In our efforts to provide accurate and informative technical literature, suggestions to improve clarity or to correct errors will receive immediate attention. Please contact the Marketing Services Department, specifying the publication and page number. 800-0420-IB-04 7/22/94

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FOREWORD

Beckwith Electric's multifunction protective relays such as the M-0420 and M-0430 offer a number of advantages to electric utilities seeking to optimize their protective systems:

1. **Self-diagnostics.** The relay is constantly checking its own operation. If not functioning correctly, it alerts the operator through an output contact. In contrast, single-function electromechanical relays must be tested periodically by station maintenance personnel.
2. **Fault Recording.** The digital electronics in the relay continuously record the waveform of the voltage and current inputs, along with the status contact inputs. When the breaker opens, as indicated by the 52b contact, the waveform data is stored in memory for later review when investigating the cause of the trip.
3. **Compact Size.** The M-0420 occupies a panel space less than 8 inches wide and 21 inches high, yet can operate fourteen protective functions.
4. **Operation.** All settings can be established or changed using the front panel controls and alphanumeric display.
5. **Communication.** Through a computer connection, all functions can be monitored and setpoints changed by a PC-compatible computer, or by a laptop PC plugged into the front panel.
6. **Functions.** The functions respond in the same manner as do electromechanical relays, including time delays, and the nomenclature is the same.

The M-0420 Instruction Book provides details of the installation and operation of the M-0420. Our team of applications engineers stands ready to assist you in applying this equipment to your electric system. Please don't hesitate to call us at (813)544-2326

Lew Roberson

Vice President, Marketing

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1 INTRODUCTION

BEFORE YOU BEGIN

The Beckwith Electric M-0420 Multifunction Relay is a sophisticated relay applicable to a wide variety of applications. While it has been carefully designed to be easy to install and configure, if you're a first-time user, we suggest that you acquaint yourself with its operation in the following manner:

- Read this **Introduction** for a general overview of the M-0420.
- Read Chapter 2, **Application**, for information on using the M-0420 to protect generators and to initiate appropriate breaker commands in response to faults and abnormal conditions.
- Refer to Chapters 3, **Front Panel Controls**, and 4, **Operation**, to familiarize yourself with the layout and operation of the M-0420 front-panel controls.
- Refer to Chapter 5, **Menu Reference**, for detailed information on the functions you will be using in your application.
- Read Chapter 6, **Installation**, for mounting dimensions, external connections, initial setup, and verification routines.
- Refer to Appendix E, **Configuration Record Forms** for forms on which to record your relay configuration and DIP switch settings.
- Refer to publication M-0429A BECOCOM™ /M-0428A BECOLOT™ User's Guide for information on configuring and interrogating the M-0420 via a personal computer running the optional BECOCOM communications software package, and for information on plotting downloaded fault data via the optional BECOLOT software package.

The M-0420 Instruction Book has been organized to address the needs of different parts of your organization. If you are responsible for verifying that the M-0420 conforms to specifications as received, please turn to Chapter 6, **Installation** for initial setup, and to Chapter 7, **Test Procedures**.

If you are responsible for the operation of the M-0420 in a specific application, please turn to Chapter 2, **Application**, for information on enabling specific functions and entering setpoints. If you are responsible for the mechanical and electrical installation of the M-0420, please refer to Chapter 6, **Installation**.

If you are interested in a description of the M-0420 capabilities, please read this **Introduction** thoroughly, and refer to Appendix A, **Theory of Operation**, for more detailed information.

In case of difficulty or apparent failure, review Chapter 8, **Troubleshooting**. Please don't hesitate to call your local sales representative or Beckwith's application engineers (813-535-3408) for assistance in resolving any problems.

CONFIGURATION AS SHIPPED

You can become familiar with the basic operation of the M-0420 before it is installed by connecting it to the appropriate power input and setting it up on a bench or desktop. Even without any test voltages connected, you will be able to step through the various menus and note the indications on the liquid crystal display (LCD) and the various light-emitting diodes (LEDs). The formal initial setup information is presented in Chapter 6, **Installation**, which includes Figure 6-5 showing the external connections.

As shipped, the M-0420 is in the following configuration:

- the clock has been disabled
- the second setpoints on various functions have been disabled, and do not appear on the display
- the DIP switch (at bottom of inside case) has been set as follows, as detailed on the yellow or pink tag attached to the equipment. The yellow tag is for 60 Hz; the pink tag is for 50 Hz.

- | | |
|---|--|
| 1 | OFF (not for user selection) |
| 2 | ON (normal operation, rather than calibration) |
| 3 | ON (normal operation, rather than diagnostic mode) |
| 4 | ON (reverse power/current sensed on any phase) |
| 5 | ON (VT inputs set for line-to-line) |
| 6 | OFF (VT secondary voltage is 120 V ac) |
| 7 | OFF (system frequency is 60 Hz—yellow tag) |
| | ON (system frequency is 50 Hz—pink tag) |
| 8 | OFF (RMS by fundamental component only) |

- the 51 voltage control and voltage restraint functions are disabled
- the access code feature is disabled
- options supplied with the equipment are noted on the yellow or pink (50 Hz) tag. These are:

phase directional overcurrent function (device 67)

input voltage (120 V ac, 125 V dc, 48 V dc, 24 V dc)

neutral current input (nominal 5 A or 1 A)

- a set of replacement fuses is attached to one of the handles. These fuses are mounted on the internal PC board.

DESCRIPTION

The M-0420 Multifunction Relay is a microprocessor-based unit that uses digital signal processing technology to provide 14 different protective relaying functions (see Table 1-1) in one compact unit. The M-0420 is designed to provide these functions in two basic applications: generation, and generator/system interties. Within these basic applications, the various devices in the M-0420 can provide protection in cases of islanding, ferroresonance, ground or phase faults, generator motoring, and other abnormal operating conditions. The internal functions of the M-0420 are listed in Table 1-1. The nomenclature follows the standards of ANSI/IEEE Std. C37.2-1979, Standard Electric Power Systems Device Function Numbers.

Function	Description
27	RMS Undervoltage relay, 3-phase
27N	RMS Undervoltage relay, Neutral Circuit or Zero Sequence
32	Directional Power relay, 3-phase Forward (32F) and Reverse (32R)
46	Negative Sequence Overcurrent relay
50	Instantaneous Overcurrent relay, 3-phase
50N	Instantaneous Overcurrent relay, Neutral
51N	Inverse Time Overcurrent relay, Neutral
51V	Inverse Time Overcurrent relay, 3-phase, with Voltage Control or Voltage Restraint
59	RMS Overvoltage relay, 3-phase
59N	RMS Overvoltage relay, Neutral Circuit or Zero Sequence
59I	Peak Overvoltage relay, 3-phase
67*	Phase Directional Overcurrent relay, 3-phase
79	Reconnect Time Delay relay
81O	Over Frequency relay
81U	Under Frequency relay
60FL	VT Fuse-Loss Detection

* Optional

TABLE 1-1 M-0420 Device Function Numbers

Since all functions are incorporated into one package, much less panel space and panel wiring is required than for individual relays, as illustrated in Figure 1-1. You can set and examine all functions via a menu-driven 2-line by 24-character LCD display or via remote communication access. Once you reprogram a value, the new value is placed in non-volatile memory where it is unaffected by a loss of power or other system disturbance.

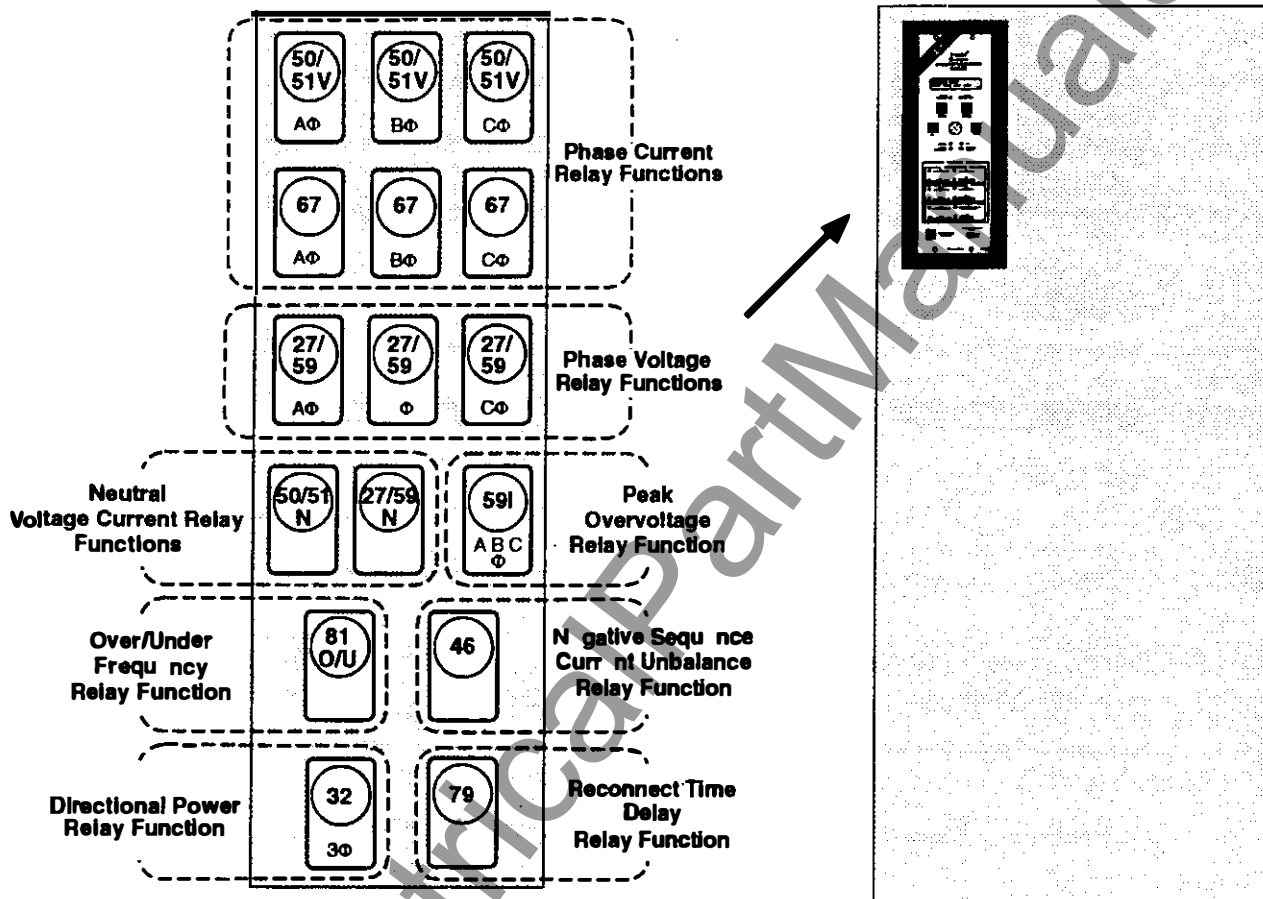


FIGURE 1-1 Traditional Relaying vs. the M-0420 Multifunction Relay

The M-0420 includes multiple output and status input contacts. It can be powered by 24, 48, or 125 V dc, or by 120 V ac, 50/60 Hz power, and is rated according to ANSI/IEEE C 37.90 and C 37.90.1. The relay includes self-test diagnostics, internal calibration correction, communication capability via two RS-232C ports, real-time display of system parameters, trip targets, and capture of fault data that occur during a system disturbance.

DESIGN CONSIDERATIONS

There are basically two approaches in the design of digital relays. In the first approach, the microprocessor simply replaces the relay logic and does not process the voltage and current signals. The performance of these relays depends on the accuracy of the analog components used, and is subject to dc offsets and gain drift with temperature, supply voltage changes, or aging. In the second approach, the microprocessor both processes the signals and performs the logic, providing a simpler design and offering performance advantages. The advent of low-cost digital signal processors (DSPs), microprocessors designed especially for the efficient numerical procedures required, paved the way for the design of a digital relay using state-of-the-art digital signal processing techniques, thereby eliminating the problems inherent with analog hardware.

The Beckwith Electric M-0420 Multifunction Relay follows this second approach: analog signal-processing hardware is replaced with a DSP. Various parameters of the input signals are estimated using digital signal-processing algorithms. The voltage and current input signals of the relay are modeled as sinusoidal signals corrupted by dc offset and harmonic components. These signals can be characterized by various parameters such as rms value, peak value, rms value/phase angle, and frequency of the fundamental component.

However, while DSPs are highly effective for signal-processing applications, they are not very efficient for general purpose applications and have limited memory space. Therefore, the M-0420 uses a dual-processor architecture. The DSP executes all the signal-processing algorithms, while a general-purpose (host) processor manages input/output and other overhead functions, monitors the keyboard for operator requests, updates memories for setpoint values, facilitates operator interaction via the alphanumeric display, establishes two-way communication using the RS-232C serial ports, analyzes the data from the DSP, and issues the trip commands.

Figures 1-2 and 1-3 present a general overview of the hardware design and functional operation of the M-0420. As shown in these diagrams, the inputs to the M-0420, filtered to remove higher order harmonics, are multiplexed and then passed through an Analog-to-Digital Converter (ADC) to the DSP, which performs a discrete Fourier transform (DFT) 16 times per cycle for each of the inputs. The host processor performs all input/output and overhead functions, including monitoring of the status inputs, and ultimately analyzes the data from the DSP to determine the need for a trip command.

One significant design feature of the M-0420 is automatic correction of the sensing transformer error caused by ambient temperature excursions. Voltage transformers exhibit enough internal resistance so that the internal regulation of the transformer results in a significant error due to changes in temperature. The M-0420 includes a temperature sensor mounted in the enclosure to measure directly and accurately the internal temperature of the relay. This temperature signal is coupled through the ADC to the DSP, which processes the information to determine the appropriate factor required to correct the sensing transformer error.

The M-0420 uses an algorithm based on the DFT to compute the frequency and to determine the phase angle for real/reactive power measurements. The algorithm uses voltage phasor estimates obtained from the DFT to compute reliable estimates of frequency unaffected by dc and harmonic components in the signal. Additionally, deriving the positive sequence voltage phasor from the DFT means that the frequency function will continue to operate should any single- or two-phase fault occur.

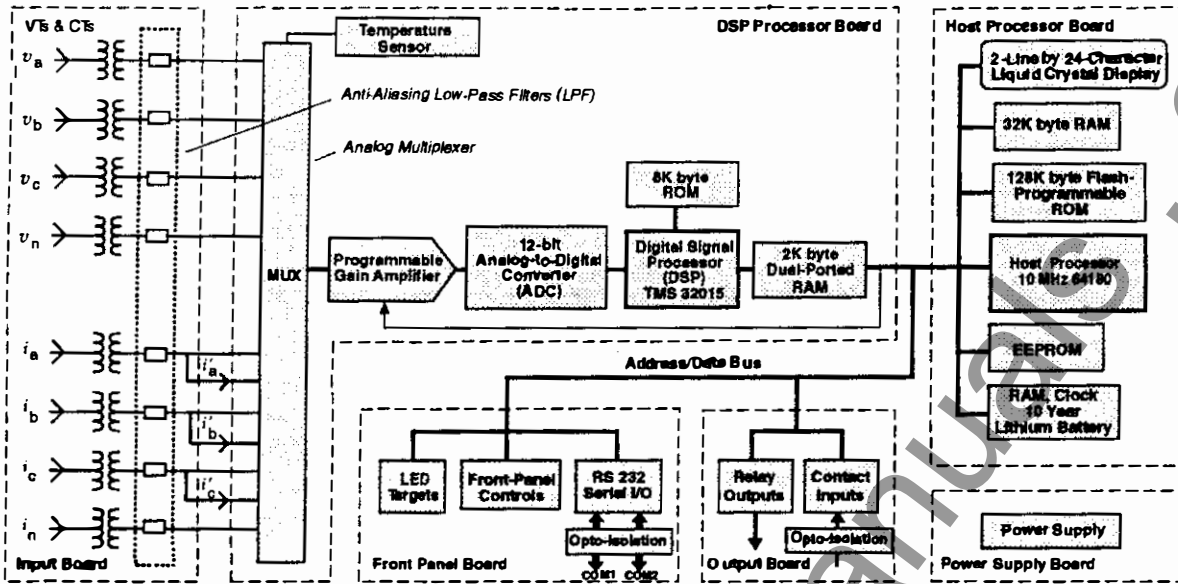


FIGURE 1-2 M-0420 Block Diagram

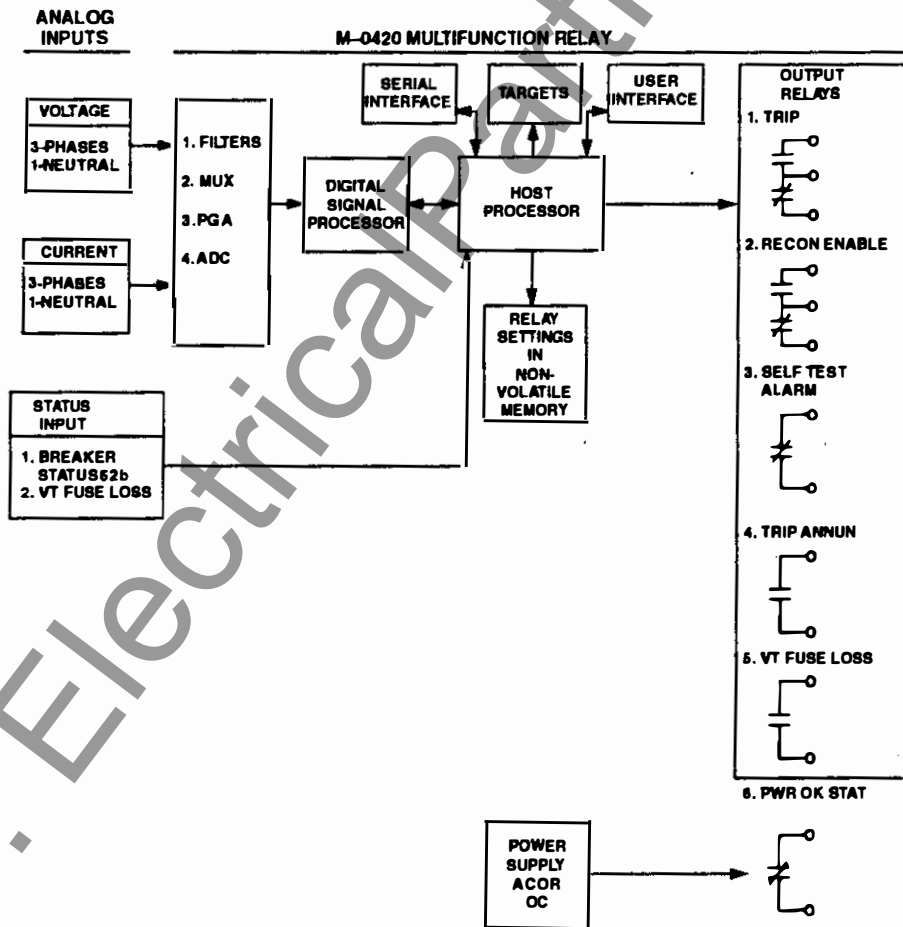


FIGURE 1-3 M-0420 Functional Diagram

USER CONSIDERATIONS

In the design of the M-0420, careful consideration was given to making its use as similar as possible of the traditional protective relays that are still found throughout typical power systems.

EASE OF USE AND COMPATIBILITY

In order to provide maximum compatibility with existing equipment, care was taken that traditional electro-mechanical nomenclature was used for setpoint values and trip characteristics. For example, the inverse time overcurrent functions (devices 51 and 51N) use industry-accepted time-curve families (Definite Time, Inverse, Very Inverse, and Extremely Inverse) based on the ABB (formerly Westinghouse) CO and COV curves. Within each family, the operator selects the tap setting and time dial setting just as though doing so on an electromechanical relay.

The user-friendly controls and display provide easy access to the various functions. The software is completely menu driven through a liquid crystal alphanumeric display (LCD). All functions and values can easily be set using the front panel pushbuttons and the rotary knob.

COMMUNICATION CAPABILITIES

One of the important features of the M-0420 is its capability for remote communications. The relay provides two RS-232C serial ports for communication via modem or direct serial connection. In a typical communications application, the rear-panel communication port is permanently connected to a modem, while the front-panel port is kept free for on-site programming via a laptop PC.

FAULT RECORDING AND ANALYSIS

The multifunction relay provides up to 96 cycles of fault waveform data with selectable distribution of the time before and after the breaker trip. This data can be downloaded via an MS-DOS computer running the M-0429A BECOCOM™ Communications Software. Once downloaded, the data can be analyzed using the associated M-0428A BECOPLOT™ Fault Data Analysis Software package.

The fault data analysis software runs on an MS-DOS computer, enabling the user to plot fault data, specifying which waveforms and inputs are displayed, and at what scale. (The sample plot shown in Figure 1-4 displays all waveforms.) A marking feature enables the user to mark any time span and zoom instantly to display it at full screen, and specific points on the waveform may be tagged in order to read actual waveform values. Displayed plots can be printed using the DOS Print Screen command.

SELF-DIAGNOSTICS

To ensure confidence in the relay's operation, the system software provides many hardware and software diagnostic checks, some of which are performed continuously, and others on processor reset. Should a failure occur, an output relay is activated, and processing stops in order to prevent misoperation. Likewise, if system power fails, an output contact closes.

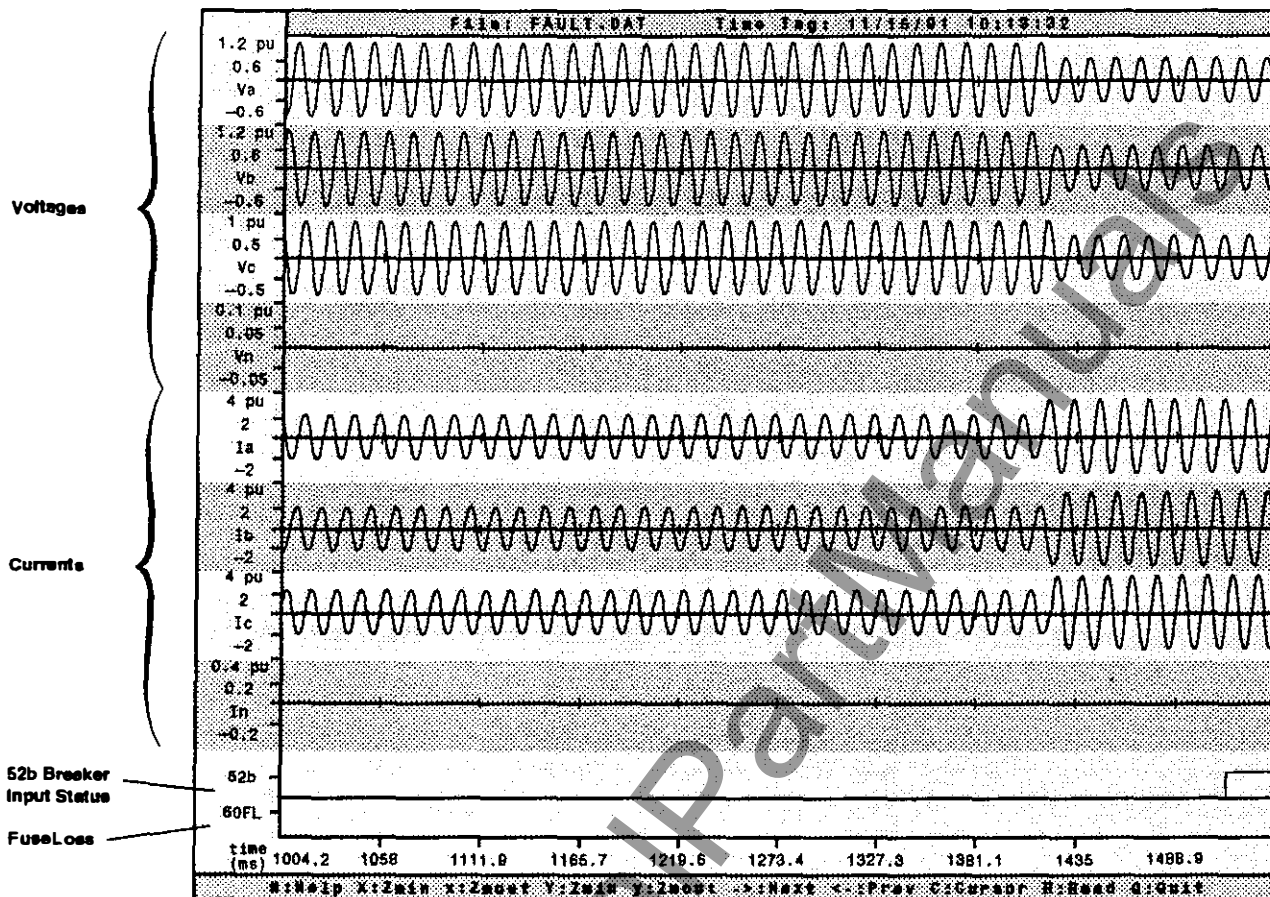


FIGURE 1-4 M-0428A BECO PLOT™ Fault Data Analysis Software Output

INTERNAL CALIBRATION CORRECTION

One of the most important and novel advantages of the M-0420 is its capability for correcting its calibration through internal software. Most existing static and microprocessor relays are designed with a number of trim pots to trim the signal offsets, and gain and phase inaccuracies. This can be a time-consuming process, during both factory calibration and routine calibration by the customer. The M-0420 does away entirely with trim pots for calibration. The gain and phase angle errors are computed using calibration coefficients stored in nonvolatile memory. When the calibration mode is selected, the relay display prompts the operator to connect the voltage inputs to 120 V and the current inputs to 5 A with zero phase angle between the signals. Then, the relay computes the gain and phase angle errors and stores the appropriate correction coefficients for use by the relay software.

OPTIONS

In addition to the selectable power inputs of 24, 48, or 125 V dc/120 V ac (50 or 60 Hz), the M-0420 can provide the following optional functions:

67 PHASE DIRECTIONAL OVERCURRENT

The M-0420 is available with the phase directional overcurrent function (67). In addition to the definite time delay provided on the 67 function, the directional element of the 67 function can be used to provide directional control of the 51 V function, thereby realizing a directional inverse time overcurrent function.

NEUTRAL CURRENT INPUT

The M-0420 is available with a nominal neutral current input of 5 A (standard) or 1 A (optional). When the 1 A input option is chosen, the M-0420 internally scales the current by a factor of 5 and the settings and status display work as though the 5 A nominal neutral current is selected. With the 1 A neutral current input, the current-related settings and status display values should be divided by 5 to obtain the actual current values.

ACCESSORIES

M-0319 DROPPING REGULATOR

The M-0319 dropping regulator is a resistor/zener-diode regulating device used to produce 125 V dc from a 250 V dc battery source. The M-0319 can be used to allow an M-0420 with the 120 V ac/125 V dc power supply option to operate from a 250 V dc source.

M-0421 PRIDE[®] TEST ADAPTER

The M-0421 test adapter makes bench testing the M-0420 an easy process. The adapter provides a complete set of rear terminals for testing the unit after it has been removed from its draw-out case.

M-0429A BECOCOM[™] COMMUNICATIONS SOFTWARE PACKAGE

The BECOCOM communications software runs on an MS-DOS computer, providing remote access to the M-0420 via either direct serial connection or modem. BECOCOM provides the following communication functions:

- Setpoint interrogation and modification
- Line status real-time monitoring
- Downloading recorded fault data

BECOCOM also provides remote access to the Beckwith Electric M-0430 Multifunction Relay.

M-0428A BECOPLOT™ FAULT DATA ANALYSIS SOFTWARE PACKAGE

The M-0428A BECOPLOT™ Fault Data Analysis Software runs on any MS DOS computer, enabling you to plot and print fault data downloaded (using the BECOCOM communications software package) from the M-0420 and M-0430 relays. Figure 1-4 illustrates typical data output.

M-0422/M-0423 SERIAL COMMUNICATIONS CABLES

The M-0422 cable is a 10-foot straight-through RS-232 cable for use between the M-0420 rear-panel (COM2) port and a modem. This cable has DB25 (25-pin) connectors at each end.

The M-0423 cable is a 5-foot null-modem RS-232 cable for direct connection between a PC and the M-0420 front-panel (COM1) port. This cable has DB9 (9-pin) connectors at each end.

REFERENCES

The references that follow provide additional information about the use of digital technology in protective relaying. References 12 and 13 present more detailed information about the design and applications of the M-0420, and are available upon request from Beckwith Electric Co., Inc.

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- [11] C.F. Henville, "Relay Replacement and Upgrading Projects," Canadian Electrical Association 1991 Spring Meeting, Toronto, Ontario, May, 1991.
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2 APPLICATION

M-0420 PROTECTIVE APPLICATIONS

The sections that follow discuss briefly the principal applications of the M-0420 relay in intertie or generator protection. The Functions section that follows the system diagrams discusses the individual functions in detail, presenting setpoint ranges, increments, and the initial default settings.

ISLANDING PROTECTION (81U, 81O, 27, 59)

When a dispersed source of 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 of detecting the island condition. The M-0420 provides both under frequency (81U) and over frequency (81O) functions. The M-0420 also provides both rms undervoltage (27) and rms overvoltage (59) functions that can be useful in detecting islanding. Each has two setpoints with time delays of from 1 to 8160 cycles, and magnitude range settings of from 10 to 200 V.

FERRORESONANCE PROTECTION (59I)

Lightly loaded islanded systems can experience ferroresonance, where the system is in resonance but the inductance is highly nonlinear as the transformer core cycles in and out of magnetic saturation. Under these conditions, the voltage waveform will be distorted to the extent that the peak voltage of the nonsinusoidal wave can be dangerously high. Since the peak overvoltage (59I) function of the M-0420 detects the value of the instantaneously sampled wave, it can act in situations where a relay reacting to rms voltage would not. The setpoint range is from 1.05 to 1.50 per unit, with a time delay variable from 1 to 8160 cycles.

UTILITY-SIDE GROUND FAULT PROTECTION AND PHASE VOLTAGE UNBALANCE PROTECTION (27N, 59N)

The M-0420 provides both rms undervoltage and rms overvoltage functions for the neutral circuit (27N and 59N). Used together with one VT connected from any one phase to ground, the 27N and 59N devices are an effective means of detecting the most common line-to-ground fault. A fault on the phase that includes the VT will pull that phase voltage low and initiate operation of the 27N function. A fault on either phase without the VT will result in $\sqrt{3}$ x normal voltage appearing at the VT, initiating operation of the 59N.

The 59N may also be used to detect system phase voltage unbalance conditions in conjunction with three VTs. To do so, the VT secondaries are connected in broken delta and the 59N device inserted. In this case, voltage at the 59N will be zero so long as the three-phase voltages are balanced, but will rise above zero with any unbalanced condition, as will occur with a utility line or ground fault.

The M-0420 implementation of the 27N and 59N functions provides two setpoints each with a range setting of 10 to 200 V and a time delay of 1 to 8160 cycles.

PHASE FAULT PROTECTION (51V, 67)

Time overcurrent relays (51), one per phase, are basic to any protection scheme. This is the main device used to trip circuits selectively and time-coordinate them with other up- or down-stream devices. Four complete series of inverse time tripping characteristics from Definite Time to Extremely Inverse (based on the ABB CO and COV curves) are included in the M-0420.

For intertie protection applications, the optional phase directional overcurrent function (67) allows greater selectivity for utility system faults, since the directional element can be set to look toward the utility system. As a generator protection relay, the 67 function, looking into the generator, can provide protection against accidental energization of the generator on turning gear. When line-side CT inputs are used, this function can also provide high-speed protection against generator winding faults. However, with line-side CTs, the protection against winding faults during off-line operation (when the breaker is open) is not available from the 51V, 50, 46, or 67 functions.

Calculation of the current used for tripping is a unique feature of the M-0420. The current is derived from an rms calculation, but (by user selection) can also be computed based on either including or not including the contribution of harmonics to the value. Since it is not well established by the industry whether the calculation should be based simply upon the fundamental frequency component or a broader frequency range, a simple switch setting allows the operator to select either one.

DIRECTIONAL POWER (32F, 32R)

The M-0420 implementation of the directional power function is straightforward, issuing a trip command when the magnitude of the power flow (in either direction as selected) exceeds the setpoint for the prescribed time. However, as opposed to reverse power relays that rely on zero crossings for phase angle information, the power calculation in the M-0420 uses the fundamental frequency phasor measurements obtained from the DFT, and thus is immune to harmonics in voltage and current signals. The setpoints for either direction range from 0.02 to 3.0 pu, with time delays from 1 to 8160 cycles.

ANTI-MOTERING PROTECTION (32R)

When the energy supply to the prime mover is cut off while the generator is still on line, the generator will act as a synchronous motor driving the prime mover. A reverse power relay is used to detect this motoring. Because the power required to motor is a function of the type of prime mover, the required sensitivity of the reverse power relay can vary widely for different applications. The M-0420 reverse power function provides 2% sensitivity, making it applicable to many anti-motoring situations. A time delay of up to 8160 cycles can be set to avoid tripping during power swings.

GROUND FAULT PROTECTION (59N, 51N, 50N)

Detection of ground faults in a high-impedance-grounded unit generator can be accomplished by an over-voltage relay in the generator neutral. For good fault sensitivity, the pickup of the relay should be about 10 to 16 V. However, because the third harmonics which normally flow in the system and neutral can easily exceed this value, they must be filtered, or the relay otherwise made insensitive to them. For this application, the M-0420 responds only to the fundamental frequency component of the neutral voltage signal.

In such a high-impedance grounding system, ground faults in the primary system will induce zero-sequence voltages at the generator due to capacitive coupling between the windings of the unit transformer. If the coupling voltage is anticipated to be greater than the 59 relay pickup, a time delay should be used to permit the primary ground relays to clear high-side faults. The M-0420 provides a variable time delay of 1 to 8160 cycles.

Alternative or additional protection can be provided with the use of an inverse-time overcurrent relay (51N) and/or an instantaneous overcurrent relay (50N). These relays must be set above the maximum unbalance current that normally flows in the generator neutral. A typical setting for the 51N function would be 1.5 to 2 times the typical value. Because the 50N function provides instantaneous protection, it must be set above the greater of normal neutral unbalance and the maximum current resulting from primary system ground faults. A typical setting would be 2 to 3 times the maximum.

NEGATIVE SEQUENCE OVERCURRENT PROTECTION (46)

Unbalanced faults and other system conditions can cause negative sequence currents in the generator, leading to second-harmonic currents in the rotor that can cause severe overheating and damage. The M-0420 implements the inverse time negative sequence overcurrent function ($I_2^2 t = K$) in order to protect the generator from the unbalanced currents.

BACKUP PHASE FAULT PROTECTION (51VC/VR)

Backup protection for system phase faults can be provided by a voltage-controlled/restrained inverse-time overcurrent relay (51VC/VR) as provided in the M-0420. The voltage restraint function is well-suited to small generators with relatively short stator time constants. The voltage control feature helps to confirm that the overcurrent is due to a fault by activating the function only when the voltage is below the voltage control setpoint. Additionally, the M-0420 can determine the equivalent high-side voltages of delta/wye unit transformers through its internal software, thus eliminating the need for auxiliary instrument transformers.

VT FUSE-LOSS PROTECTION

If the internal blown-fuse detection is enabled, or the external fuse-loss input is connected, the M-0420 will provide user-selectable blocking of the 27, 51V, 67, and 32R functions upon detection of a VT fuse-loss condition. Additionally, the relay will activate an output contact indicating the blown-fuse condition. This external contact can be used to block other relays which may be affected by the blown-fuse condition (for example, a loss-of-field relay).

POWER OK STATUS

The green POWER LED on the front panel remains on as long as power is applied and the power supply is operating properly. When system power fails or is removed, a normally-closed output relay opens to provide an alarm function.

TRIP CONFIGURATION VS. APPLICATION

Figures 2-1 through 2-6 illustrate the M-0420's protection capabilities and trip logic for both intertie and generator protection modes. To optimize the M-0420 for the specific application, access the **CONFIGURE RELAYS** menu (see Chapter 5, **Menu Reference**) and do the following:

- 1) Press **ENTER**. The legend **VOLTAGE RELAY** will appear on the display.
- 2) Turn the rotary knob four steps to the right. The legend **CONFIGURE TRIP CIRCUIT** will appear on the top line, and **TRIP** will appear on the bottom line.
- 3) Press **ENTER**. The legend **TRIP CIRCUIT TYPE** will appear on the top line, with the two choices **INTERTIE** and **generator** on the bottom line.
- 4) Select one of these, using the rotary knob, and press **ENTER**.

When **INTERTIE** is selected, all M-0420 functions are available at all times (individual functions can be disabled via the **CONFIGURE RELAYS** menu).

When **GENERATOR** is selected, the M-0420 disables the 27, 81O, 81U, 27N, 32F, and 32R functions when the 52b status input indicates that the breaker is open. This feature ensures that the M-0420 will not send an unwanted trip signal while the generator is off-line, such as when being brought up to speed.

When **GENERATOR** is selected, the following conditions must be true:

- The 52b status input *must* be connected.
- High-speed reverse power *must not* be selected.

■ **NOTE:** For generator protection during off-nominal frequency operation, more accurate response will be achieved if the total waveform (including harmonics) is used as the basis for the rms magnitude of voltage and current. (This option is selected via the internal configuration DIP switch as explained in Chapter 6, **Installation**.)

INTERTIE PROTECTION

The system one-line diagram shown in Figure 2-1 and the system three-line diagram in Figure 2-2 illustrate the typical intertie protection capabilities of the M-0420. Figure 2-3 illustrates the trip logic used when the M-0420 is configured for intertie protection.

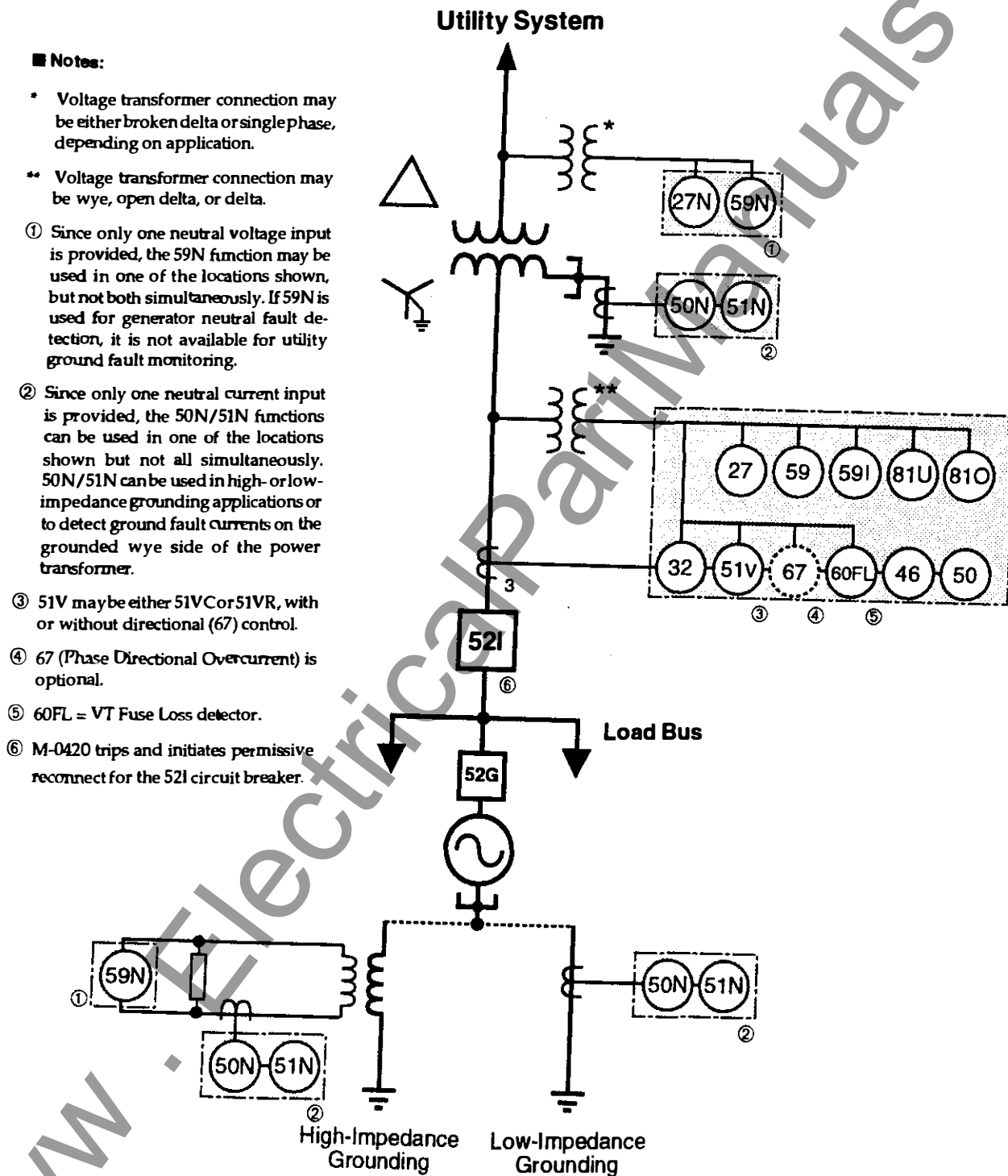
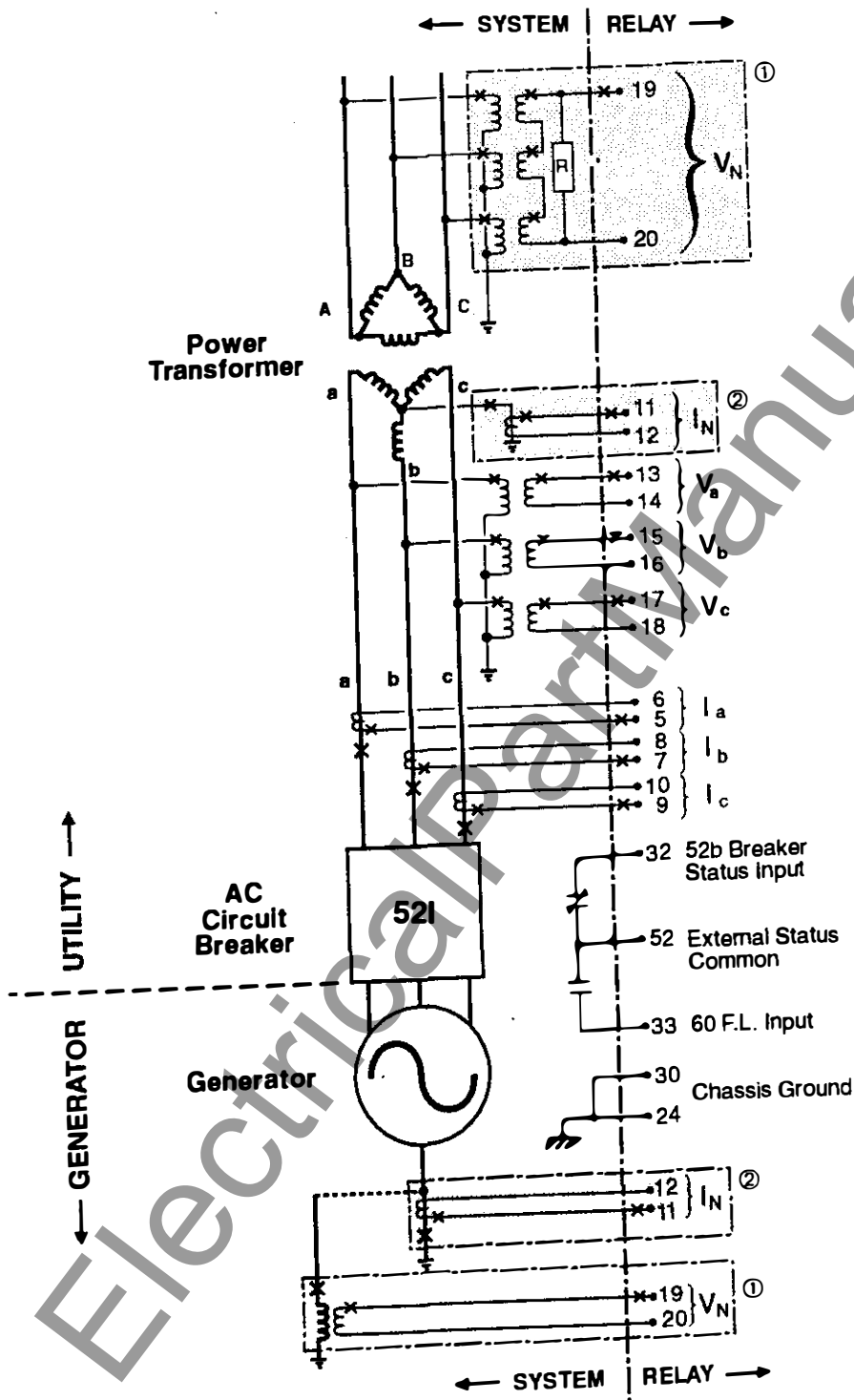


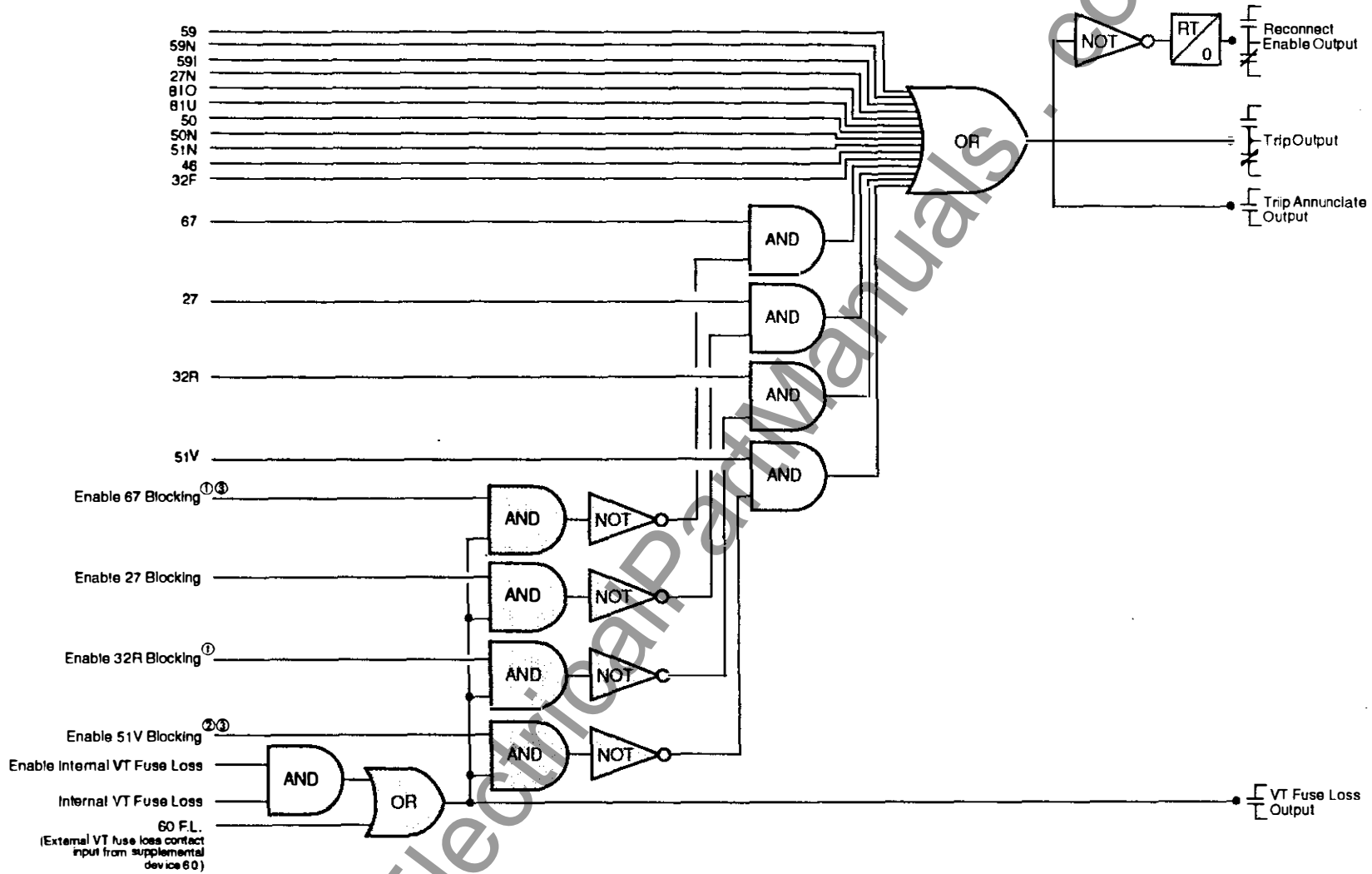
FIGURE 2-1 Intertie Protection—Typical One-Line Diagram



- NOTES: ① If voltage is used for generator neutral fault detection, the 59N input is not available for utility ground fault monitoring at terminals 19 and 20. ② The Neutral Current input can be used either at the transformer neutral or the generator neutral, but not both simultaneously.

FIGURE 2-2 Intertie Protection—Typical Three-Line Diagram

FIGURE 2-3 Inter tie Protection—Trip Logic



- **NOTES:** ① When the high-speed setting has been selected for the 32R or 67 functions, the respective blocking function should not be enabled. ② If 51V blocking is enabled when a blown VT fuse condition is detected, the M-0420 disables 51VC (if VC is enabled) or disables VR of 51VR (keeping the tap setting at the value established for the rated voltage input). ③ If 51V is controlled by the directional element of 67, 51V will be blocked when 67 is blocked.

GENERATOR PROTECTION

The system one-line diagram shown in Figure 2-4 and the system three-line diagram shown in Figure 2-5 illustrate the typical generator protection capabilities of the M-0420. Figure 2-6 illustrates the trip logic used when the M-0420 is configured for generator protection. Table 2-1 provides general guidelines for the placement of current transformers for generator phase-to-phase fault protection. (Note that these are guidelines only and may not apply to all situations.)

Notes:

- Voltage transformer connection may be wye, open delta, or delta.
- ① Since only one neutral current input is provided, the 50N/51N functions can be used in one of the locations shown, but not all simultaneously. 50N/51N can be used in high- or low-impedance grounding or to detect ground fault currents on the grounded wye side of the power transformer.
- ② 51V may be either 51VC or 51VR, with or without directional (67) control.
- ③ 67 (Phase Directional Overcurrent) function is optional.
- ④ 60FL = VT Fuse Loss detector.

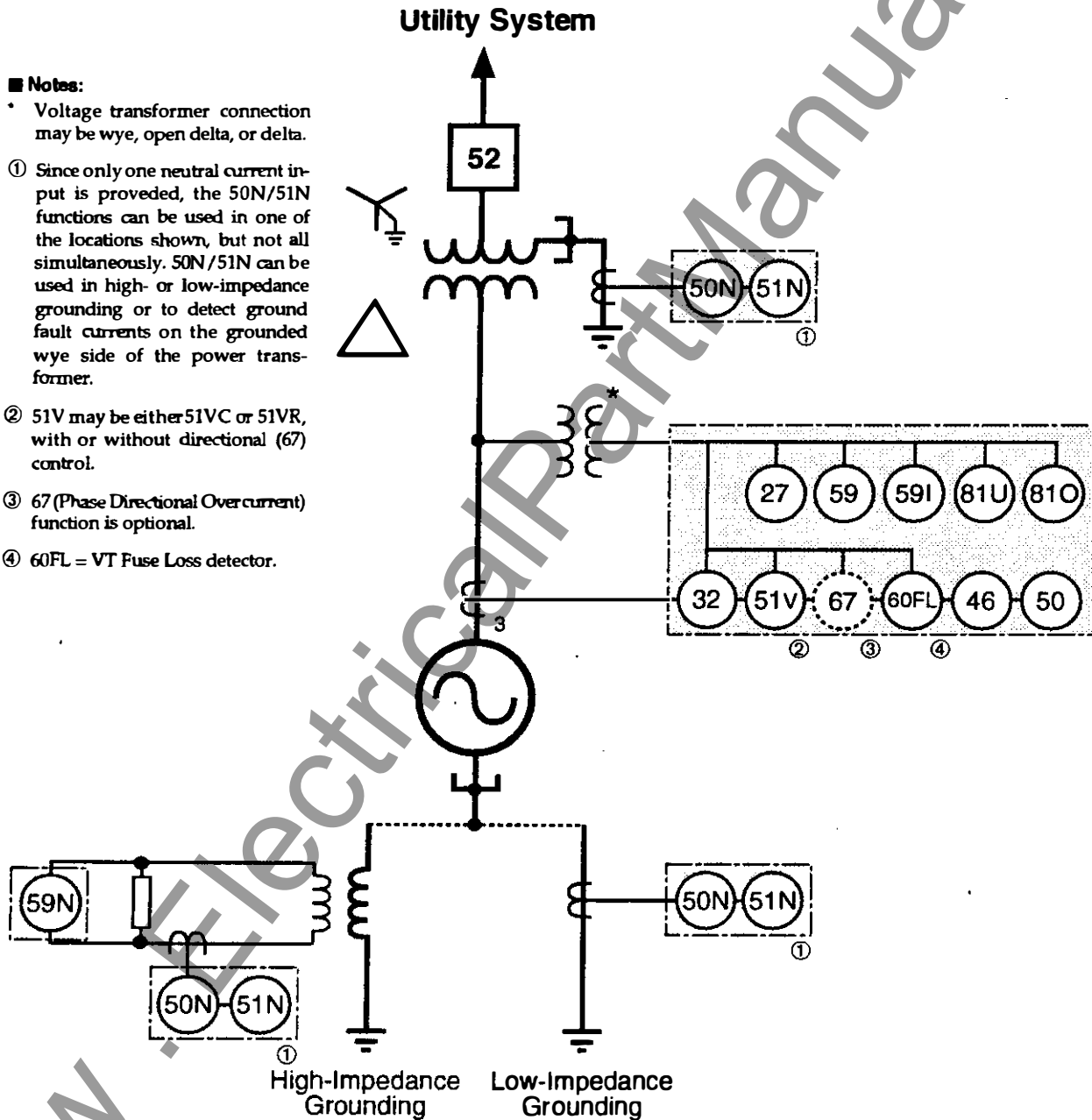
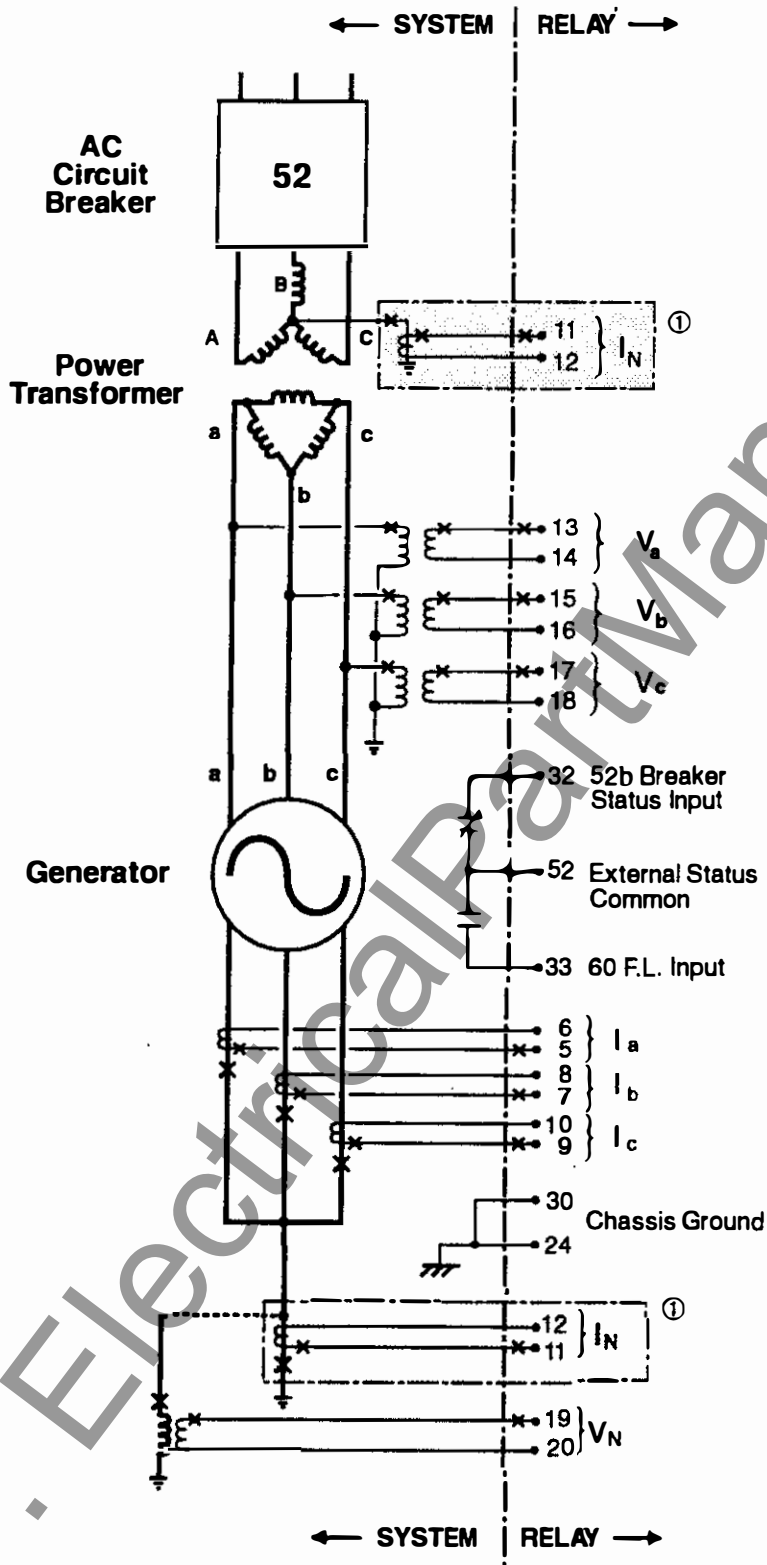


FIGURE 2-4 Generator Protection—Typical One-Line Diagram



■ NOTE: ① The neutral current input can be used either at the transformer neutral or the generator neutral, but not both simultaneously.

FIGURE 2-5 Generator Protection—Typical Three-Line Diagram

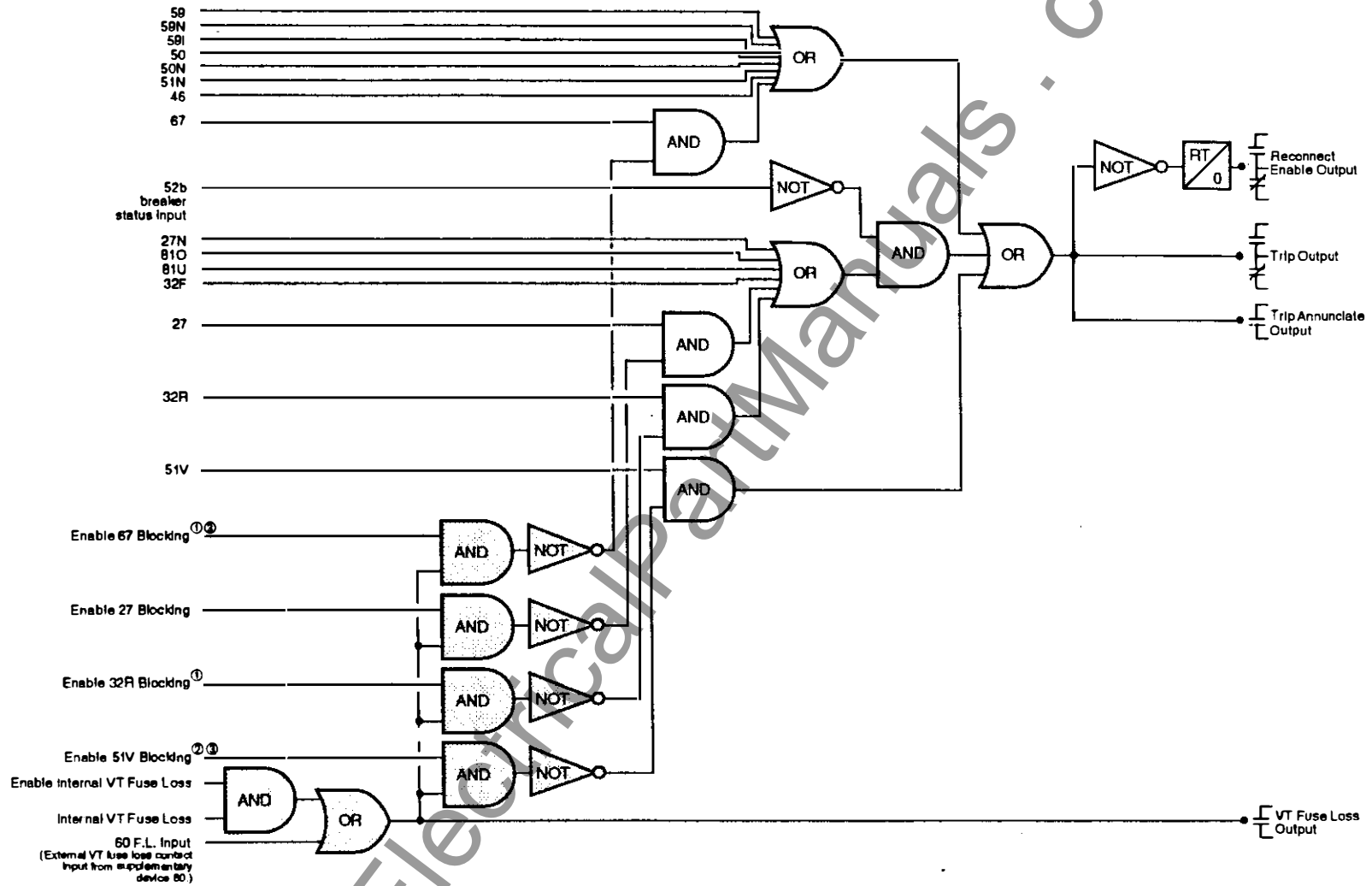
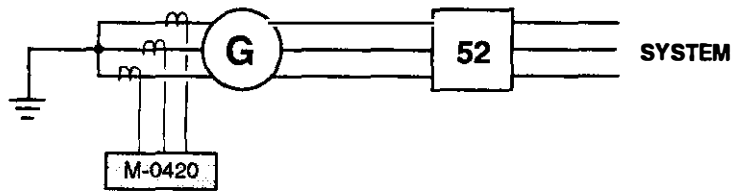


FIGURE 2-6 Generator Protection—Trip Logic

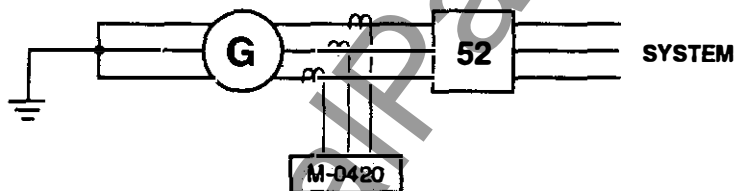
- NOTES: ① When the high-speed setting has been selected for the 32R or 67 functions, the respective blocking function should not be enabled. ② If 51V blocking is enabled when a blown VT fuse condition is detected, the M-0420 disables 51VC (if VC is enabled) or disables VR of 51VR (keeping the tap setting at the value established for the rated voltage input). ③ If 51V is controlled by the directional element of 67, 51V will be blocked when 67 is blocked.

CTs on Neutral Side



Protection Applications — Phase-to-Phase Faults		
Protective Device Function	Offline (Synchronizing)	On-Line
50 51 VR	Applicable Protection	Applicable Protection
67*	Not Applicable	Not Applicable
46	Applicable Protection	Applicable Protection

CTs on Line Side



Protection Applications — Phase-to-Phase Faults		
Protective Device Function	Offline (Synchronizing)	On-Line
50 51 VR	Not Applicable	Applicable Protection
67*	Not Applicable	Applicable Protection (MSA must be set towards generator.)
46	Not Applicable	Applicable Protection

*NOTE: The 67 phase directional overcurrent function is optional. Using the 67 function for protection against inadvertent energization is applicable to both CT positions.

TABLE 2-1 Current Transformer Placement Considerations for Generator Phase-to-Phase Fault Protection

SETPOINTS

The M-0420 provides programmable setpoints for each function. Current-related functions incorporate instantaneous or inverse time characteristics consistent with industry standards. Voltage and frequency functions can have a magnitude #1 and a magnitude #2 setpoint in conjunction with a time delay #1 and a time delay #2 setting.

- NOTE:** Functions having two setpoints have the second one disabled as shipped. These will not appear on the menu until they have been enabled. See Chapter 5, **Menu Reference**.

As an example, consider the 81 device. The over frequency value can be set in the relay from 60.05 to 63.00 Hz in 0.05 Hz increments, and the associated time delay may be set from the minimum relay operating time of 2 cycles to 8160 cycles. Specific user requirements may mean that this function will be programmed, for example, to trip at 240 cycles if the frequency increases to 60.2 Hz, but trip at 10 cycles at 61 Hz—a first approximation of an inverse characteristic (shown in Figure 2-7). As illustrated in this figure, the under frequency setpoints are independent and need not mirror the setpoints used for over frequency.

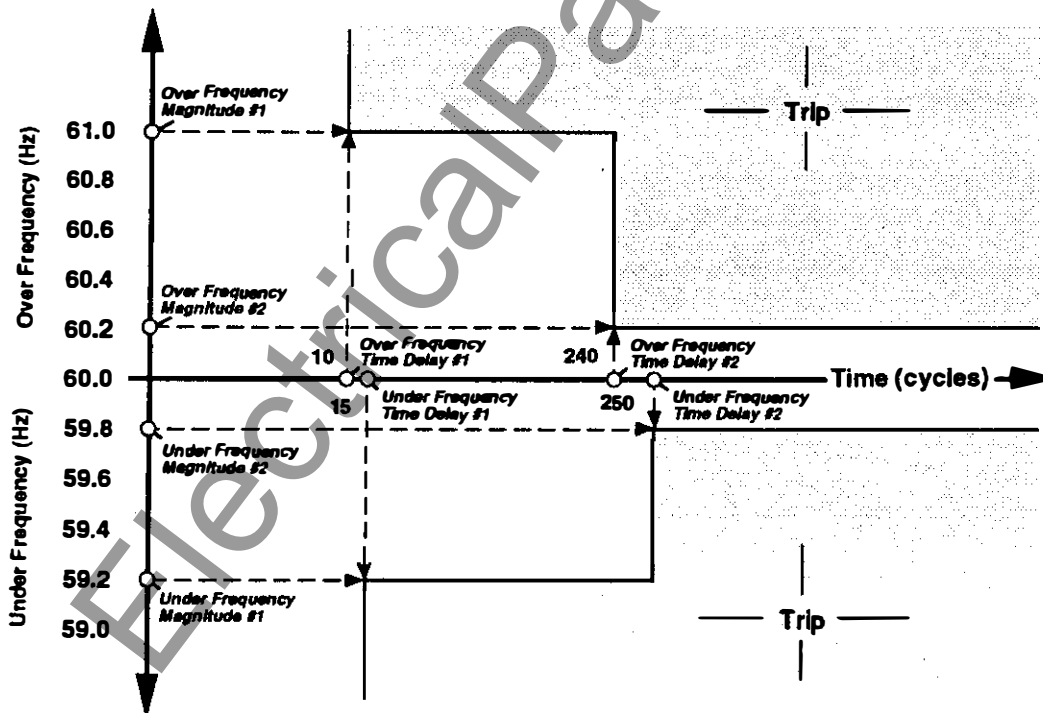


FIGURE 2-7 Example of Trip Characteristics: Over and Under Frequency

FUNCTIONS

The M-0420 protective functions are discussed individually on the following pages.

Function	Page
81O, 81U	2-14
59, 27	2-15
59I	2-16
59N, 27N	2-17
51V (51VC, 51VR)	2-20
51N	2-27
50, 50N	2-28
46	2-29
32	2-31
67	2-33
79	2-35
60FL VT Fuse-Loss Detection	2-36
VT Fuse-Loss Blocking	2-36
Fault Recorder	2-37

81O/81U Over Frequency/Under Frequency

When a dispersed source of 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 relays 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 6 cycles.

A second school of thought, however, 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 just at this time that all available DSG should be kept on-line to help avoid a complete system collapse. If this is the objective, it may be useful to set one under frequency 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	INITIAL SETTING*
Over Frequency (81O)			
Magnitude #1, #2	60.05 – 63.00 Hz (50.05 – 53.00 Hz)	0.05 Hz	60.50 Hz
Time Delay #1, #2	2 – 8160 cycles	1.0 cycle	30 cycles
Under Frequency (81U)			
Magnitude #1, #2	53.00 – 59.95 Hz (43.00 – 49.95 Hz)	0.05 Hz	59.50 Hz
Time Delay #1, #2	2 – 8160 cycles	1.0 cycle	30 cycles
* Initial Setting: The value is in setpoint memory until reprogrammed by the operator; functions with two setpoints have only setpoint #1 enabled as shipped from the factory.			

TABLE 2-2 Over (81O) and Under (81U) Frequency Setpoint Ranges

59/27 Overvoltage/Undervoltage

Voltage is also 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 less than generation will result in a rapid rise of potentially damaging voltage. Except for those systems prone to ferroresonance, the voltage waveform will remain essentially sinusoidal, making the use of rms measurement appropriate for these functions. 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. For instantaneous overvoltage operation, IEEE suggests that the first setpoint (with a short time delay) be set at up to 150% of the nominal voltage, and the second setpoint (with a long time delay) 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).

- ▲ **CAUTION:** When 69.3 V is chosen for the VT secondary voltage, 69.3 V is internally converted to 120 V (1 pu) for all calculations and for setting and display purposes. For example, if a pickup of 73 V (1.1 pu) is desired when 69.3 V has been chosen for the VT secondary voltage, this will be displayed and entered as 126.4 V (1.1 pu on 120 V base).

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING*
RMS Overvoltage, 3-Phase (59)			
Magnitude #1, #2	10 – 200 V	1.0 V	132 V
Time Delay #1, #2	1 – 8160 cycles	1.0 cycle	30 cycles
RMS Undervoltage, 3-Phase (27)			
Magnitude #1, #2	10 – 200 V	1.0 V	108 V
Time Delay #1, #2	1 – 8160 cycles	1.0 cycle	30 cycles

* Initial Setting: The value is in setpoint memory until reprogrammed by the operator; functions with two setpoints have only setpoint #1 enabled as shipped from the factory.

TABLE 2-3 Overvoltage (59) and Undervoltage (27) Setpoint Ranges

59I Peak Overvoltage

Unless otherwise noted, an overvoltage relay is presumed to operate based on the rms value of voltage. There is, however, a system phenomenon known as ferroresonance that can occur on a lightly loaded islanded system. As the name implies, a system experiencing ferroresonance is in resonance, but the inductance is highly non-linear, 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. Then, with the peak value of a nominal 120 V sine wave being $120 \times \sqrt{2} = 170$ V, a 1.2 per unit setting would initiate tripping action at $1.2 \times 170 = 204$ V, as instantaneously detected. Note that, because of the nonsinusoidal voltage waveform expected, the rms value of this voltage cannot be so simply calculated as $204 \text{ V}/\sqrt{2} = 144$ Volts, but may be very much less than that value. One suggestion is that this function be set at 1.3 to 1.5 per unit with the time delay set to operate very quickly, i.e., at less than 10 cycles of delay.

- **NOTE:** When 69.3 V is chosen for the VT secondary voltage, 1 pu peak voltage is equivalent to $69.3 \times \sqrt{2} = 98$ V.

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING*
Peak Overvoltage (59I)†			
Magnitude #1, #2	1.05 – 1.50 pu	0.01 pu	1.10 pu
Time Delay #1, #2	1 – 8160 cycles	1.0 cycle	30 cycles
†(Instantaneous voltage magnitude response; intended for ferroresonance protection)			
* Initial Setting: The value is in setpoint memory until reprogrammed by the operator; functions with two setpoints have only setpoint #1 enabled as shipped from the factory.			

TABLE 2-4 Peak Overvoltage (59I) Setpoint Ranges

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

These devices may be adapted in various ways depending upon the location in the circuit and the protection objective. The 59N device is very effective in detecting generator ground faults when generator neutral impedance grounding is used in conjunction with a distribution transformer. In such a high-impedance grounding system, ground faults in the primary system will induce zero-sequence voltages at the generator due to capacitive coupling between the windings of the unit transformer. If the coupling voltage is anticipated to be greater than the 59N relay pickup voltage, a time delay should be used to permit the primary ground relays to clear high-side faults. For good fault sensitivity, the pickup of the 59N function should be about 10 to 16 V. However, because the third and higher harmonic voltages that normally appear at the generator neutral can easily exceed this value, they must be filtered or the relay otherwise be made insensitive to them. Additionally, a greater portion of the generator stator windings can be protected by tuning the 59N function to the fundamental frequency only. For these reasons, the M-0420 59N and 27N functions respond only to the fundamental frequency component while rejecting all harmonics. (This is true regardless of the setting of internal configuration DIP switch 8.)

Other 27N/59N applications, shown in Figures 2-11 and 2-12, 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).

- ▲ **CAUTION:** When 69.3 V is chosen for the VT secondary voltage, 69.3 V is internally converted to 120 V (1 pu) for all calculations and for setting and display purposes. For example, if a pickup of 73 V (1.1 pu) is desired when 69.3 V has been chosen for the VT secondary voltage, this will be displayed and entered as 126.4 V (1.1 pu on 120 V base).

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING*
RMS Overvoltage, Neutral Circuit or Zero Sequence (59N)			
Magnitude #1, #2	10 – 200 V	1.0 V	150 V
Time Delay #1, #2	1 – 8160 cycles	1.0 cycle	30 cycles
RMS Undervoltage, Neutral Circuit or Zero Sequence (27N)			
Magnitude #1, #2	10 – 200 V	1.0 V	60 V
Time Delay #1, #2	1 – 8160 cycles	1.0 cycle	30 cycles

*Initial Setting: The value is in setpoint memory until reprogrammed by the operator; functions with two setpoints have only setpoint #1 enabled as shipped from the factory.

TABLE 2-5 Overvoltage (59N) and Undervoltage (27N) Setpoint Ranges

Ground Fault Detection Using 59N and Broken-Delta VTs

The 59N 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 59N device is inserted, as illustrated in Figure 2-8.

In this case, voltage at 59N in Figure 2-8 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.*)

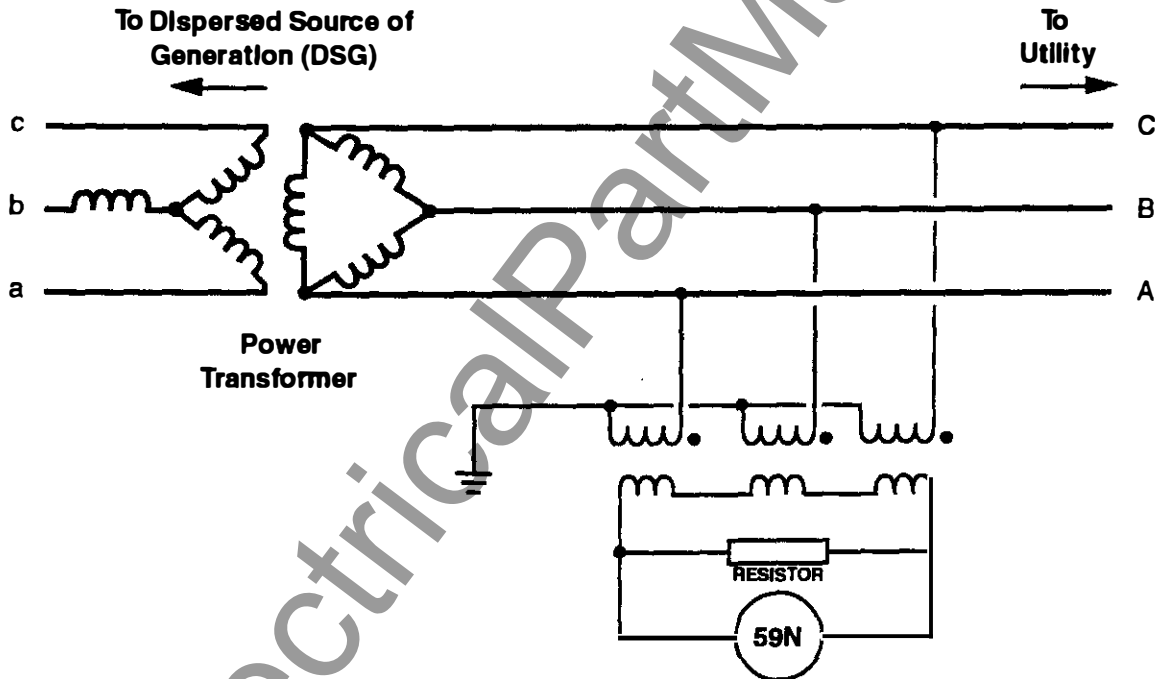


FIGURE 2-8 Ground Fault Detection Using 59N and Broken-Delta VTs

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

An alternate, but not recommended, scheme uses the 27N and 59N devices with one VT rated for line-to-line voltage, but connected from any one phase to ground as shown in Figure 2-9. 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 27N 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 59N.

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.

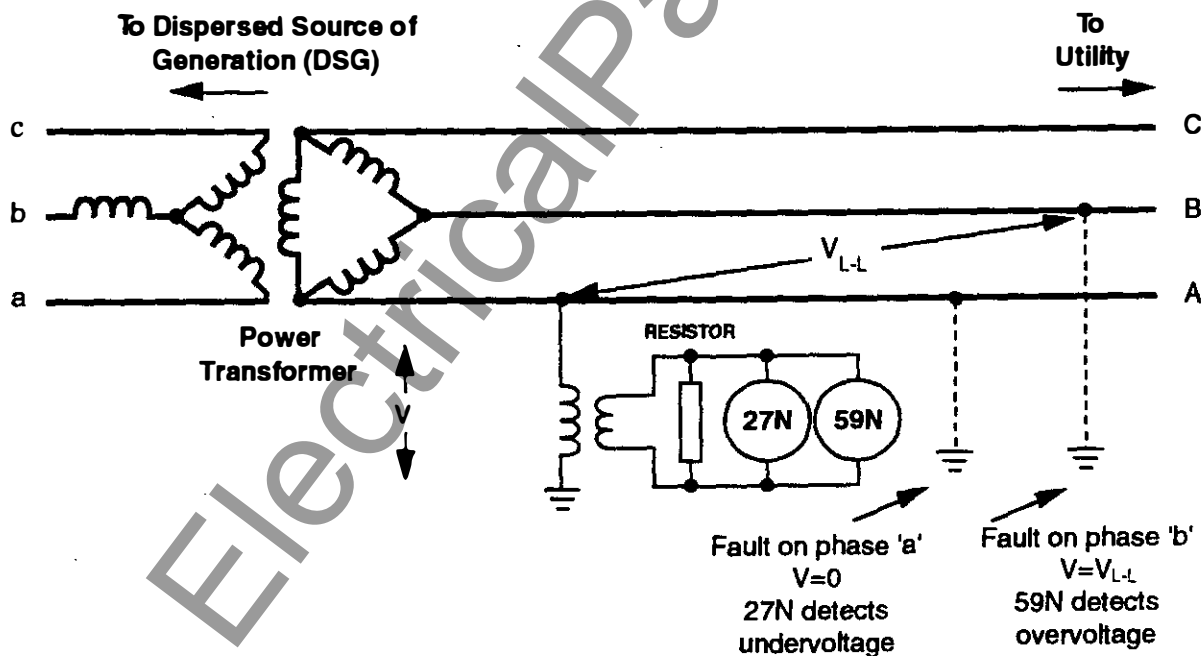


FIGURE 2-9 Ground Fault Detection Using 27N and 59N with One VT

51V Inverse Time Overcurrent, Three-Phase with Voltage Control or Voltage Restraint

Time-overcurrent relays, one per phase, 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 down-stream devices. For this function, four complete series of inverse time tripping characteristics are included, based on the ABB CO and COV curves. This is accomplished in a way that allows the protection engineer to use all the same descriptions and nomenclature which are traditionally used with electromechanical relays. Thus, the four curve families to be chosen are definite time, inverse, very inverse or extremely inverse, which relate to the degree of slope of the basic characteristic curves. In the menu, these are abbreviated as **DEF**, **INV**, **VINV**, and **EINV**. Within each family, the operator selects time dial setting and tap setting through the M-0420 menu, just as though doing so by the time-proven electromechanical means.

The curves available for use are shown in Figures 2-10 through 2-13. They cover a range of from 1.5 to 20 times the tap setting. An additional one-cycle time delay should be added to these curves in order to obtain the relay operating time. For currents beyond 20 times the tap setting, the relay operating time will be the same as the time for 20 times the tap setting; i.e., the relay operates at definite minimum time. 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.

A unique feature of this relay concerns the calculation of the current used for tripping. The current is derived from an rms calculation, but, by user selection, will be computed based on either including or not including the contribution of harmonics to the value. Since it is not well established by the industry whether the calculation should be based simply upon the fundamental frequency component or a broader frequency range, a simple DIP switch setting (No. 8) allows the operator to select either one.

The inverse time overcurrent function can be voltage controlled (VC) or voltage restrained (VR). When voltage restraint is selected, the tap setting of the 51VR is modified continuously according to the voltage inputs as shown in Figure 2-14. 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 as shipped from the factory.) When the generator is connected to the system through a delta/bye transformer, proper voltages (equivalent to the high-side of the transformer) should be used for the 51VR or 51VC element. The M-0420 can internally determine the equivalent high-side voltages of the delta/bye unit transformer, saving auxiliary instrument transformers. The voltage-current pairs used are shown in Table 2-6.

- ▲ **CAUTION:** When 69.3 V is chosen for the VT secondary voltage, 69.3 V is internally converted to 120 V (1 pu) for all calculations and for setting and display purposes. For example, if a pickup of 73 V (1.1 pu) is desired when 69.3 V has been chosen for the VT secondary voltage, this will be displayed and entered as 126.4 V (1.1 pu on 120 V base).

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 2-6 Delta/Wye Transformer Voltage-Current Pairs

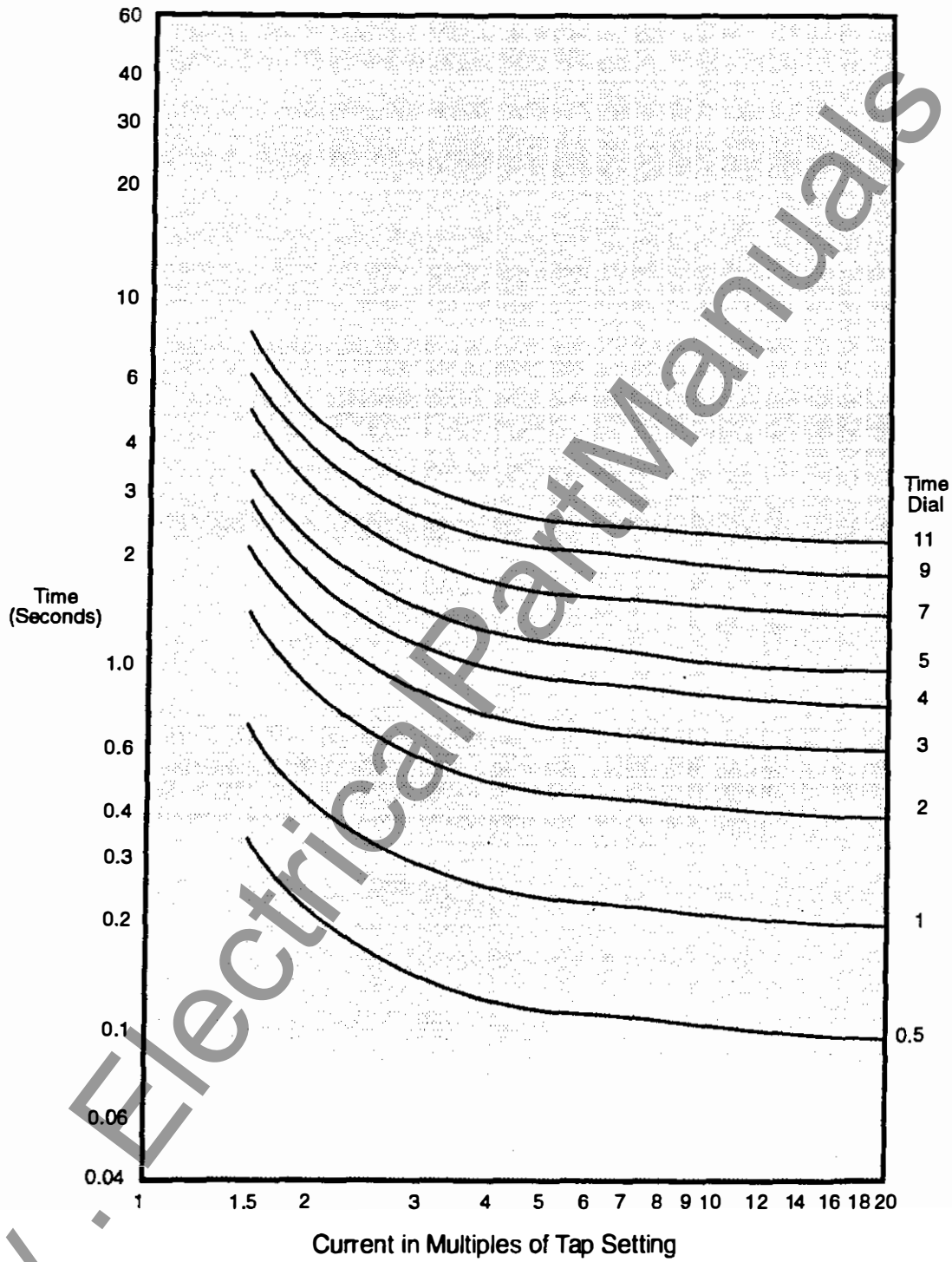
For voltage controlled operation, the function is not active unless the voltage is below the voltage control setpoint, which can be used to help confirm that the overcurrent is due to a system fault. When applied, most users will set voltage control in the range of 0.7 to 0.9 per unit rms voltage. (Voltage control is disabled as shipped from the factory. The initial setting of 1.1 pu also effectively disables this function.)

If the M-0420 is equipped with the optional phase directional overcurrent function (67), the 51V element can be controlled by it, thereby realizing a directional inverse time overcurrent function. The various features of the 51V function, such as voltage control, voltage restraint, voltage transformations (for delta-wye unit transformers), and directional control can be programmed by the operator.

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING*
Inverse Time Overcurrent, 3-Phase, with Voltage Control or Voltage Restraint (51V)			
Characteristic Curves	Definite Time Inverse Very Inverse Extremely Inverse		Very Inverse
Tap Setting	0.50 - 1.45 A 1.50 - 2.90 A 3.00 - 5.80 A 6.00 - 12.00 A	0.05 A 0.10 A 0.20 A 0.50 A	6.0 A
Time Dial Setting	0.5 - 11.0	0.1	5.0
Voltage Control (VC)† or Voltage Restraint (VR)†	10 - 200 V (0.08 - 1.67 pu) Linear Restraint	1 V	132 V (1.1 pu)

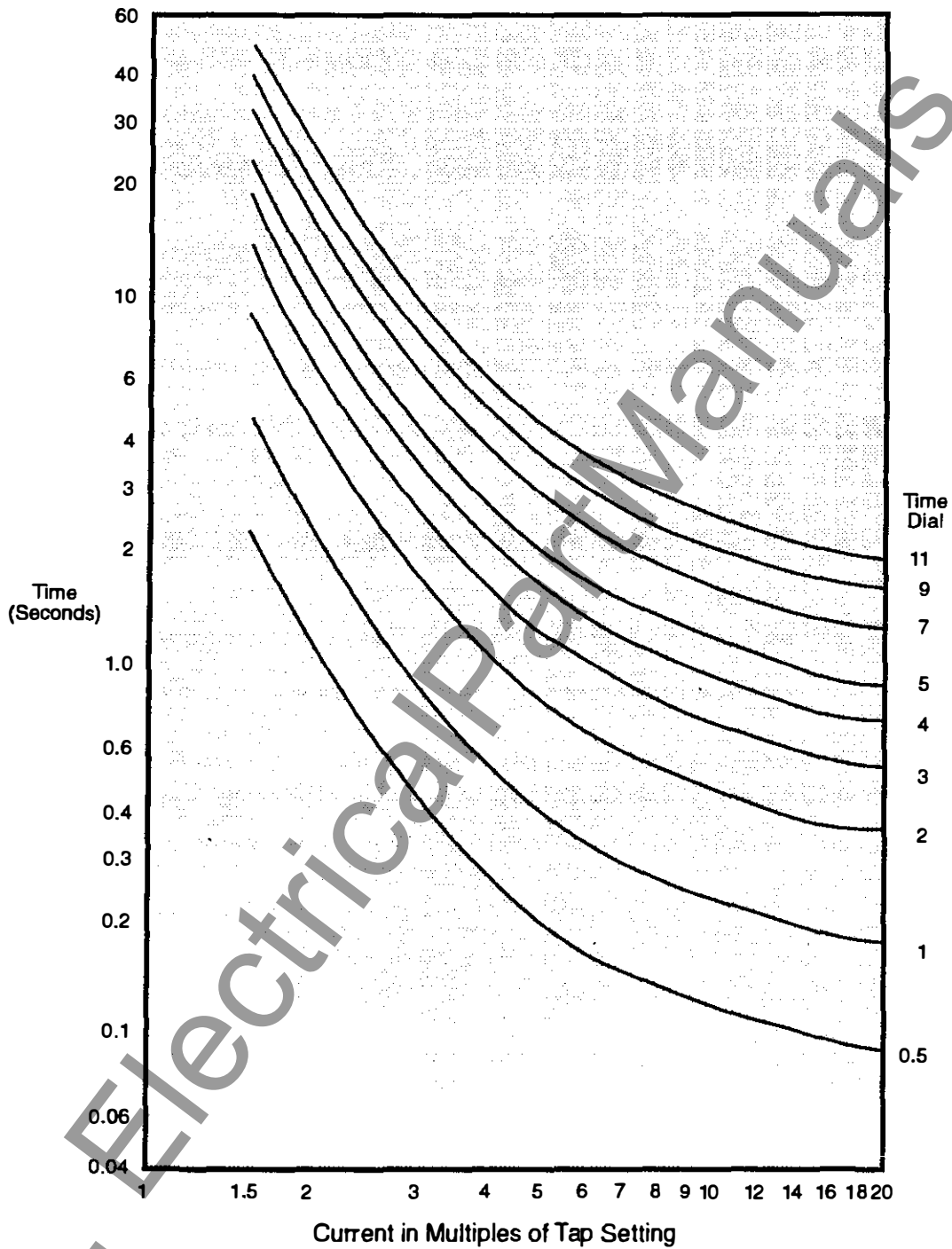
*Initial Setting: The value is in setpoint memory until reprogrammed by the operator.
† Disabled as shipped from the factory.

TABLE 2-7 Inverse Time Overcurrent with Voltage Control/Voltage Restraint (51VC/VR) Setpoint Ranges



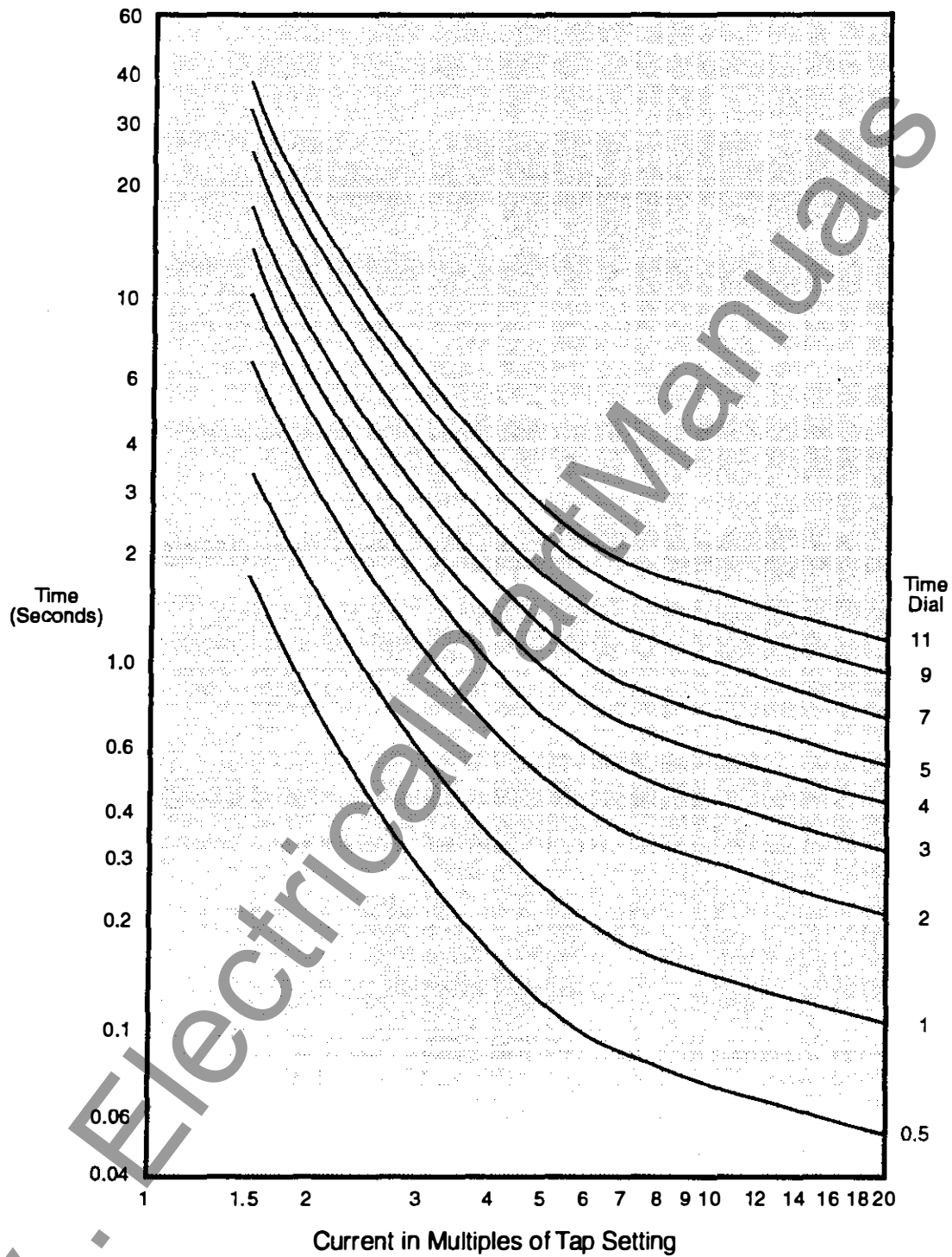
■ NOTE: An additional one-cycle time delay should be added to these curves in order to obtain the relay operating time.

FIGURE 2-10 Definite Time Overcurrent Curve



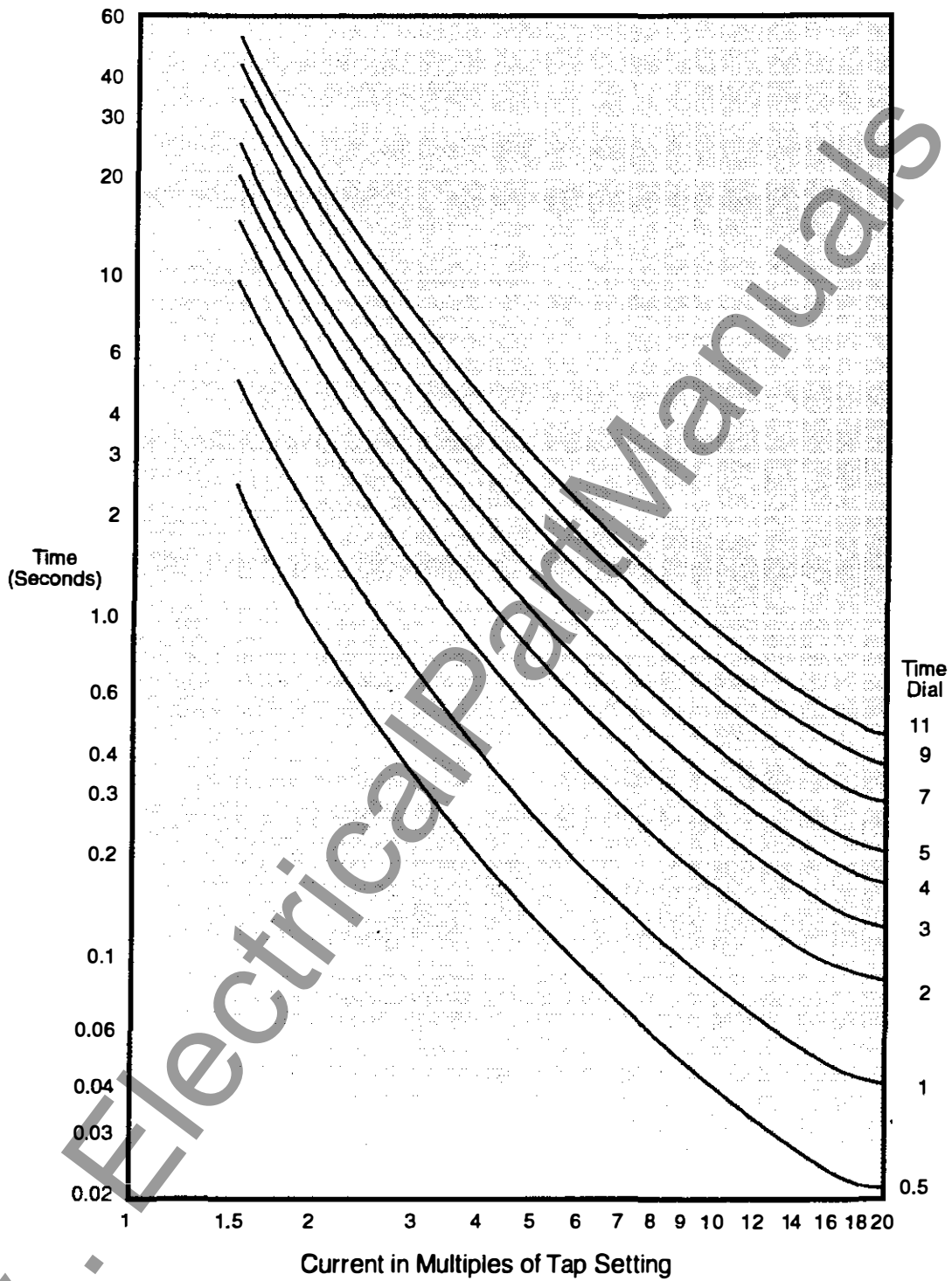
■ NOTE: An additional one-cycle time delay should be added to these curves in order to obtain the relay operating time.

FIGURE 2-11 Inverse Time Overcurrent Curve



■ **NOTE:** An additional one-cycle time delay should be added to these curves in order to obtain the relay operating time.

FIGURE 2-12 Very Inverse Time Overcurrent Curve



■ NOTE: An additional one-cycle time delay should be added to these curves in order to obtain the relay operating time.

FIGURE 2-13 Extremely Inverse Time Overcurrent Curve

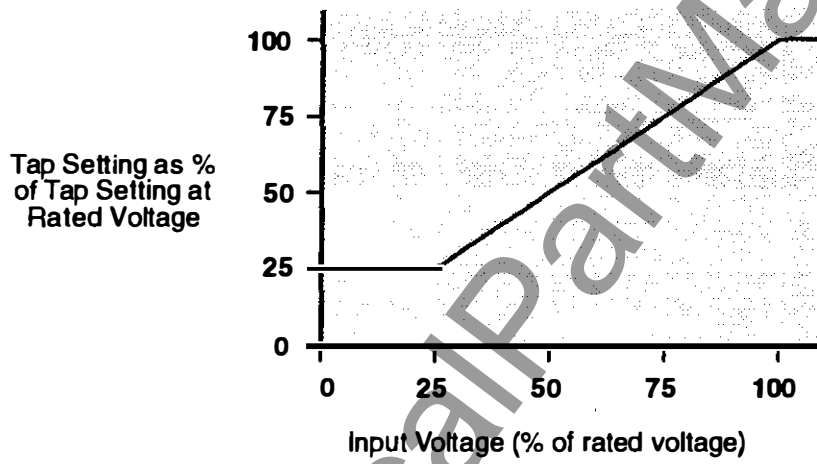


FIGURE 2-14 Voltage Restraint (51VR) Characteristic

51N Inverse Time Overcurrent, Neutral Circuit

This is identical in function to 51V except that, since it is intended for use in the neutral, it will operate by detecting zero sequence current that flows during ground faults, and can usually be set to a more sensitive value than those on the individual phases. (Voltage control or voltage restraint are not provided in the neutral circuit since they are not needed.) When used for generator ground fault protection, 51N provides alternative or backup ground-fault protection to 59N. This relay must be set above the maximum zero sequence current that normally flows in the generator neutral. A typical setting would be 1.5 to 2 times the expected maximum zero sequence current value.

If the 51N function is not used at the generator neutral circuit, it can be used to detect ground faults on the system by monitoring the current through the ground connection of a wye-connected power transformer.

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING*
Inverse Time Overcurrent, Neutral (51N)			
Characteristic Curves	<i>Definite Time Inverse Very Inverse Extremely Inverse</i>		<i>Very Inverse</i>
Tap Setting	0.50 – 1.45 A 1.50 – 2.90 A 3.00 – 5.80 A 6.00 – 12.00 A	0.05 A 0.10 A 0.20 A 0.50 A	6.0 A
Time Dial Setting	0.5 – 11.0	0.1	5.0
<i>*Initial Setting: The value is in setpoint memory until reprogrammed by the operator.</i>			

TABLE 2-8 Inverse Time Overcurrent Neutral (51N) Setpoint Ranges

50/50N Instantaneous Overcurrent, Three-Phase and Neutral Circuits

The instantaneous phase (50) and neutral overcurrent (50N) functions provide fast tripping times for high fault currents. The settings for 50 and 50N should be chosen such that they will not respond to faults on the adjacent system. Similar to 51N, the 50N function can also be applied either at the generator neutral or transformer neutral.

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING*
Instantaneous Overcurrent, 3-Phase (50)			
Magnitude	1.0 – 240.0 A†	0.1 A	10.0 A
Trip Time Response	2 cycles max.		
† Not to exceed 20 times the maximum phase overcurrent tap setting for the range chosen for 51V.			
Instantaneous Overcurrent, Neutral (50N)			
Magnitude	1.0 – 240.0 A†	0.1 A	10.0A
Trip Time Response	2 cycles max.		
† Not to exceed 20 times the maximum phase overcurrent tap setting for the range chosen for 51N.			
* Initial Setting: The value is in setpoint memory until reprogrammed by the operator.			

TABLE 2-9 Instantaneous Overcurrent (50) and Instantaneous Overcurrent (50N) Neutral Setpoint Ranges

46 Negative Sequence Overcurrent

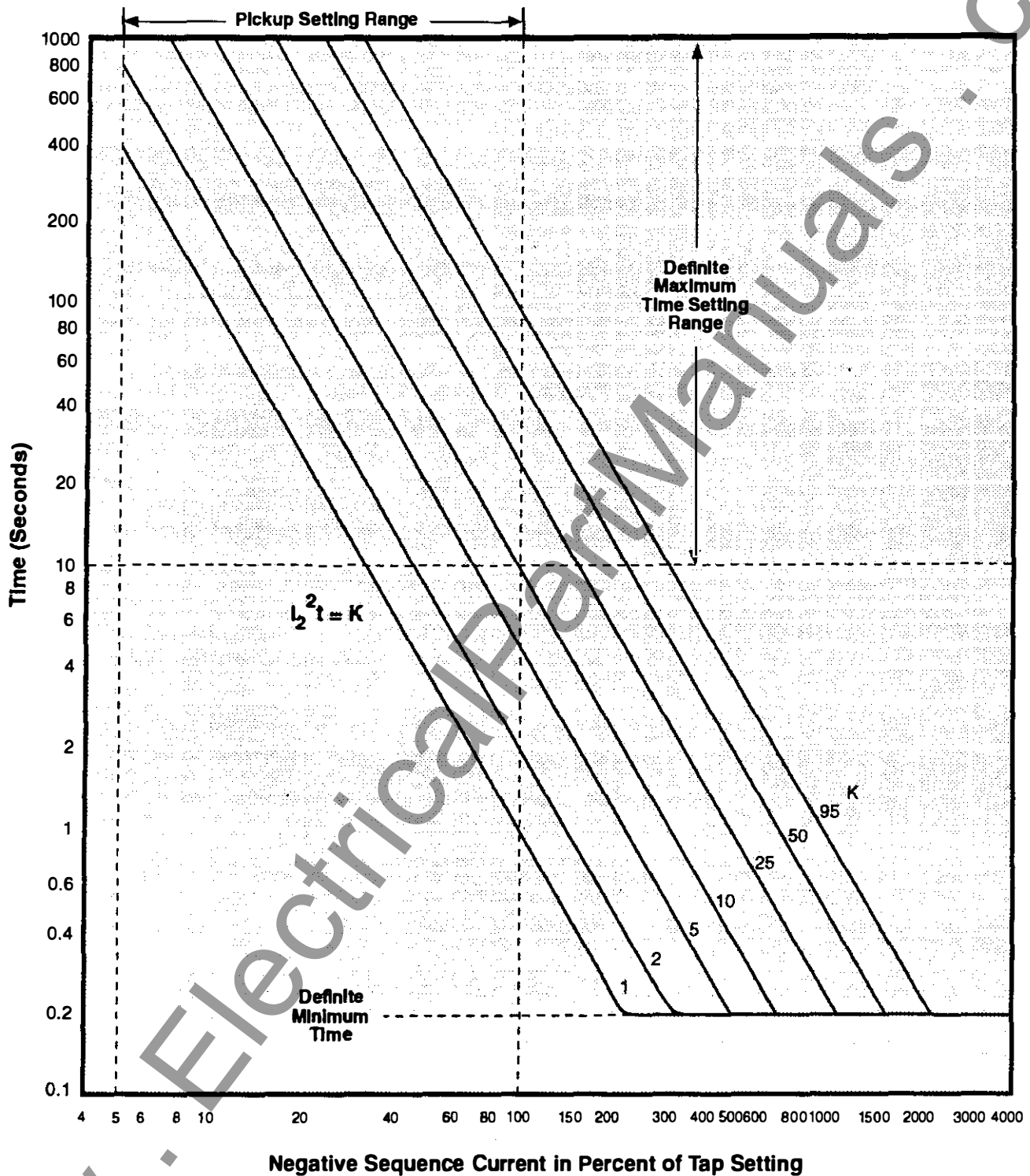
Unbalanced faults and other system conditions can cause unbalanced three-phase currents in the generator. The negative sequence components of these currents cause double-frequency currents in the rotor that can lead to severe overheating and damage. The negative sequence overcurrent function is set to operate before the specified limit for the machine is reached. As established by the ANSI standards, limits are expressed as $I_2^2 t = K$, where I_2 is the negative sequence current in multiples of the tap setting, t is the operating time of the negative sequence relay element in seconds, and K (the time dial setting) is a constant established by the machine design.

As implemented in the M-0420, the negative sequence overcurrent function has a tap setting variable from 1 A to 5 A and a pickup setting variable from 5% to 100%. Also, the value of K can vary from 1 to 95, making this function suitable for any generator size.

The minimum delay for this function is factory set at 12 cycles to avoid nuisance tripping. The maximum delay can be set by the user to reduce the tripping times for modest imbalances. An important feature that helps protect the generator from damage due to recurring imbalances is a linear reset characteristic: when I_2 decreases below the pickup value, the trip timer takes 4 minutes to reset from its 100% trip level. Figure 2-15 illustrates the inverse time characteristic of the negative sequence current function.

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING*
Negative Sequence Overcurrent (46)			
Tap Setting	1.0 – 5.0 A	0.1 A	5.0 A
Pickup as % of Tap Setting	5 – 100%	1%	50%
Time Dial Setting	1 – 95	1.0	25.0
Definite Maximum Time to Trip	600 – 60,000 cycles	5 cycles	10,000 cycles
* Initial Setting: The value is in setpoint memory until reprogrammed by the operator.			

TABLE 2-10 Negative Sequence Overcurrent (46) Setpoint Ranges



■ **NOTE:** These curves are valid only for cases where the phase current is less than 30 A (A/D converter full scale). When the phase current exceeds 30 A, the actual times will be longer than the ones shown here.

FIGURE 2-15 Negative Sequence Overcurrent Inverse Time Characteristic

32 Directional Power, Three-Phase

The implementation of the directional power function is straightforward, issuing 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 0.02 pu to 3.0 pu.

The reverse power function has a single-phase option that, when selected, can detect reversal of power in anyone phase. (This function is available only with the line-to-neutral voltage option selected on the internal configuration DIP switch.)

The minimum inherent time delay of the relay to a reversal of power is 0.75 cycle (selected by choosing the high-speed setting), and may be adjusted by the user up to 8160 cycles of intentional delay.

For generator protection, with VT and CT connections as illustrated in Figure 2-5, reverse power is defined as power flow into the generator, forward power as power flow out. This function provides protection against generator motoring (power flowing into the generator). 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 power flow.

The base volt-amperes per unit for line-to-line and line-to-neutral operation (selected via the internal configuration DIP switch) are derived as follows:

Line-to-Line Voltage Input Option

	120 V secondary VTs	69.3 V secondary VTs
Base volt-amperes (1 pu)	$= \sqrt{3} \times V_L \times I_L$	$= \sqrt{3} \times V_L \times I_L$
	$= \sqrt{3} \times 120 \times 5$	$= \sqrt{3} \times 69.3 \times 5$
	$= 1039 \text{ VA}$	$= 600 \text{ VA}$

These volt-amperes are used as the base value (1 pu) for forward and reverse power relay functions and for display of real and reactive power.

Line-to-Neutral Voltage Input Option

The forward power function and the display of real and reactive power use three-phase volt-amperes as the base:

	120 V secondary VTs	69.3 V secondary VTs
Base volt-amperes (1 pu)	$= 3 \times V_{\text{Phase}} \times I_{\text{Phase}}$	$= 3 \times V_{\text{Phase}} \times I_{\text{Phase}}$
	$= 3 \times 120 \times 5$	$= 3 \times 69.3 \times 5$
	$= 1800 \text{ VA}$	$= 1039 \text{ VA}$

The reverse power function has single-phase/three-phase options. The base volt-amperes (1 pu) for these options are as follows:

Three-phase (line-to-line voltage input) reverse power base volt-amperes:

120 V secondary VTs	69.3 V secondary VTs
$= 1800 \text{ VA}$	$= 1800/\sqrt{3} = 1039 \text{ VA}$

Single-phase (line-to-neutral voltage input) reverse power base volt-amperes:

120 V secondary VTs	69.3 V secondary VTs
$= 600 \text{ VA}$	$= 600/\sqrt{3} = 346 \text{ VA}$

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING*
Directional Power, 3-Phase (32)			
Forward Power Flow Magnitude	0.02 – 3.0 pu	0.01 pu	3.0 pu
Time Delay	1 – 8160 cycles	1.0 cycle	30 cycles
Reverse Power Flow Magnitude	0.02 – 3.0 pu	0.01 pu	3.0 pu
Time Delay †	1 – 8160 cycles	1.0 cycle	30 cycles
† Time Delay, High-Speed setting has no intentional delay; response time = 0.75 cycle ±0.5 cycle.			
* Initial Setting: The value is in setpoint memory until reprogrammed by the operator.			

TABLE 2-11 Directional Power (32) Setpoint Ranges

67 Phase Directional Overcurrent Option

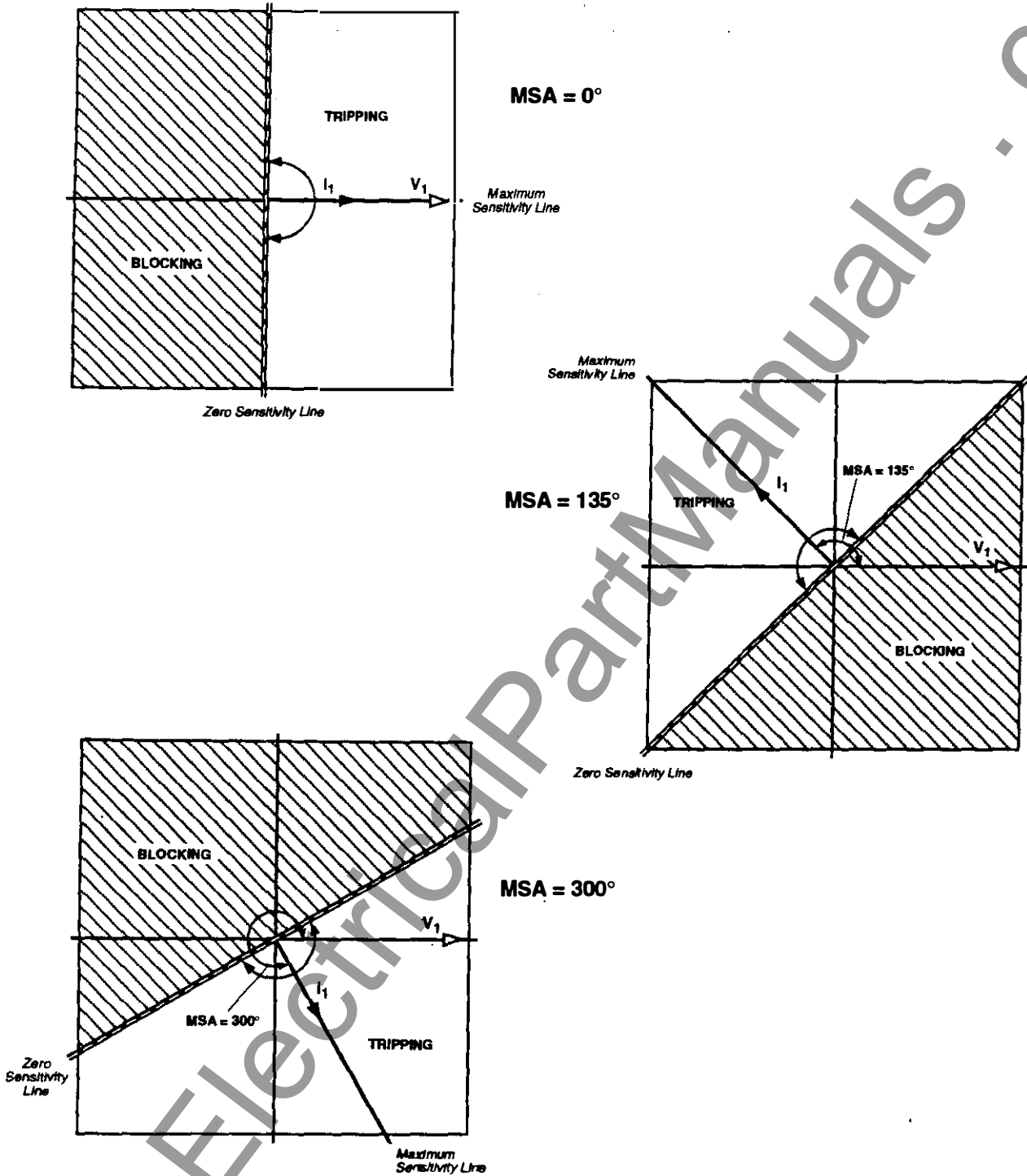
For intertie protection applications, the phase directional overcurrent relay allows greater selectivity for utility system faults, since the directional element can be set to look toward the utility system. As a generator protection relay, the 67 function, looking into the generator, can provide protection for accidental energization of the generator on turning gear. When line-side CT inputs are used, this function can also provide high-speed protection for generator winding faults. However, with line-side CTs, the protection for winding faults during off-line operation (when the breaker is open) is not available from the 51V, 50, 46, or 67 functions.

A single directional element is used to provide directional discrimination for all types of phase-to-phase and three-phase faults. The directional element is 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). The directional element is equipped with a pre-fault voltage memory of eight cycles to provide correct directional discrimination for bolted three-phase faults.

Examples of the tripping and blocking directions of the directional element are shown in Figure 2-16.

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING*
Phase Directional Overcurrent (67)			
Overcurrent Element			
Magnitude	1 – 240* A	0.1 A	10.0 A
Time Delay **	1 – 8160 cycles	1.0 cycle	30 cycles
Directional Element			
Maximum Sensitivity (Torque) Angle (MSA)	0° – 359°	1°	85°
Sensitivity at MSA	0.5 VA (positive sequence)		
Prefault Memory	8 cycles (positive sequence voltage)		
Polarizing Quantities	Positive sequence voltage and positive sequence current.		
*Not to exceed 20 times the maximum tap setting of the range into which the 3-phase overcurrent tap setting chosen for 51V falls.			
**High Speed setting has no intentional delay; response time = 0.75 ± 0.5 cycle.			

TABLE 2-12 Phase Directional Overcurrent (67) Setpoint Ranges



■ **NOTE:** V_1 = Positive Sequence Voltage; I_1 = Positive Sequence Line Current (at MSA). For forward power, unity power factor condition V_1 and I_1 are in-phase both for line-to-ground and line-to-line VT input conditions (with line-to-line VTs, thirty degrees phase shift is corrected internally in the software).

FIGURE 2-16 Phase Directional Overcurrent (67) Trip Characteristics

79 Reconnect Time Delay

The reconnect relay is a permissive output that may be set to close from 1 to 8160 cycles after all parameters are within limits. The reconnect time delay may also be used as a seal-in timer on the trip output contact.

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING*
Reconnect Time Delay (79)			
Reconnect (Close) Relay	1 – 8160 cycles	1.0 cycle	60 cycles
<i>* Initial Setting: The value is in setpoint memory until reprogrammed by the operator.</i>			

TABLE 2-13 Reconnect Time Delay (79) Setpoint Ranges

60FL VT FUSE-LOSS DETECTION

Since some M-0420 relay functions may otherwise send an inadvertent trip signal when a voltage-transformer fuse is blown, the M-0420 detects the loss of both internal and external VT fuses. The status of the fuses can be determined from the front panel or via remote communications.

For internal detection of a fuse-loss condition, an algorithm compares positive and negative sequence voltages and currents. The presence of negative sequence voltage, accompanied by the absence of negative sequence current is considered to signal the fuse-loss condition. The actual algorithm used is provided below:

A fuse-loss condition is considered to exist when

$$(V_1 > 12.8 \text{ volts}) \text{ and } (V_2 > 0.33 V_1) \text{ and } [(I_2 < 0.167 I_1) \text{ or } (I_1 < 0.33 \text{ amps})]$$

where V_1 = positive sequence voltage, V_2 = negative sequence voltage, I_1 = positive sequence current, and I_2 = negative sequence current

The $V_1 > 12.8 \text{ V}$ condition determines if the VT inputs are applied to the relay. For a VT fuse failure condition, the negative sequence voltage is always greater than 50% of the positive sequence voltage; hence, $V_2 > 0.33 V_1$ provides a reliable blown VT fuse indication. However, negative sequence voltage will also be present during phase-to-phase fault conditions. The blown VT fuse condition is distinguished from the fault condition by verifying that $I_2 < 0.167 I_1$. Finally, determining if $I_1 < 0.33 \text{ A}$ prevents the VT fuse output contacts from chattering when a VT fuse blows during a no-load condition.

The above logic can reliably detect a blown VT fuse. However, for any specific application, if the above logic cannot reliably be used (such as when the current inputs to the relay are not connected, the sustained positive sequence current in a phase-to-phase fault is less than 0.33 A, or the negative sequence currents are not present during phase-to-phase or ground fault conditions ($I_2 < 0.167 I_1$)), the internal VT fuse loss detection logic can be disabled via the **CONFIGURE V.T. FUSE LOSS** menu under the **CONFIGURE RELAYS** menu selection. In these cases, and since the detection algorithm cannot detect the condition of all three fuses being blown (two in case of open delta), the M-0420's external contact input on terminal 33—usually from a supplemental device 60—can be used as an external indication of a blown VT fuse.

The status of the fuses can be determined by selecting **MONITOR FUSE STATUS** under the **MONITOR STATUS** menu.

VT FUSE-LOSS BLOCKING

If the internal fuse-loss detection is enabled, or the external fuse loss input is connected, the M-0420 will provide user-selectable blocking of the 27, 51V, 67, and 32R functions upon detection of a VT fuse-loss condition. Additionally, the M-0420 will send an output contact indicating the blown fuse condition (**VT Fuse Loss** output). This external contact can be used to block other relays which may be affected by the blown fuse condition (for example, a loss-of-field relay). Internal VT fuse-loss detection and function blocking can be selected via the **CONFIGURE V.T. FUSE LOSS** menu under the **CONFIGURE RELAYS** menu selection.

If blocking of the 51 V function is enabled when the blown VT fuse condition is detected, the M-0420 will disable 51 VC (if VC is enabled) or disable VR of 51 VR (keeping the tap setting at the value established for the rated voltage input).

If blocking of the 67 function is enabled and the directional element of the 67 function is being used to provide directional control of the 51V function, the 51V function will be effectively blocked along with 67 during a blown-fuse condition.

When the high-speed setting has been selected for the 32R or 67 functions, the respective blocking function should not be enabled.

FAULT RECORDER

The fault recorder provides comprehensive fault data recording for all monitored waveforms (at 16 samples per cycle) and status inputs. Fault data can be downloaded via the RS-232C ports to any MS-DOS personal computer running the M-0429A BECOCOM™ Communications Software package. Once downloaded, the waveform data can be examined and printed using the M-0428A BECOPLOT™ Fault Data Analysis Software package.

Operation

The fault recorder can be either armed or disarmed; if armed, it can be triggered either manually through serial communications via BECOCOM or automatically via the 52b status input. When armed and untriggered, the recorder continuously records waveform data, keeping the most recent 96 cycles of data (at 16 samples per cycle) in its memory. When triggered, the recorder continues recording for a period selected by the operator and then goes to unarmed mode, keeping the 96-cycle snapshot of waveform data in its memory for downloading via the BECOCOM communications software. Rearming the fault recorder restarts the process (overwriting the stored fault data). You can determine the status of the fault recorder (whether armed or not, and if armed, whether triggered or not) through the front panel or via remote communications using BECOCOM.

- **NOTE:** The fault recorder is initially disarmed after power up.

Auto-Rearming

The fault recorder can also be set to rearm itself automatically when the relay detects a closing breaker via the 52b input. When auto-rearming is enabled, the fault recorder is armed when the breaker closes (as indicated by the 52b input).

- ▲ **CAUTION:** The previous fault record is lost once the recorder is rearmed. *When auto-rearming is enabled, the fault record must be downloaded while the breaker is open.*

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3 FRONT PANEL CONTROLS

INTRODUCTION

The M-0420 has been designed to be quick and easy for you to set and interrogate. An integral part of this design is the layout and function of the front panel indicators and controls, illustrated in Figure 3-1. These controls logically fall into two groups: user interface indicators and controls, and target/status indicators and controls.

USER INTERFACE INDICATORS AND CONTROLS

The user interface indicators and controls consist of the Liquid Crystal Display, the **SELECT FUNCTION** and **ENTER SETPOINT** LEDs, the left- and right-arrow pushbuttons, the **EXIT** and **ENTER** pushbuttons, and the rotary knob. You use these controls to navigate the system software and set and interrogate the unit. Detailed information on using these controls is provided in Chapter 4, **Operation**.

LIQUID CRYSTAL DISPLAY

To assist you in setting and interrogating the M-0420, the LCD displays menus that guide you to the desired M-0420 function or setpoint value. These menus consist of two lines. The bottom line lists lower case abbreviations of each menu selection with the current menu selection highlighted by being in uppercase. The top menu line provides an expanded description of the current menu selection.

When you're not using the controls, and the relay has not tripped, the LCD is blanked and remains blanked until you press **ENTER**, at which time the first-level menu is displayed. If the unit has tripped, the LCD cycles through a sequence of screens summarizing the trip status conditions until **ENTER** is pressed.

SELECT FUNCTION LED

The red **SELECT FUNCTION** LED is lit when a menu is displayed on the LCD, prompting you to choose a menu selection using either the left- and right-arrow pushbuttons or the rotary knob.

ENTER SETPOINT LED

The red **ENTER SETPOINT** LED lights to prompt you to enter a value, such as a setpoint magnitude or time delay. Enter or change values by using the left- and right-arrow pushbuttons and/or the rotary knob to increment or decrement the currently displayed value.

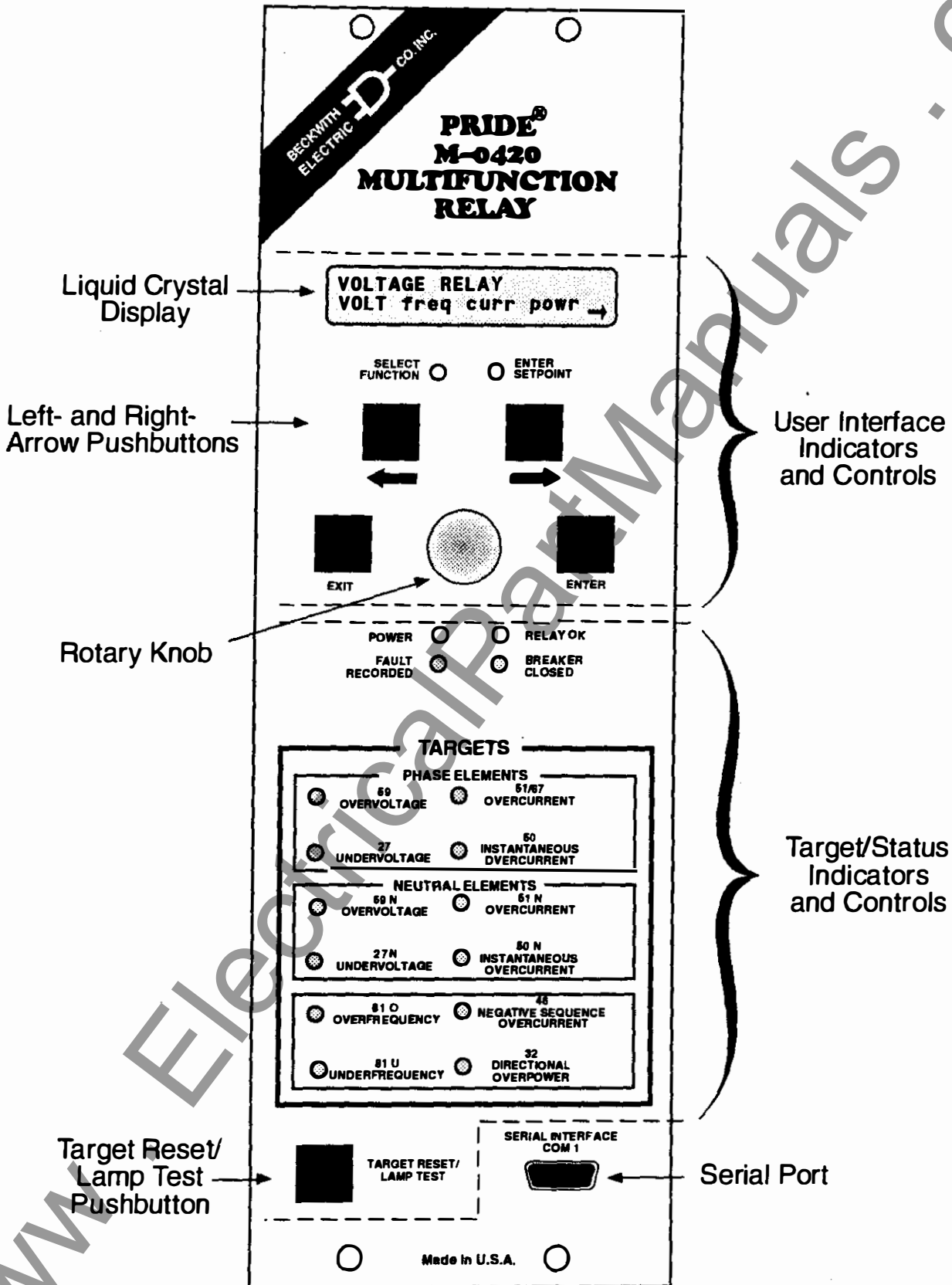


FIGURE 3-1 M-0420 Front Panel

LEFT- AND RIGHT-ARROW PUSHBUTTONS

You use the left- and right-arrow pushbuttons to choose among the menu selections displayed and, when entering values, to select the digit (by moving the cursor) of the displayed setpoint that will be incremented or decremented by turning the rotary knob.

EXIT PUSHBUTTON

Use the **EXIT** pushbutton to exit from a displayed screen and return to the immediately preceding menu.

ENTER PUSHBUTTON

The **ENTER** pushbutton 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 **ENABLE** or **DISABLE** a function.

ROTARY KNOB

Use the rotary knob to increment (by rotating clockwise) or decrement (by rotating counterclockwise) a value currently displayed. (This new value is not stored and does not affect the unit's calculations until **ENTER** is pressed.) For values with a large range, use the left- and right-arrow pushbuttons to move the cursor (an underline) to any digit. Incrementing and decrementing will then start with the underlined digit.

You can also use the rotary knob instead of the left- and right-arrow pushbuttons to choose among menu selections displayed on the LCD.

TARGET/STATUS INDICATORS AND CONTROLS

The target/status indicators and controls consist of the **POWER** and **RELAY OK** LEDs, the **FAULT RECORDED** and **BREAKER CLOSED** LEDs, the twelve target LEDs, and the **TARGET RESET/LAMP TEST** pushbutton.

POWER LED

The green **POWER LED** indicator will remain lit whenever power is applied to the unit.

RELAY OK LED

The green **RELAY OK LED** is under control of the M-0420 microprocessor. For units having software version 4.00 and above, you can program this LED either to flash or to remain on continuously when the relay is functioning properly. To make this selection, go to the **SETUP UNIT** menu, use the right-arrow pushbutton or rotary knob to display the **RELAY OK LED FLASH** menu, and select either **DISABLE** or **ENABLE**.

FAULT RECORDED LED

The red **FAULT RECORDED LED** will light to indicate that fault data has been recorded in the unit's memory in response to a 52b breaker open status, if the fault recorder has been armed. You can arm or disarm the fault recorder using the **FAULT RECORDER** menu selection.

BREAKER CLOSED LED

The red **BREAKER CLOSED LED** will light to indicate when the breaker status input (52b) is open.

TARGET INDICATORS AND TARGET RESET/LAMP TEST PUSHBUTTON

Normally, the twelve red target LEDs are not lit. If the unit trips, the LEDs corresponding to the cause(s) of the trip will light and stay lit until reset. Pressing and releasing the **TARGET RESET/LAMP TEST** pushbutton will momentarily light all LEDs (providing a means to test them) and reset the target LEDs if the trip condition is not present. Detailed information about the cause of the last five trips is, however, retained in the unit's memory for access through the display via the **VIEW TARGET HISTORY** menu.

Pressing and holding the **TARGET RESET/LAMP TEST** pushbutton will display the pick up status of the relay functions.

SERIAL INTERFACES (COM 1 AND COM 2)

The **SERIAL INTERFACE COM 1** port is a standard 9-pin RS-232C communications port. This port will normally be used for local setting and interrogating of the M-0420 via a portable computer. An additional port, **COM 2**, is available at the rear of the M-0420. This 25-pin port will normally be used for remote setting and interrogation of the M-0420 via a modem and a compatible communications protocol. Detailed information on the use of the communications ports is provided in Appendix C, **Communications** and the M-0429A BECO-COM™/M-0428A BECO PLOT™ User's Guide.

4 OPERATION

INTRODUCTION

While the M-0420 is a sophisticated unit that performs a number of complex functions, care has been taken to make it easy to use. This chapter provides general information on the software flow and the use of the front panel controls to maneuver through the menus, enter values, and set and interrogate the unit. Figure 4-1 illustrates the overall software flow. Detailed information on each menu selection is provided in Chapter 5, **MENU REFERENCE**.

SOFTWARE FLOW

POWER-ON SELF-TEST AND STATUS SCREENS

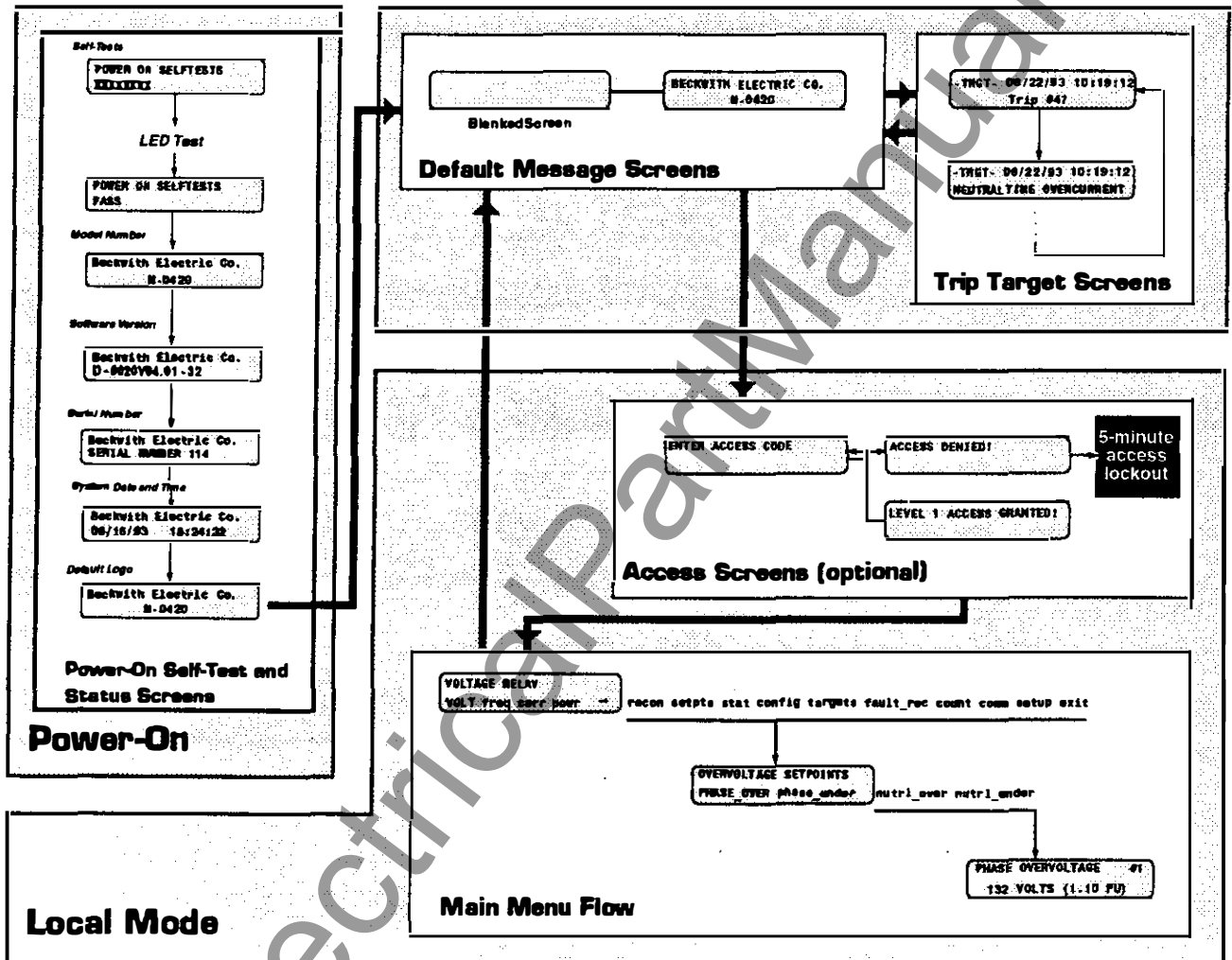
Each time it is powered up, the M-0420 performs a number of self-tests to ensure its correct operation. During the self-tests, the display presents a lower-case "x" for each test successfully executed. When all tests have been executed successfully, it will briefly display **PASS** and then a series of unit status screens, including the Beckwith Electric Co. copyright notice, the software version number, the serial number of the unit, the date and time as set in the system clock, and the default user logo (Beckwith Electric Co.). (Figure 4-2 illustrates this sequence of screens.) If any test should fail, an error code will be displayed and the unit will not allow operation to proceed. In such a case, note the error code and contact the factory. A list of error codes and their descriptions is provided in Appendix B, **Self-Test Error Codes**.

DEFAULT MESSAGE SCREENS

Normally, when the M-0420 is powered and unattended, the display is blanked to increase its lifespan. The display is automatically blanked after exiting from the main menu and from *most* other screens after 5 minutes of unattended operation.

However, if the unit has tripped and has not been reset, it will display the time and date of the trip and will automatically cycle through status screens for each applicable target. (This sequence is illustrated in Figure 4-3.) In either case, pressing **ENTER** will begin local mode operation, displaying the access code entry screen or, if no access code has been defined, the first-level menu.

- **NOTE:** Communication through the front-and-rear-panel communication ports is suspended while the unit is in local mode. To resume communication and ensure security, you should always exit from the main menu after configuring or interrogating the M-0420 from the front panel.



■ NOTE: Communications through the front- and rear-panel communications ports is suspended while the M-0420 is in local mode.

FIGURE 4-1 Software Flow

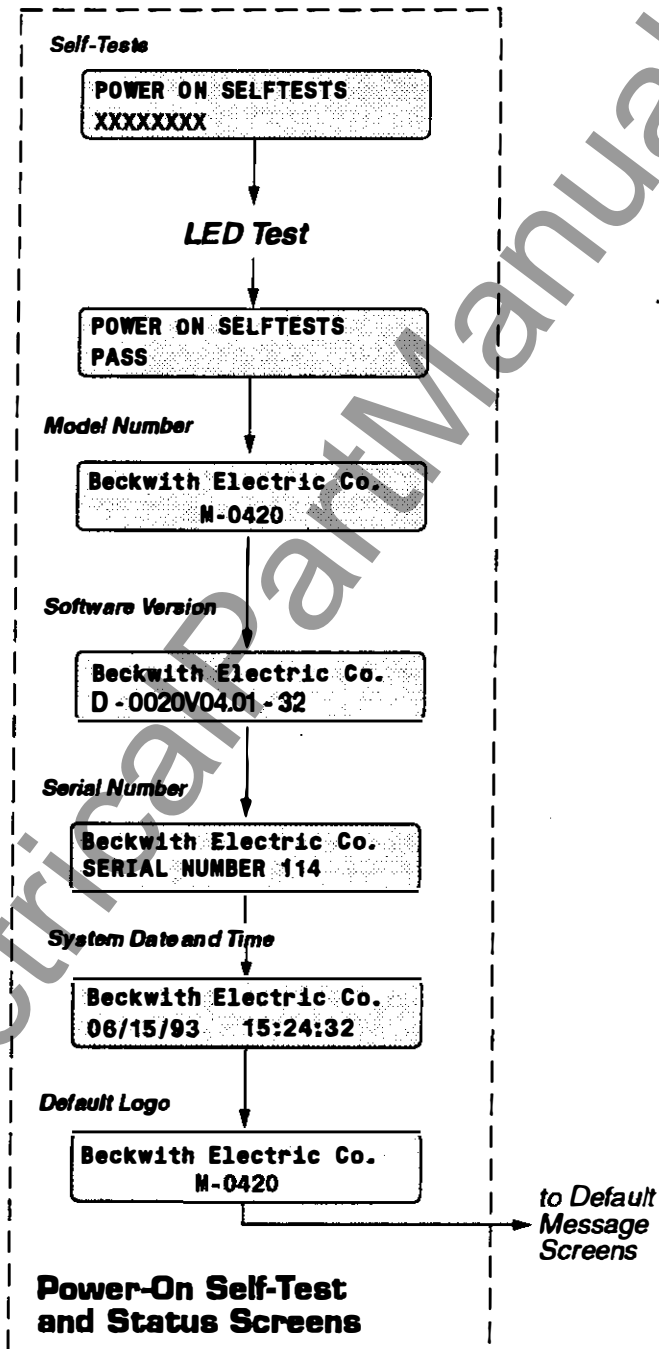
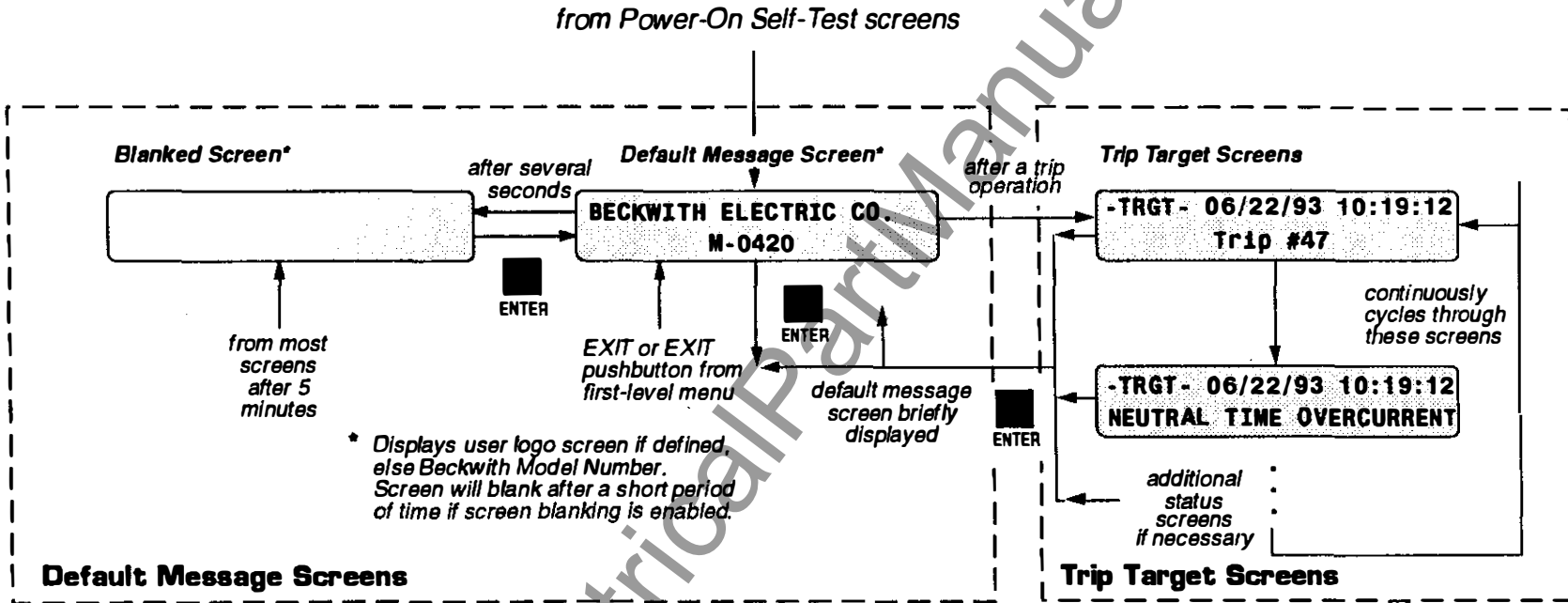


FIGURE 4-2 Power-On Self-Test and Status Screens

FIGURE 4-3 Default Message Screens



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ACCESS SCREENS

To prevent unauthorized access to the M-0420 functions, the software has the provision for assigning access codes. If access codes have been assigned, the access code entry screen, illustrated in Figure 4-4, will be displayed after **ENTER** is pressed from the default message screen (see above). The M-0420 is shipped with the access code feature disabled.

If a valid access code is entered, the unit will notify the user that access has been granted. However, on the third entry of an invalid code the unit will lock out access through the front panel for five minutes. Detailed information on defining and entering access codes is provided below and in Chapter 5, **Menu Reference**.

MENU FLOW

If access is granted, the unit will display the first-level menu. This left-to-right scrolling menu provides access to a second level of menus which in turn provide access to the M-0420 functions. Figure 4-5 illustrates the relationship between the menu levels and the use of the front panel controls to navigate between them. Detailed information on the use of the front panel controls for moving between menus is provided below.

MOVING BETWEEN MENUS

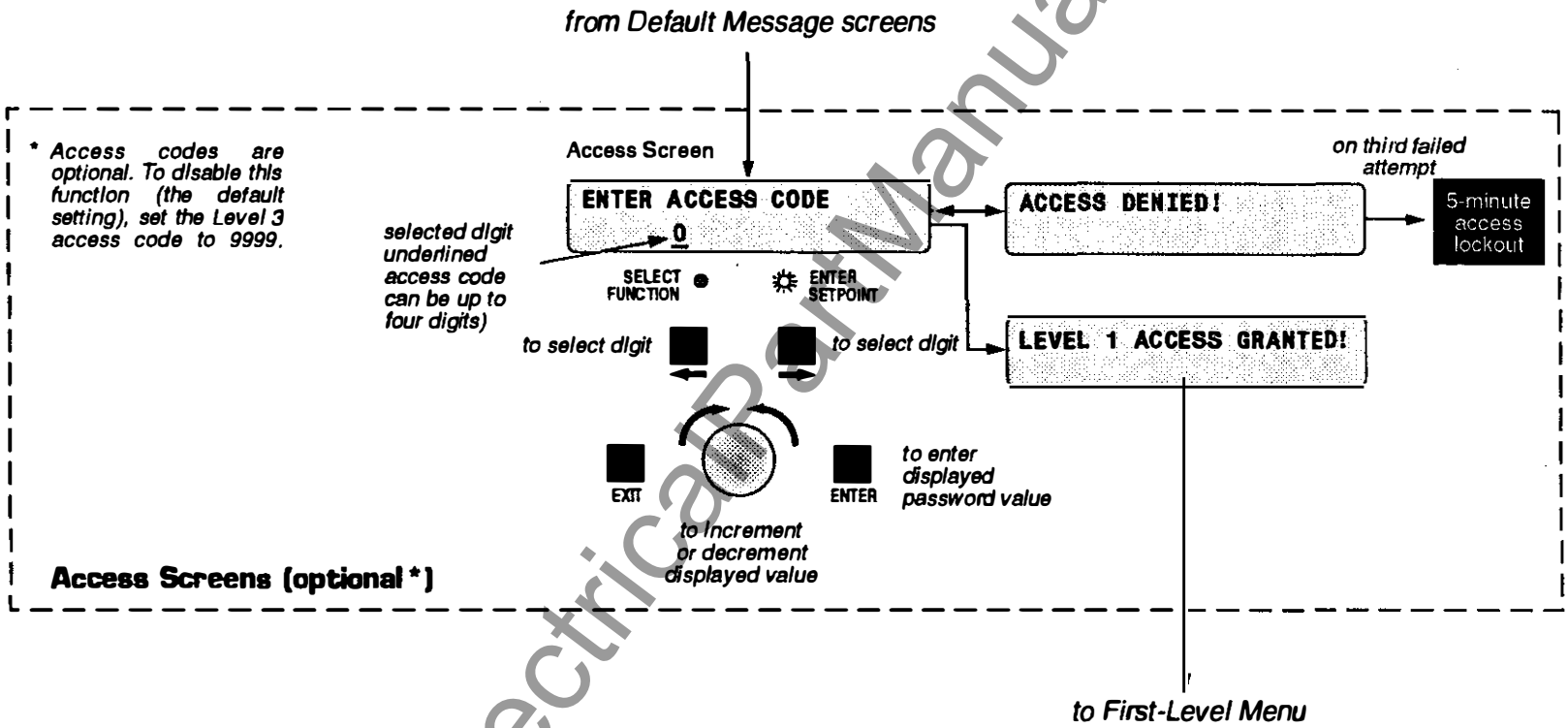
As shown in Figure 4-5, each menu has two lines. On the bottom line appear lower case abbreviations of each menu selection with the current menu selection “highlighted” by being displayed in upper case. An expanded description of the highlighted menu selection is displayed on the top line of the display. The left- and right-arrow pushbuttons are used to highlight the desired menu selection. If more selections exist on a given menu than can be displayed at one time, an arrow at one or both sides of the display signifies that the display will scroll in that direction. As a prompt, the **SELECT FUNCTION** LED lights to signify that a menu selection should be made.

Once the desired menu selection has been highlighted, it is chosen by pressing the **ENTER** pushbutton. Depending on the menu selection chosen, the display shows either a second-level menu (with the **SELECT FUNCTION** LED lit), a value to be inspected or changed, or a choice to be made, such as enable or disable. (If a value can be changed or a selection can be made, the **ENTER SETPOINT** LED will be lit.)

ENTERING VALUES

Numeric values must be entered for the M-0420 setpoints, for certain configuration data, and for access codes. When a value must be entered, the unit will light the **ENTER SETPOINT** LED as a prompt.

A value is entered or changed by incrementing or decrementing the currently displayed value using the rotary knob. Turning the knob clockwise will increment the displayed value. Turning the knob counterclockwise will decrement the displayed value.

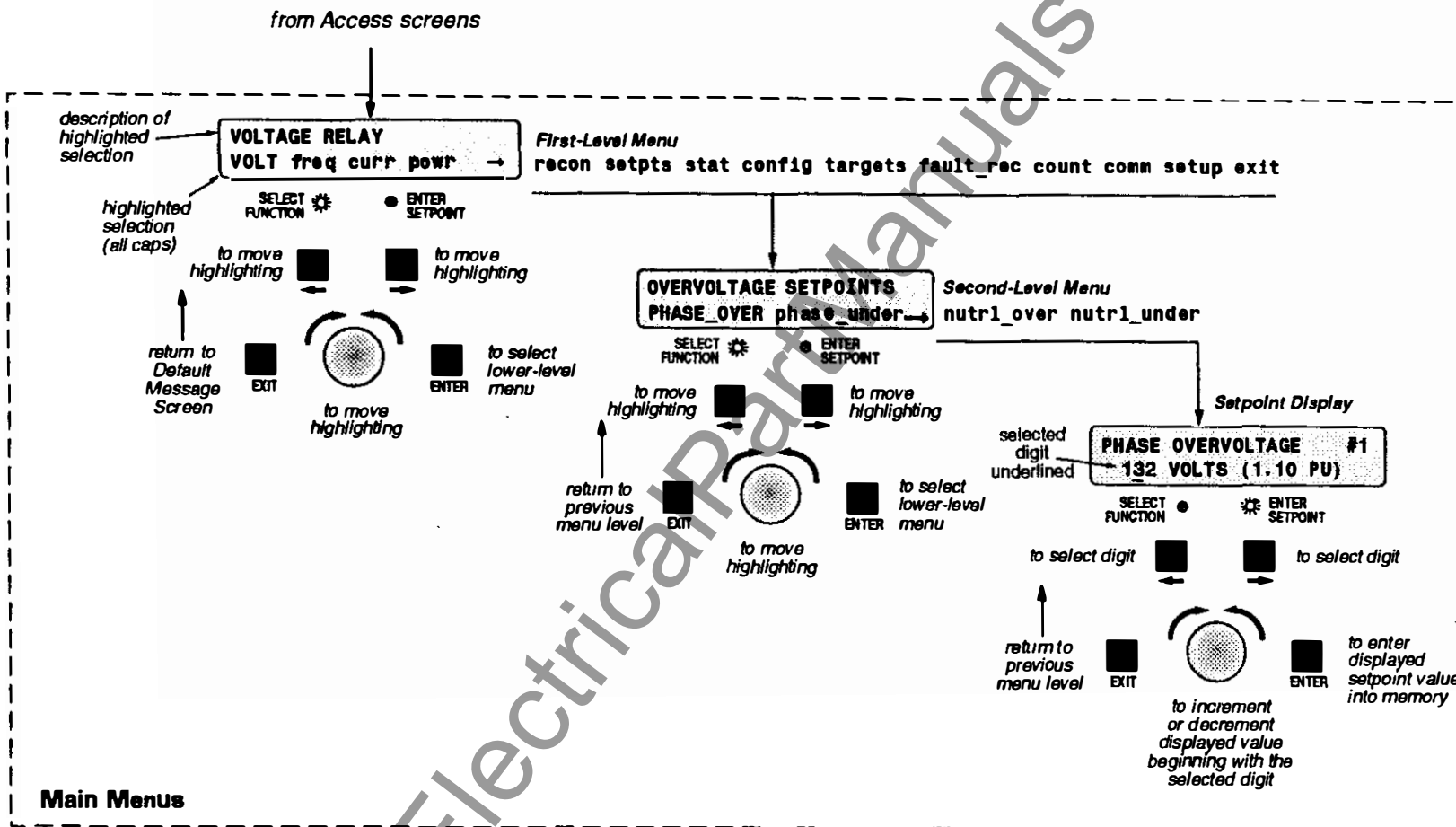


* Access codes are optional. To disable this function (the default setting), set the Level 3 access code to 9999.

FIGURE 4-4 Access Screens

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FIGURE 4-5 Front Panel Operation



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- **NOTE:** While the rotary knob has click detents, these are only to provide tactile feedback. Passing one detent does not necessarily mean that the displayed value will be incremented or decremented by one. Turning the knob too quickly may result in an unanticipated change in the displayed value.

As shown in Figure 4-5, an underline cursor is displayed in the position of the least significant digit of the value to be entered or changed. When the value to be incremented has a wide range, the left- or right-arrow pushbuttons can be used to move the underline to any displayed digit. Turning the front panel knob will increment or decrement the value beginning with the underlined digit.

Once the value is set, press the **ENTER** pushbutton to store the new value into the unit's memory. It will become the active setpoint as soon as **ENTER** is pressed (unless inhibited by the presence of another function).

- **NOTE:** The M-0420 will not allow you to enter a digit out of the applicable range of values. See the table of values for each function in Chapter 2, **Application**, for a detailed listing of the setpoint ranges and initial settings.

ACCESS CODES

The M-0420 supports three levels of access codes. Depending on the access code they hold, users have varying levels of access to the M-0420:

Level 3 access	access to all relay functions and diagnostics
Level 2 access	read and change setpoints, monitor status, view trip history
Level 1 access	read setpoints, monitor status, view trip history

- **NOTE:** Each access code is a user-defined one- to four-digit number. If the Level 3 access code is set to 9999, the access code feature is disabled. When this feature is disabled, the access screens are bypassed.

Access codes are entered in the same manner as any other value, using the rotary knob (and the left- and right-arrow pushbuttons, if desired). Access codes can be altered by choosing the **ALTER ACCESS CODES** menu selection under the **SETUP UNIT** menu.

- ▲ **CAUTION:** If you forget your access code, you will have to contact the factory for information on resetting the unit.

ENABLING AND DISABLING RELAY FUNCTIONS

Each function on the M-0420 can be individually enabled or disabled via the **CONFIGURE RELAY** menu selection. To enable or disable a function, merely highlight the **ENABLE** or **DISABLE** choice for the appropriate function under the **CONFIGURE RELAY** menu and press **ENTER**. A disabled function *will not appear* under any other menu or screen. However, if *all* functions of a device (individual target) are disabled, the message **FUNCTION(S) DISABLED—SEE CONFIGURE MENU** will appear if it is selected.

- **NOTE:** Functions having two setpoints are shipped with the second setpoint disabled. Disabling unused functions improves the response time of the indicators and controls.

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5 MENU REFERENCE

This chapter provides a short description for each main menu selection available in the M-0420 Version 4.01 software. Flowcharts are provided for the relay configuration menus. (Figure 5-1 summarizes the M-0420 main menu flow.) The functions in this chapter are presented in the same order as on the main menu.

- **NOTES:** The descriptions assume that the M-0420 settings are enabled or disabled as shipped from the factory (see Figure 7-1).

Setpoint Configuration Record Forms are provided in Appendix E. These forms provide a comprehensive, standardized means of recording setpoint values.

Voltage Relay	5-3
Frequency Relay	5-9
Current Relay	5-12
Power Relay	5-17
Reconnect Relay	5-20
Review Setpoints	5-21
Monitor Status	5-22
Configure Relays	5-23
View Target History	5-28
Fault Recorder	5-29
Read Counter	5-30
Communication	5-31
Setup Unit	5-33
Exit Local Mode	5-36

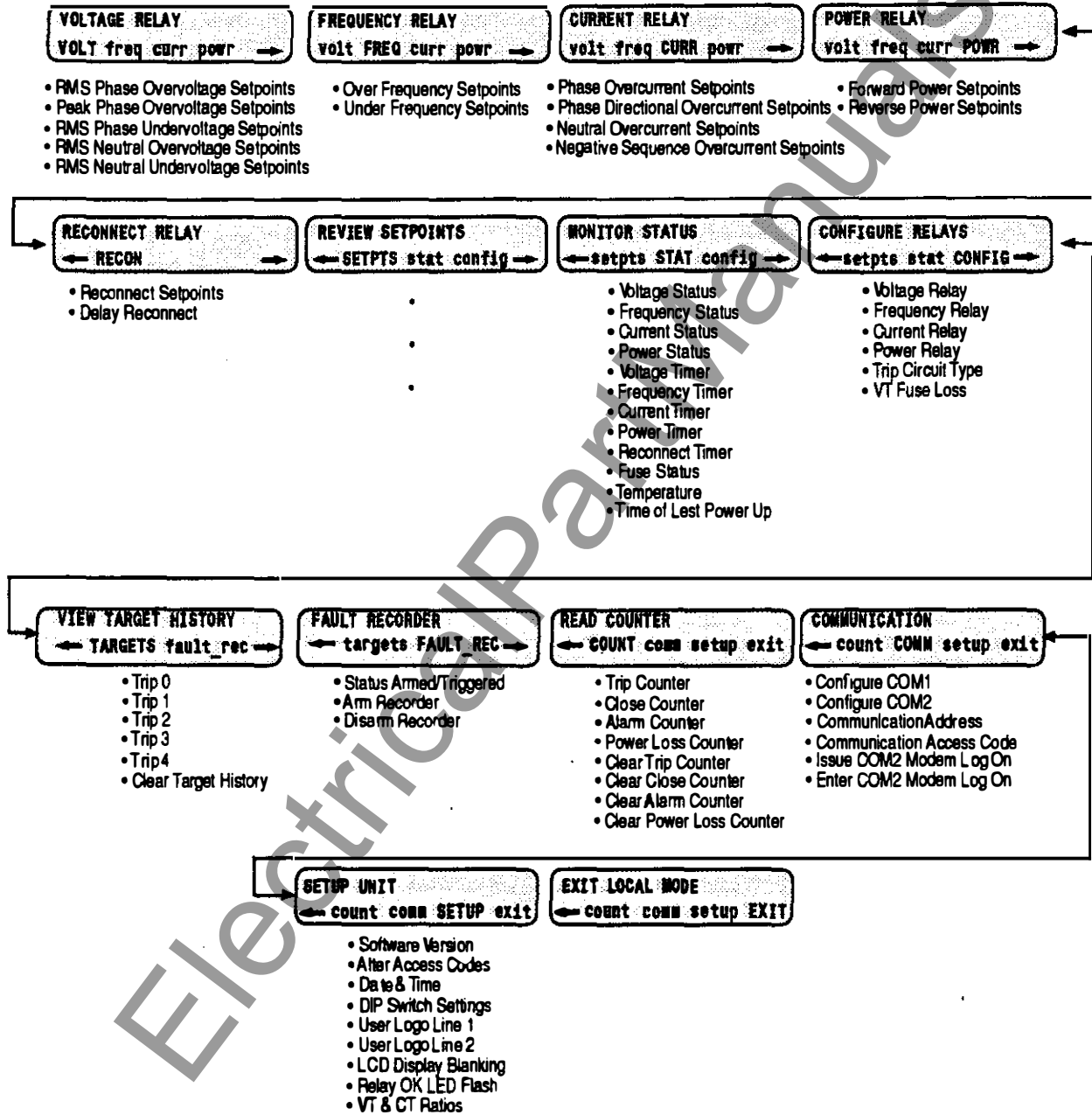


FIGURE 5-1 M-0420 Menu Flow, Version 4.01 Software

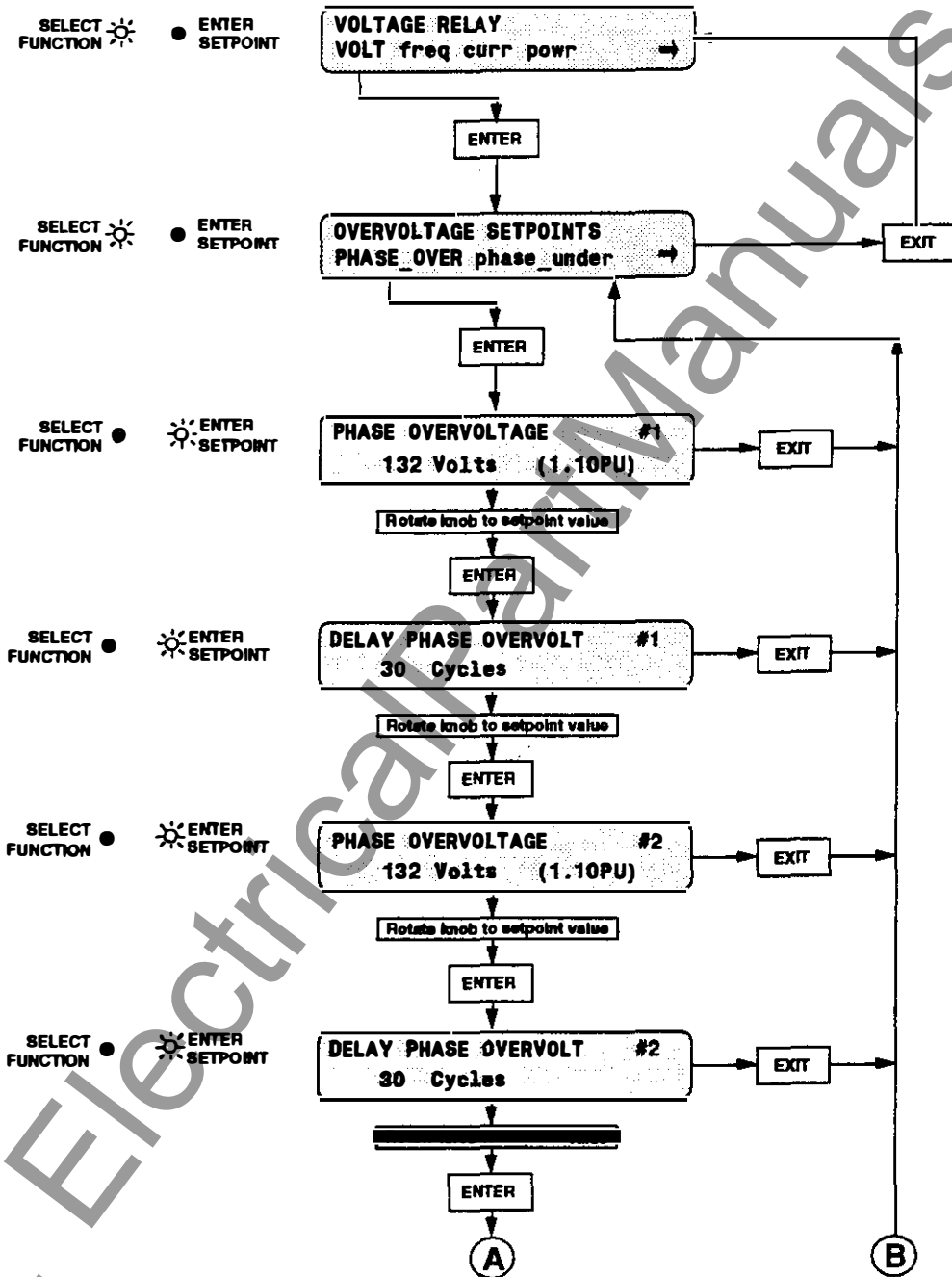
VOLTAGE RELAY



The **VOLTAGE RELAY** menu selection provides access to the voltage functions of the M-0420. Figures 5-2 through 5-6 illustrate the software flow for these functions. Setpoint ranges and initial settings are provided in Chapter 2, **Application**, and in the Specifications at the front of this book.

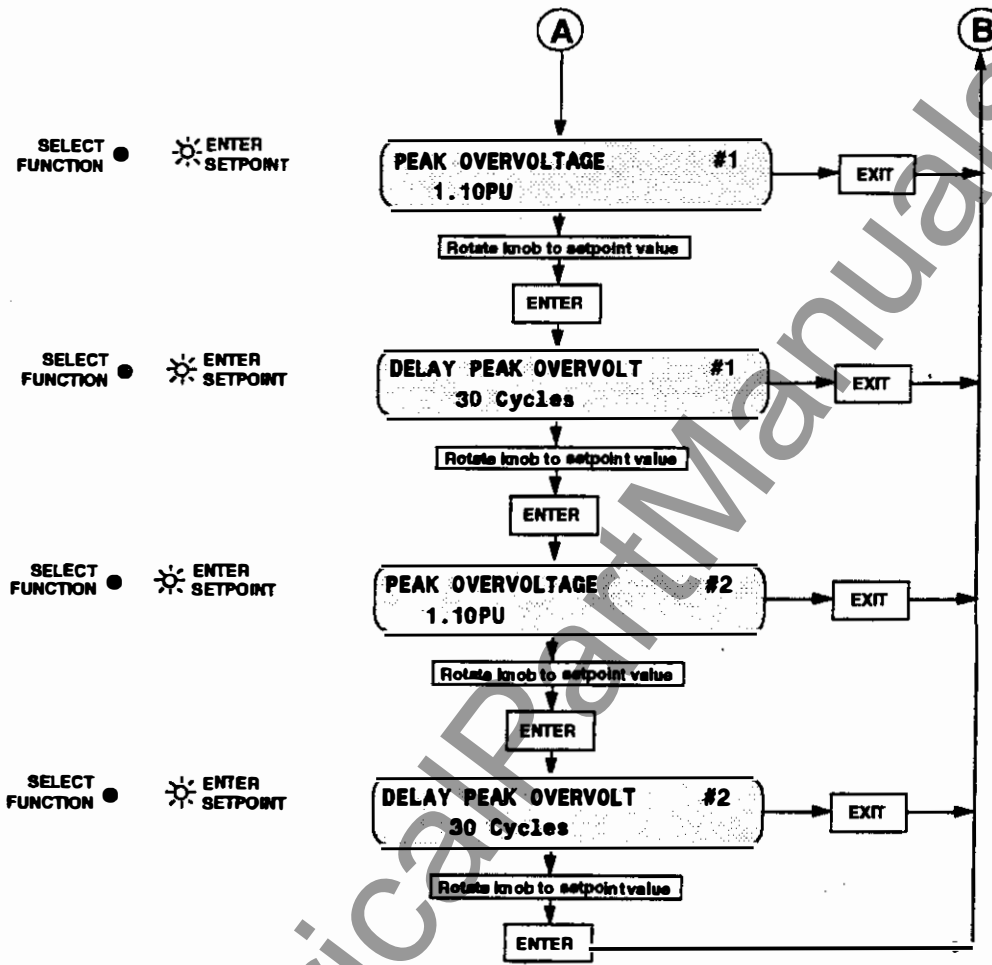
- 59 RMS Overvoltage, 3-Phase *Figure 5-2*
- 59I Peak Overvoltage, 3-Phase..... *Figure 5-3*
- 27 RMS Undervoltage, 3-Phase *Figure 5-4*
- 59N RMS Overvoltage, Neutral Circuit or Zero Sequence *Figure 5-5*
- 27N RMS Undervoltage, Neutral Circuit or Zero Sequence..... *Figure 5-6*

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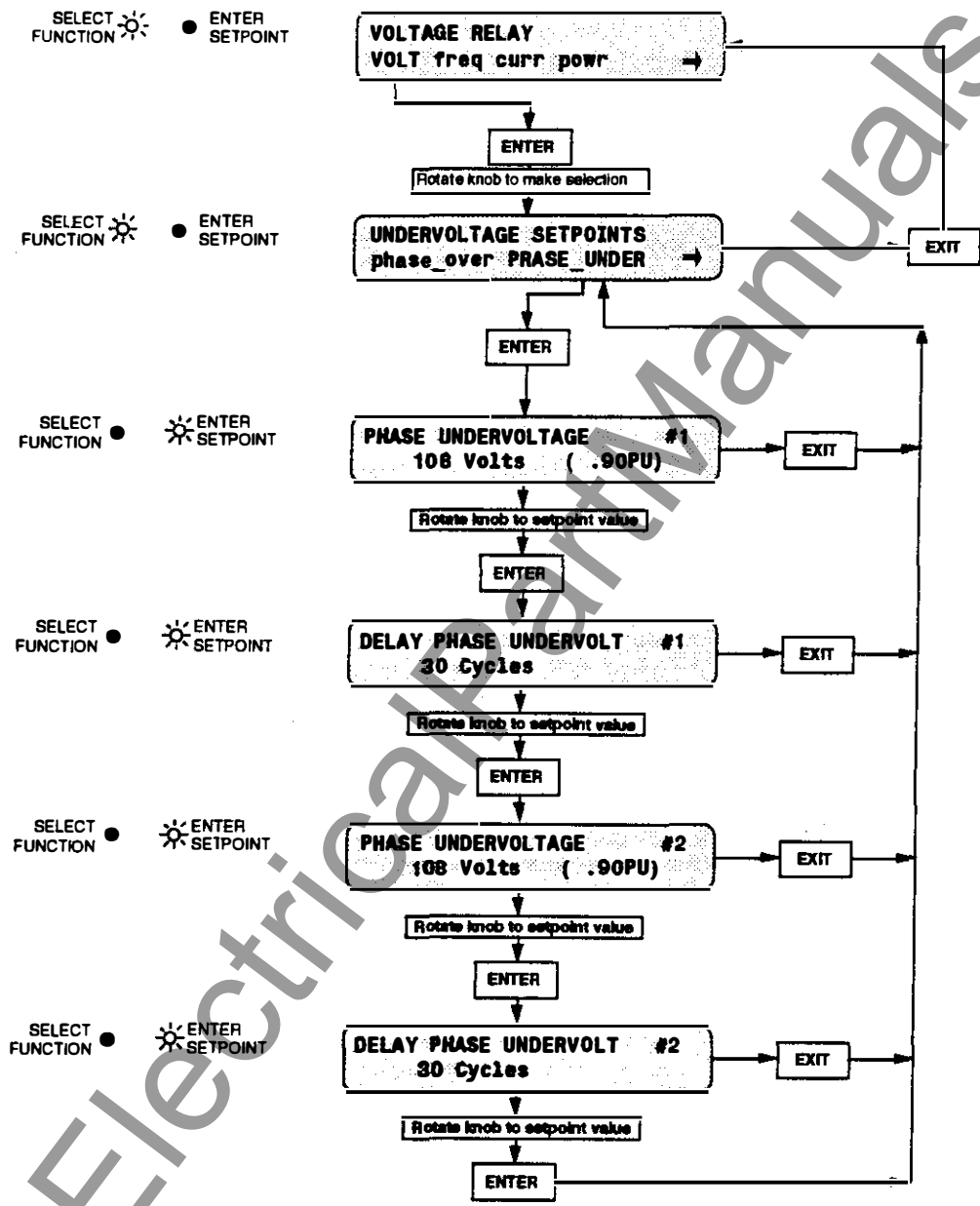
NOTE: Setpoints #2 are disabled as shipped, and do not appear on the menu. Use CONFIGURE RELAYS menu to enable them.

FIGURE 5-2 Voltage Relay: RMS Overvoltage, 3-Phase (59)



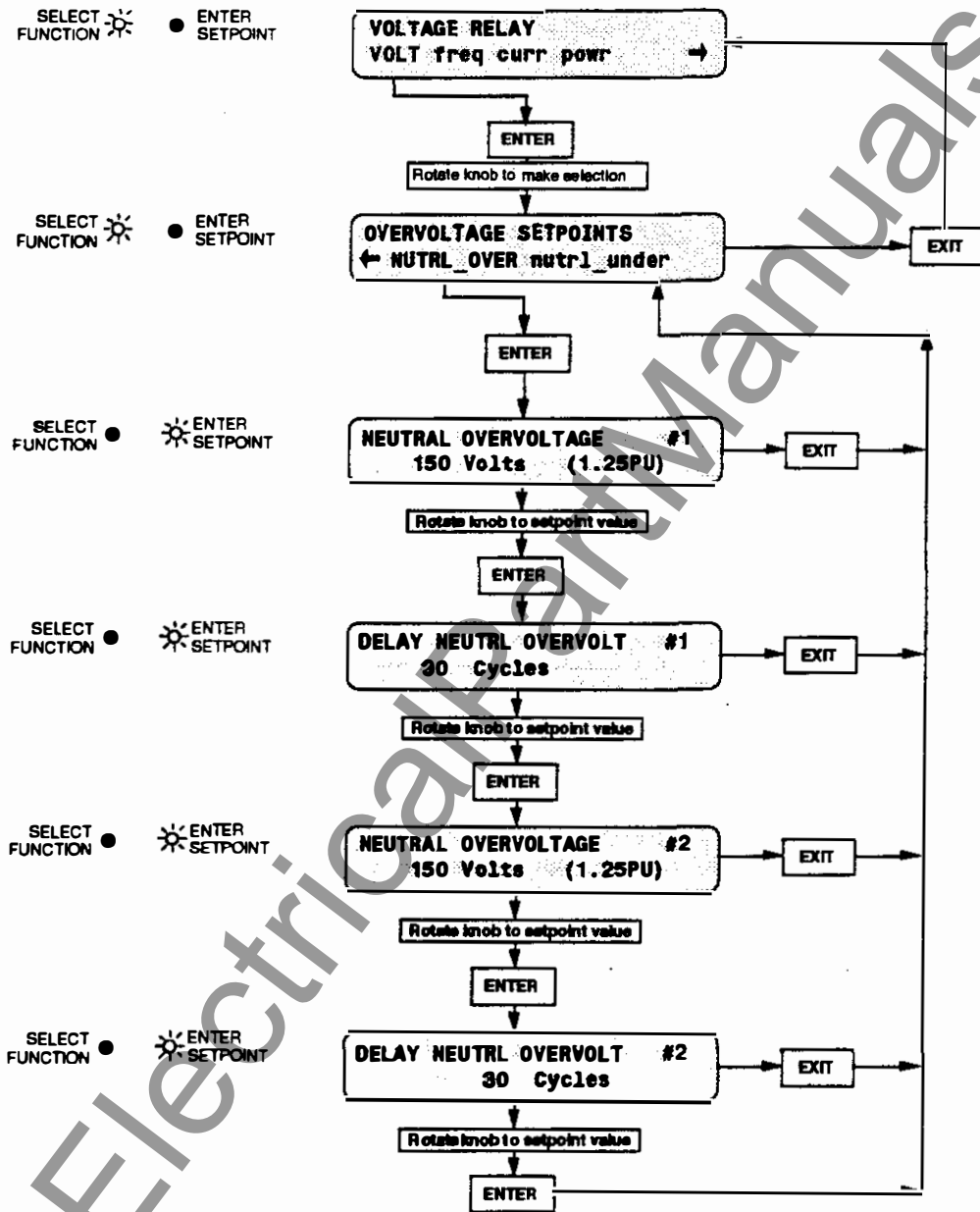
■ NOTE: Setpoints #2 are disabled as shipped, and do not appear on the menu. Use CONFIGURE RELAYS menu to enable them.

FIGURE 5-3 Voltage Relay: Peak Overvoltage, 3-Phase (59I)



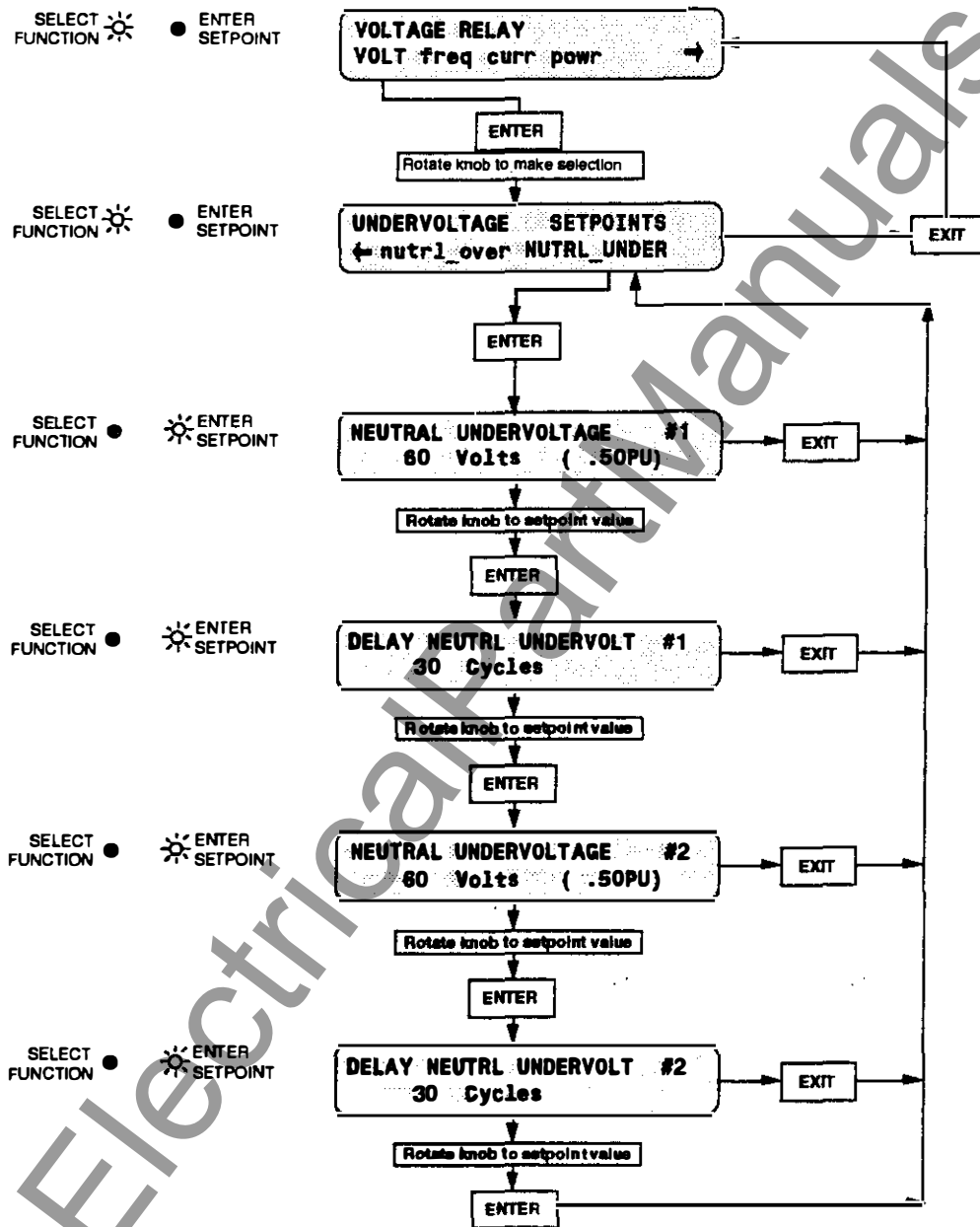
■ NOTE: Setpoints #2 are disabled as shipped, and do not appear on the menu. Use CONFIGURE RELAYS menu to enable them.

FIGURE 5-4 Voltage Relay: RMS Undervoltage, 3-Phase (27)



■ NOTE: Setpoints #2 are disabled as shipped, and do not appear on the menu. Use CONFIGURE RELAYS menu to enable them.

FIGURE 5-5 Voltage Relay: RMS Overvoltage, Neutral Circuit or Zero Sequence (59N)



■ NOTE: Setpoints #2 are disabled as shipped, and do not appear on the menu. Use CONFIGURE RELAYS menu to enable them.

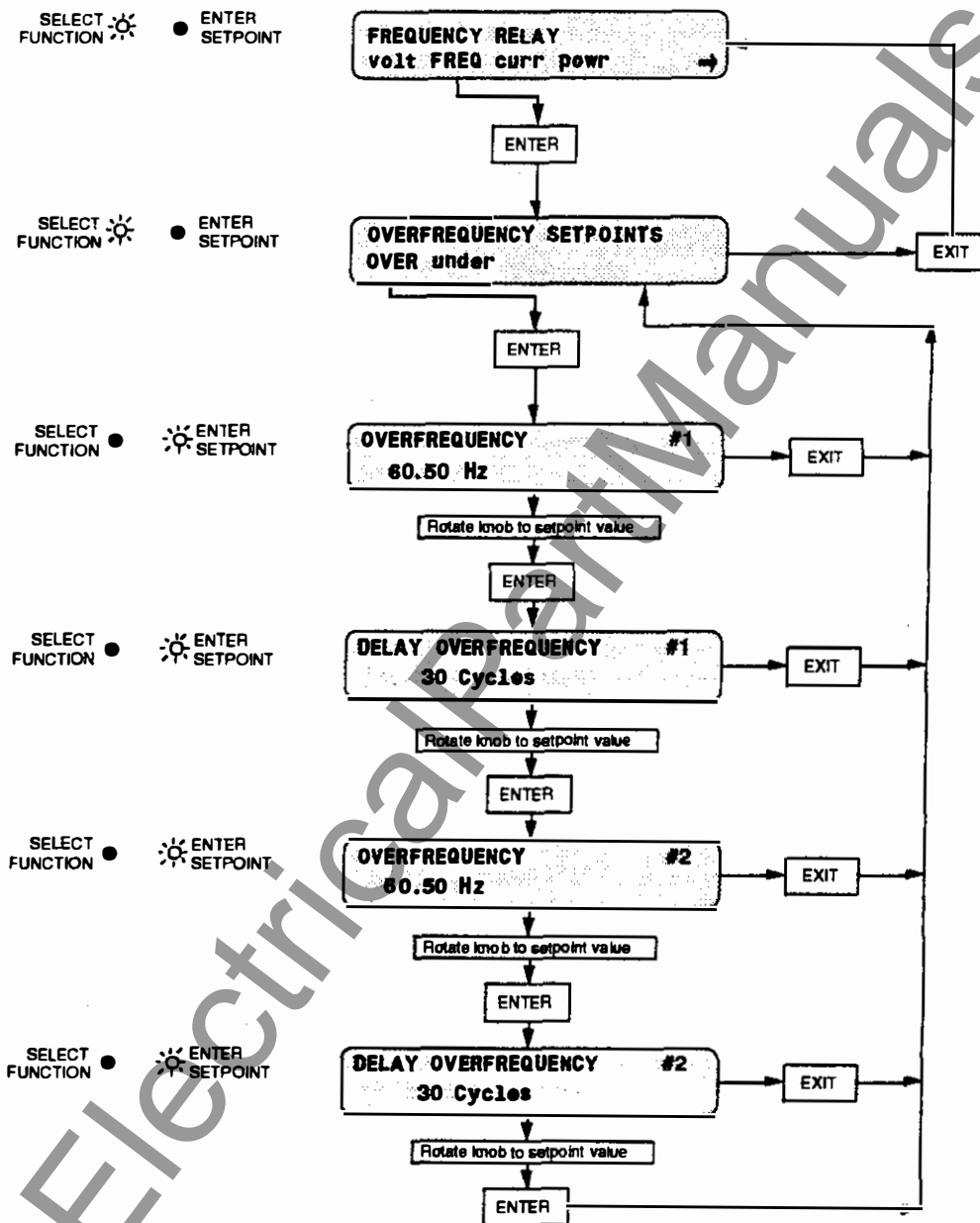
FIGURE 5-6 Voltage Relay: RMS Undervoltage, Neutral Circuit or Zero Sequence (27N)

FREQUENCY RELAY



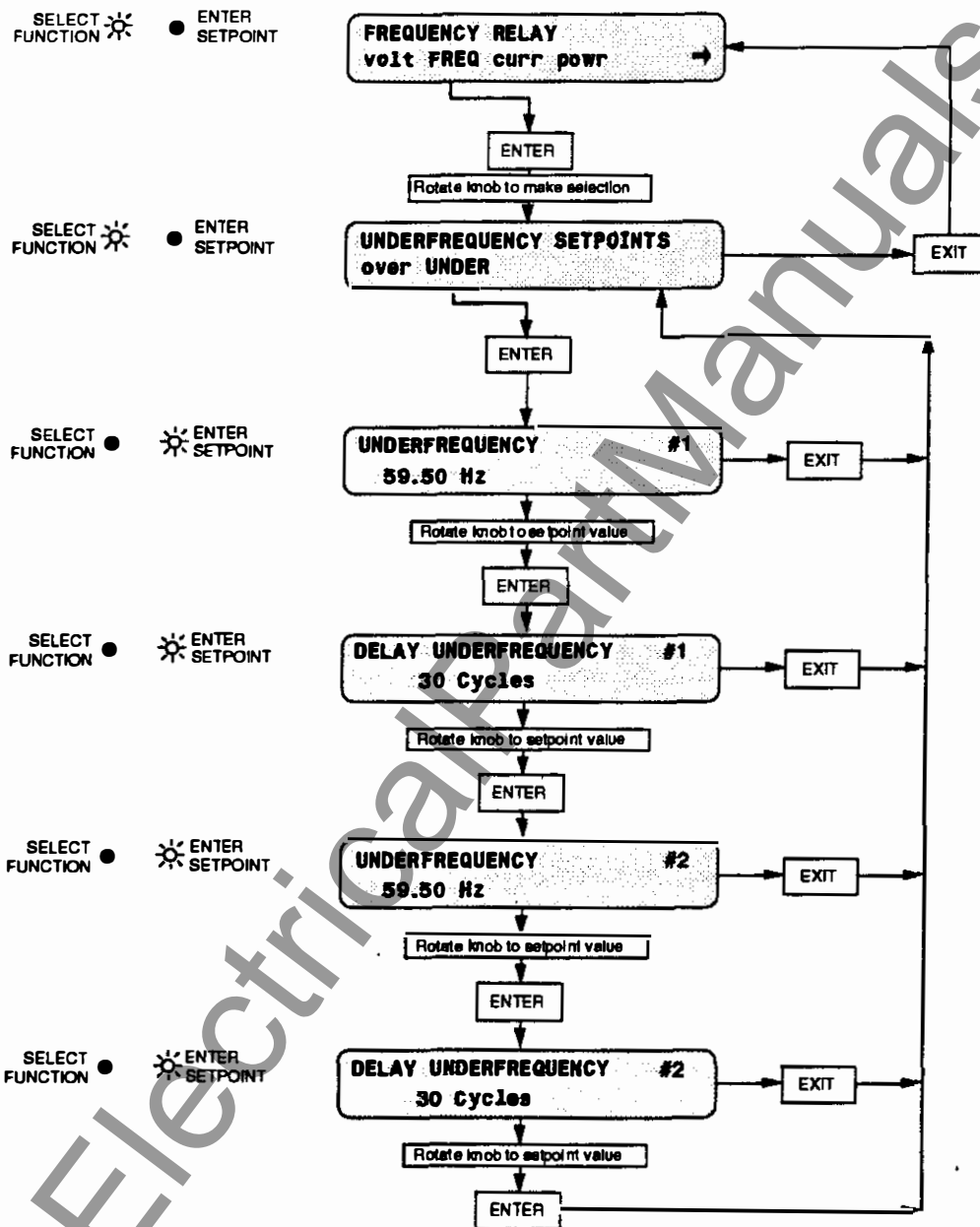
The **FREQUENCY RELAY** menu selection provides access to the frequency functions of the M-0420. Figures 5-7 and 5-8 illustrate the software flow for these functions. Setpoint ranges and initial settings are provided in Chapter 2, **Application**, and in the Specifications at the front of this book.

- 81O Over Frequency*Figure 5-7*
- 81U Under Frequency*Figure 5-8*



■ **NOTE:** Setpoints #2 are disabled as shipped, and do not appear on the menu. Use **CONFIGURE RELAYS** menu to enable them.

FIGURE 5-7 Frequency Relay: Over Frequency (810)



■ **NOTE:** Setpoints #2 are disabled as shipped, and do not appear on the menu. Use **CONFIGURE RELAYS** menu to enable them.

FIGURE 5-8 Frequency Relay: Under Frequency (81U)

CURRENT RELAY



The **CURRENT RELAY** menu selection provides access to the current functions of the M-0420. Figures 5-9 through 5-12 illustrate the software flow for these functions. Setpoint ranges and initial settings are provided in Chapter 2, **Application**, and in the Specifications at the front of this book.

51V/50	Inverse Time / Instantaneous Overcurrent, 3-Phase	Figure 5-9
67	Phase Directional Overcurrent, 3-Phase	Figure 5-10
51N/50N	Inverse Time / Instantaneous Overcurrent, Neutral	Figure 5-11
46	Negative Sequence Overcurrent	Figure 5-12

■ **NOTE:** During the time that a setpoint associated with the inverse time/instantaneous phase overcurrent, phase directional overcurrent, inverse time/instantaneous neutral overcurrent, or negative sequence overcurrent functions is being changed, that function and the functions associated with it are disabled. They are re-enabled when you exit from the setpoint menu.

■ **NOTE:** Function 67, phase directional overcurrent, is an option that may be purchased for installation at the factory. If 67 is present, and the directional function is enabled, additional setpoint screens appear in the **CURRENT RELAY** menu, as shown in Figures 5-9 and 5-10.

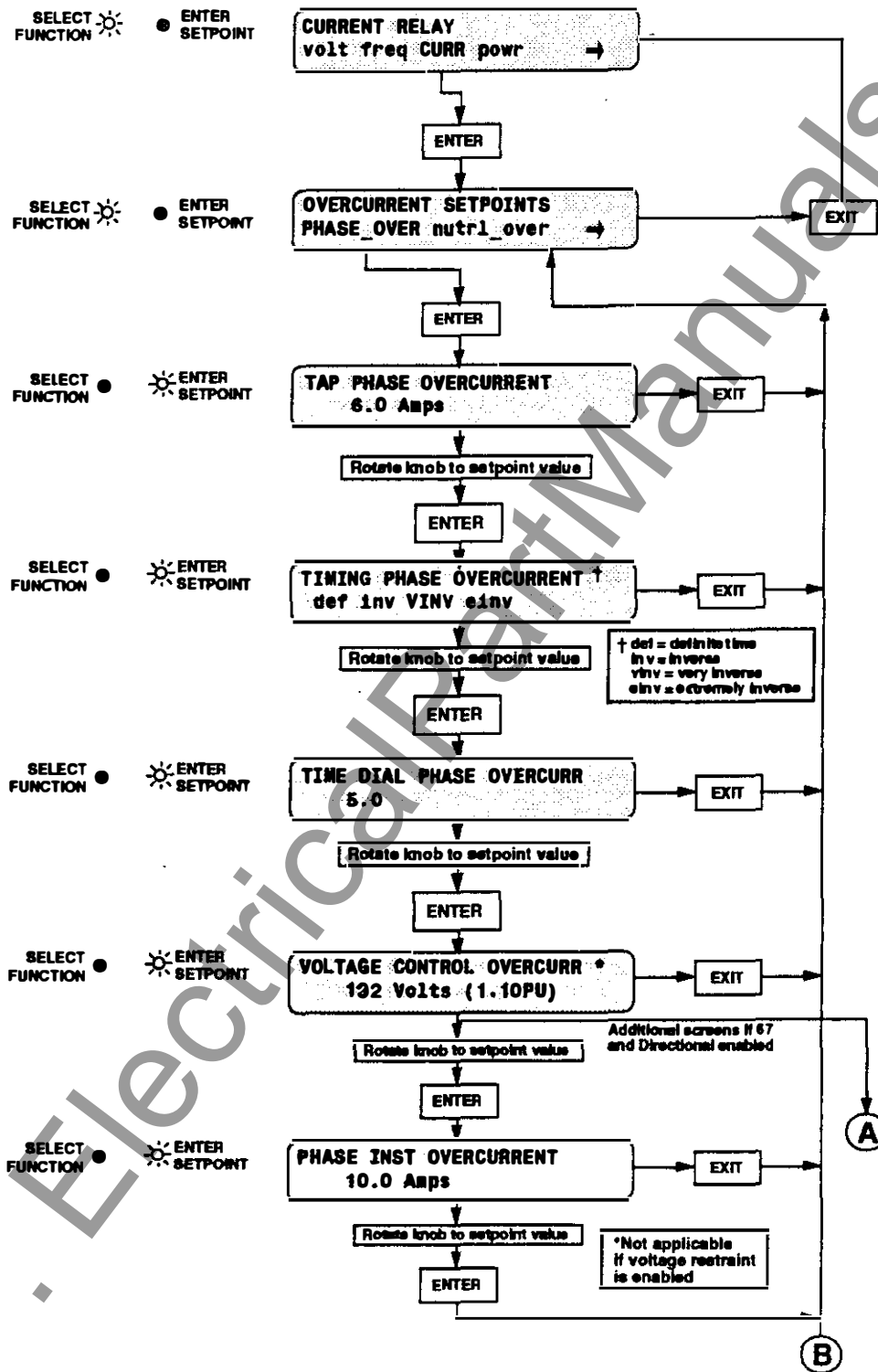
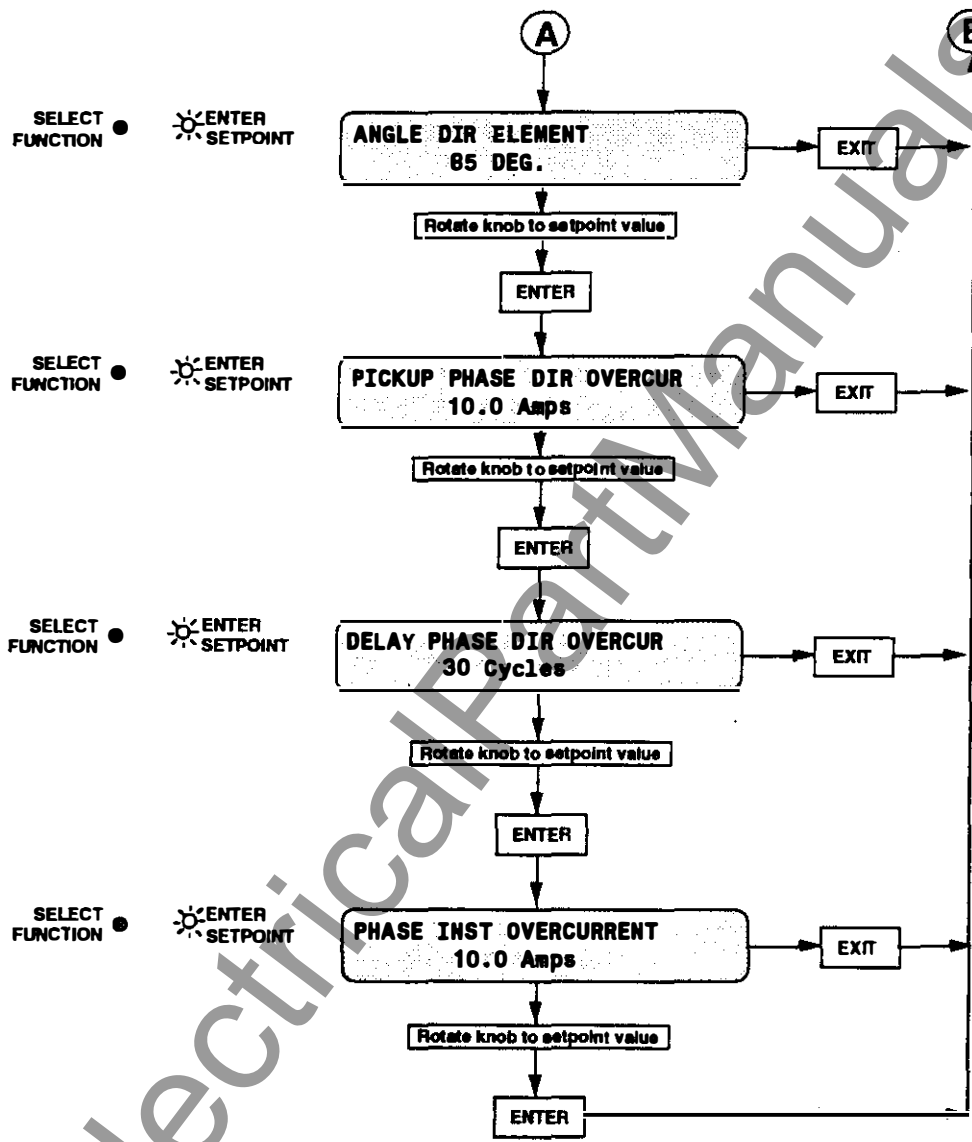


FIGURE 5-9 Current Relay: Inverse Time Overcurrent, 3-Phase (51V)
instantaneous Overcurrent, 3-Phase (50)



NOTE: The first three screens relate to the phase directional overcurrent function (67), an option that must be installed at the factory.

FIGURE 5-10 Current Relay: Phase Directional Overcurrent, 3-Phase (67)

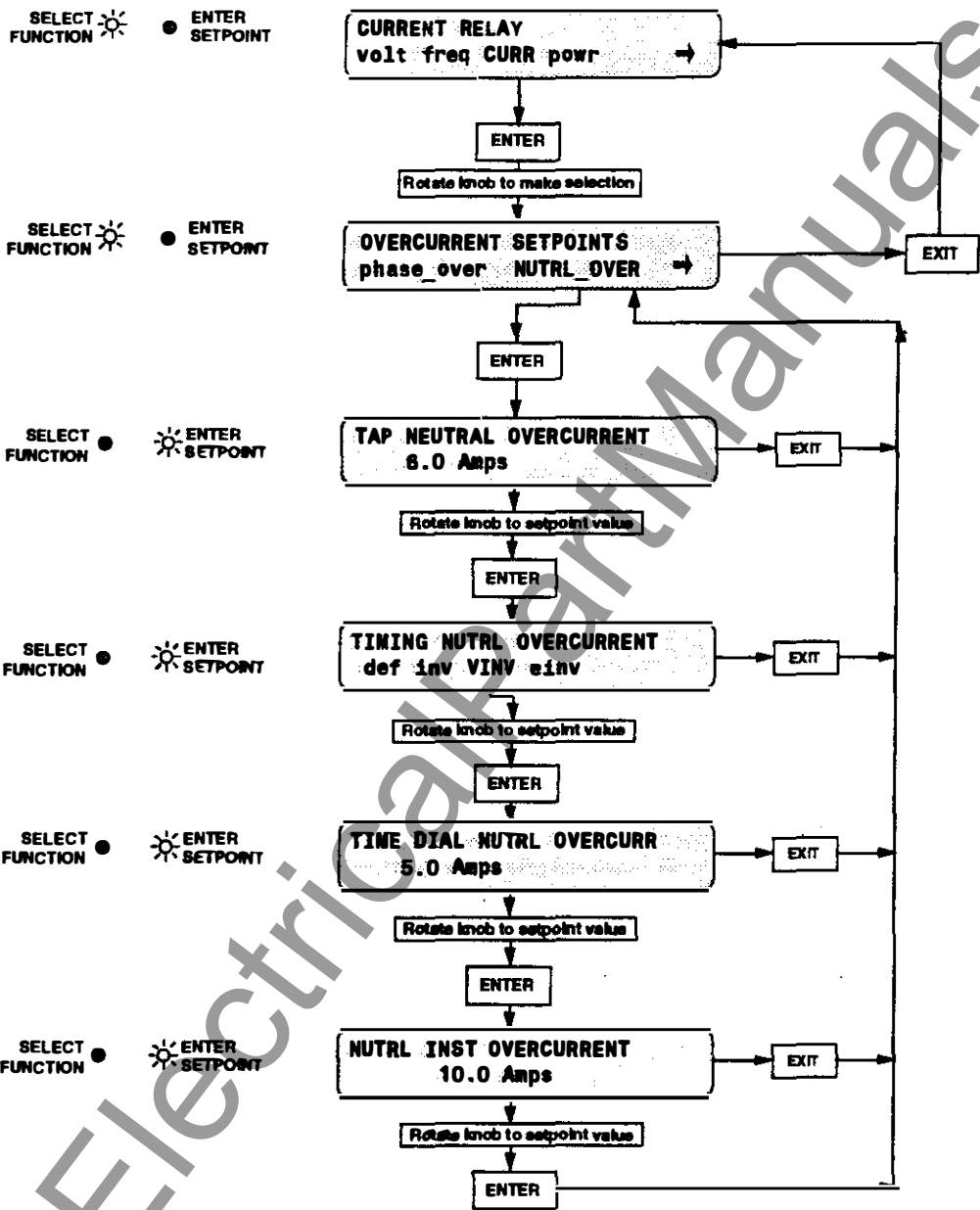


FIGURE 5-11 Current Relay: Inverse Time Overcurrent, Neutral (51N)
Instantaneous Overcurrent, Neutral (50N)

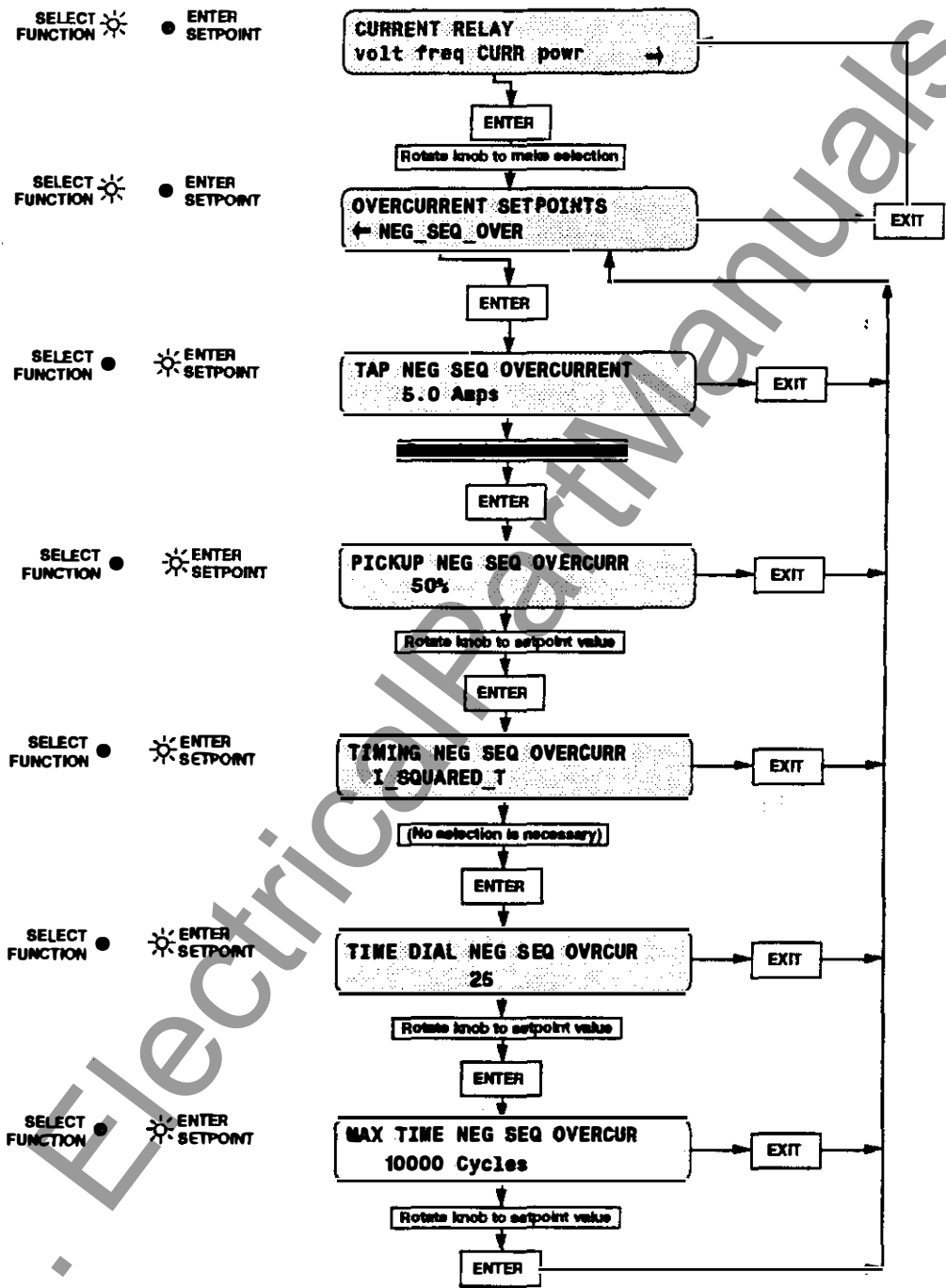


FIGURE 5-12 Current Relay: Negative Sequence Overcurrent (46)

POWER RELAY

The **POWER RELAY** menu selection provides access to the power functions of the M-0420. Figures 5-13 and 5-14 illustrate the software flow for these functions. Setpoint ranges and initial settings are provided in Chapter 2, **Application**, and in the Specifications at the front of this book.

- 32F Forward Overpower *Figure 5-13*
- 32R Reverse Overpower..... *Figure 5-14*

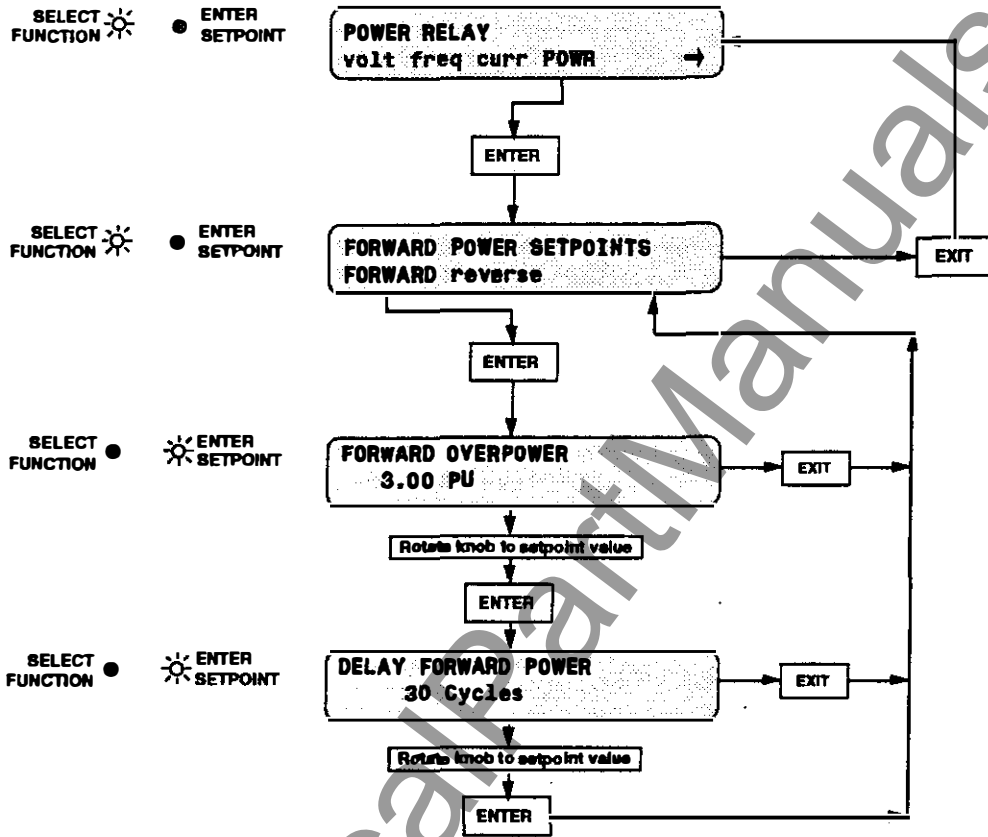


FIGURE 5-13 Power Relay: Forward Overpower (32F)

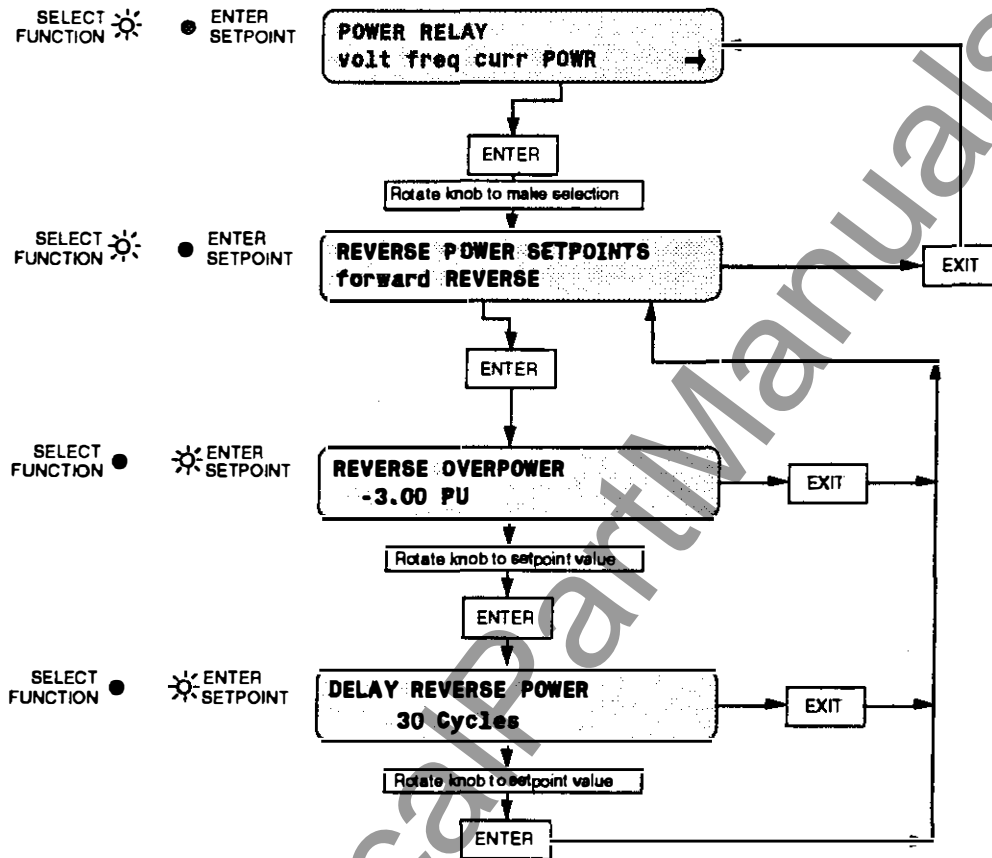


FIGURE 5-14 Power Relay: Reverse Overpower (32R)

RECONNECT RELAY



The **RECONNECT RELAY** menu selection provides access to the reconnect function of the M-0420. Figure 5-15 illustrates the software flow for this function. Setpoint ranges and initial settings are provided in Chapter 2, **Application**, and in the Specifications at the front of this book.

79 Reconnect RelayFigure 5-15

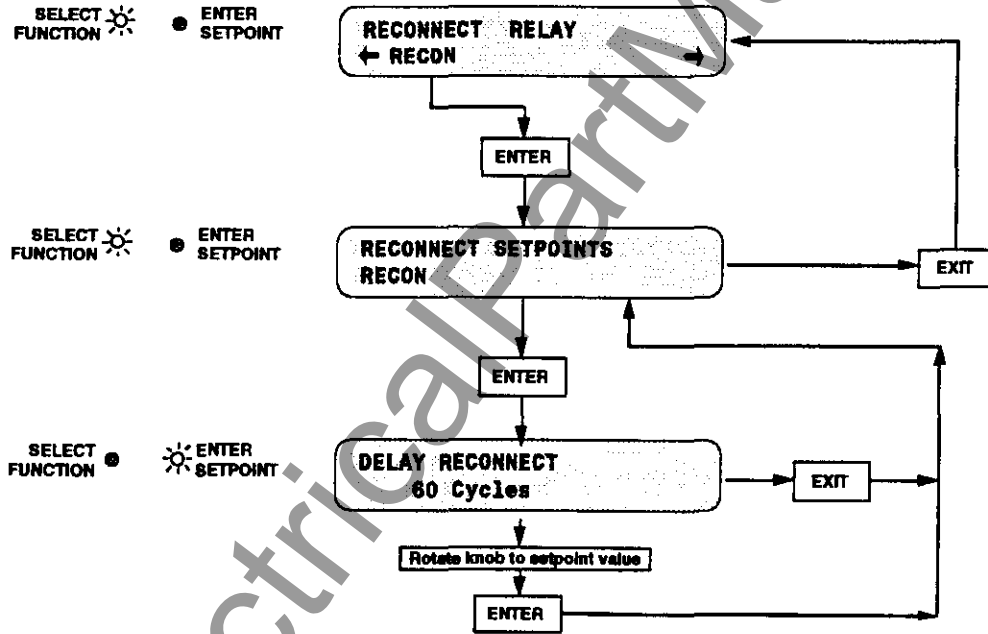


FIGURE 5-15 Reconnect Relay (79)

REVIEW SETPOINTS



The **REVIEW SETPOINT** menu selection enables you to review the existing settings of all *enabled* setpoint values and time delays. This menu can only be scrolled forward and cannot be scrolled backward.

■ **NOTE:** Setpoint values cannot be changed via this menu.

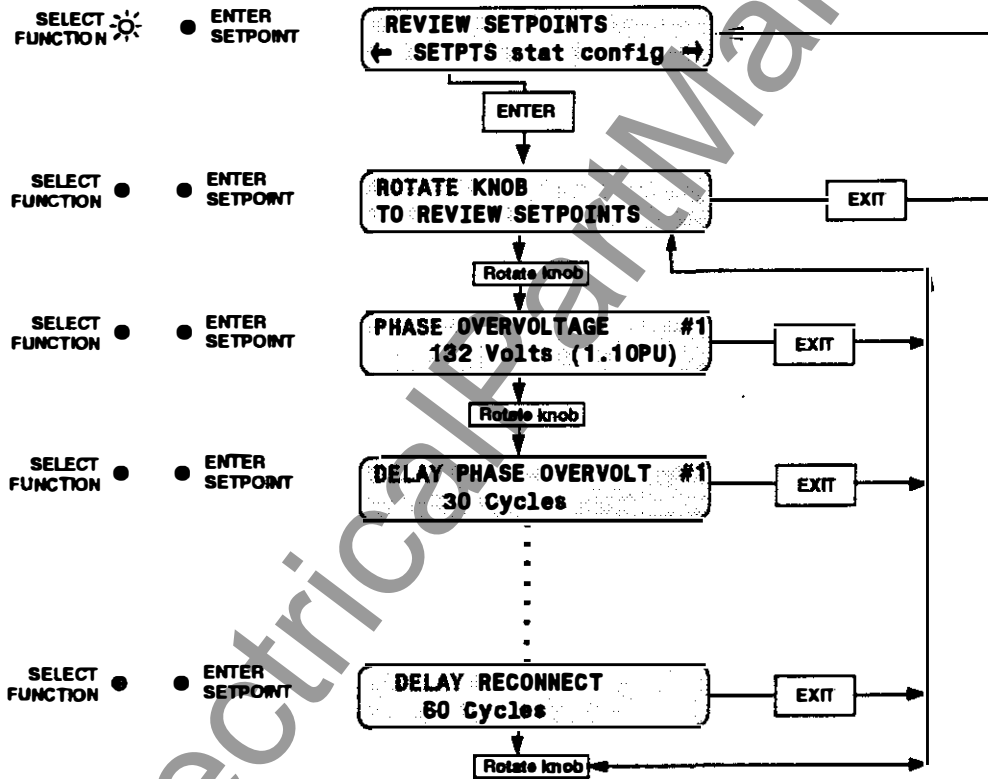


FIGURE 5-16 Review Setpoints

MONITOR STATUS



The **MONITOR STATUS** menu selection enables you to examine the system status and the relay timers in real-time for each function. Each status display may be scrolled in either direction by means of the front panel knob. The second-level menu presents the following status options:

Voltage Status

including phase, neutral, peak phase, positive, negative, and zero sequence voltages.

Frequency Status*

Current Status

including phase, neutral, and negative sequence currents.

Power Status

including real and reactive power, and power factor.

Voltage Timer

Frequency Timer

Current Timer

Power Timer

Reconnect Timer

Fuse Status

–the status of the fuses in the voltage input circuit, including the external VT fuses and the M-0420 internal fuses.

Temperature

–the unit's internal temperature as reported by the onboard temperature sensor

Time of Last Power Up

*■ **NOTE:** If there is no VT input, the **FREQUENCY STATUS** menu reports **LOW VOLT DISABLE**. If the applied positive sequence voltage is approximately below 20 V, the **FREQUENCY STATUS** menu displays **LOW VOLT DISABLE**.

CONFIGURE RELAYS

The **CONFIGURE RELAYS** menu selection allows you to enable or disable the individual relay functions and to optimize the M-0420 for either generator or intertie protection.

The second-level menu presents the following selections:

Voltage Relay

Frequency Relay

Current Relay

Power Relay

Trip Circuit Type (Intertie or Generator)

VT Fuse Loss

VOLTAGE / FREQUENCY / CURRENT / POWER RELAYS

Each of these menus allows you to enable or disable individual relay functions. To enable or disable a function, highlight the **ENABLE** or **DISABLE** choice for the appropriate function and press **ENTER**. (Some functions have additional choices to allow you to enable or disable specific features.) The **CONFIGURE** menu for the phase overcurrent relay is shown in Figures 5-17 and 5-18.

- **NOTE:** A disabled function *will not appear* under any menu or screen other than the **CONFIGURE RELAYS** menu. If all functions for a relay are disabled, the message **FUNCTION DISABLEDSEE CONFIG MENU** will be displayed when the main menu selection is chosen. Additionally, certain functions can have their operation modified by other functions or menu selections; for example, the 51V function can be directionally controlled by enabling the directional control selection for the 51V function under the configuration menu. (Note that disabling unused functions improves the response of the user indicators and controls.)

TRIP CIRCUIT TYPE

TRIP CIRCUIT TYPE
INTERTIE generator

The M-0420 can be optimized for either generator or intertie protection by means of the **TRIP CIRCUIT TYPE** screen. To select the trip circuit type, highlight the desired selection and press **ENTER**.

When **INTERTIE** is selected, all M-0420 functions work as described in this Instruction Book.

When **GENERATOR** is selected, the M-0420 inhibits the trip outputs from the 27, 81O, 81U, 27N, 32F, and 32R functions when the 52b status input (closed contact) indicates that the breaker is open. This feature ensures that the M-0420 will not send an unwanted trip signal while the generator is offline, such as when being brought up to speed. The functions, however, are still active, and their setpoints can be changed.

When **GENERATOR** is selected, the following conditions must be true:

- The 52b breaker status input **MUST** be connected.
- The high-speed option on the reverse power and directional overcurrent functions **MUST NOT** be selected.

Additionally, more accurate response will be achieved during off-nominal-frequency operation if the total waveform (including harmonics) is used as the basis for the rms magnitude of voltage and current. (This option is selected by setting switch 8 of the internal configuration DIP switch to **ON**.)

- **NOTE:** Functions 59N and 27N respond to the fundamental frequency component regardless of the setting of DIP Switch 8.

VT FUSE LOSS DETECTION

INTERNAL FUSE LOSS LOGIC
disable ENABLE

Internal VT fuse-loss detection can be enabled or disabled under user control. Additionally, blocking of the 27, 51V, 67, and 32R functions during a fuse-loss condition can be individually selected. As shown in Figure 5-19, fuse-loss detection and blocking are selected via the **CONFIGURE V.T. FUSE LOSS** menu under the **CONFIGURE RELAYS** menu selection.

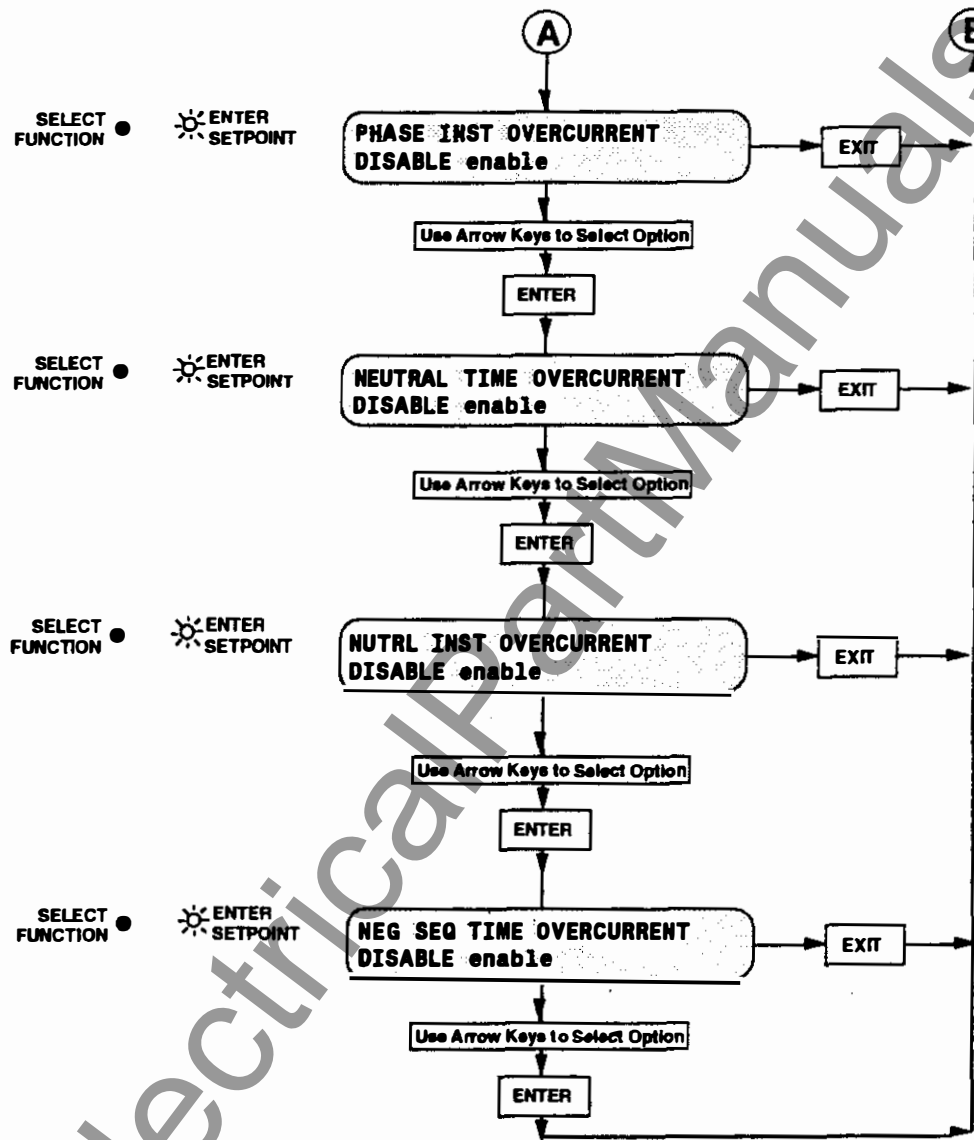


FIGURE 5-18 Configure Phase Overcurrent Relay (continued)

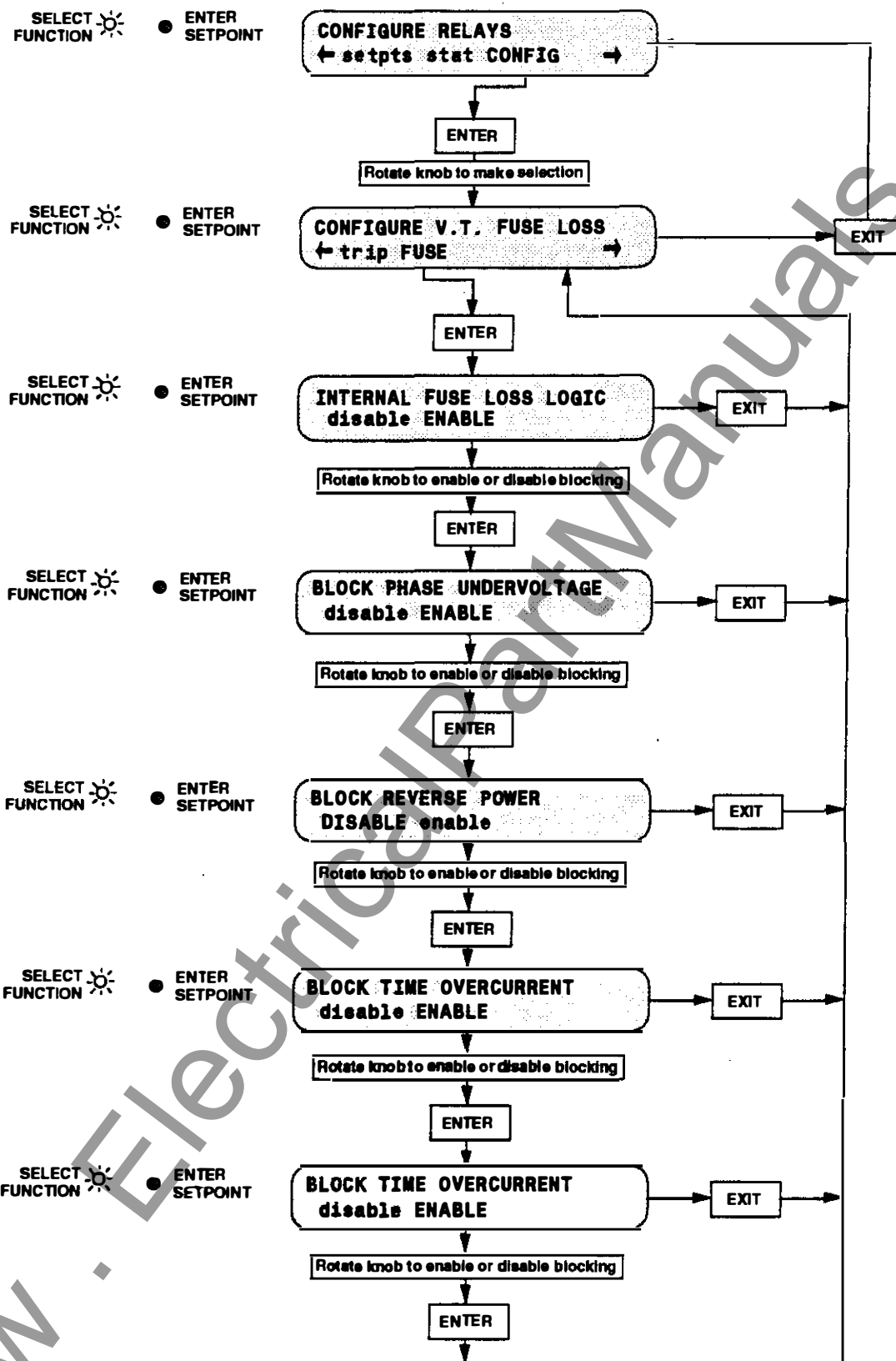


FIGURE 5-19 Configure VT Fuse-Loss Blocking

VIEW TARGET HISTORY



The **VIEW TARGET HISTORY** menu enables you to review the targets for the previous five trip conditions. As shown in the example below, the target history for each trip cycles continuously through a sequence of screens until you press **EXIT**. Both status information (which indicates when a value was outside the setpoint range) and timer information (which indicates when a value was outside the setpoint range and the timer expired) are shown, along with individual phase element information where appropriate. A time/date tag and the trip counter are also displayed. The second-level menu presents the following selections, with Target 0 being the latest trip. You can clear all trip history data to provide a clean starting point for further target recording by pressing **ENTER** at the final selection.

- Target 0
- Target 1
- Target 2
- Target 3
- Target 4
- Clear Target History

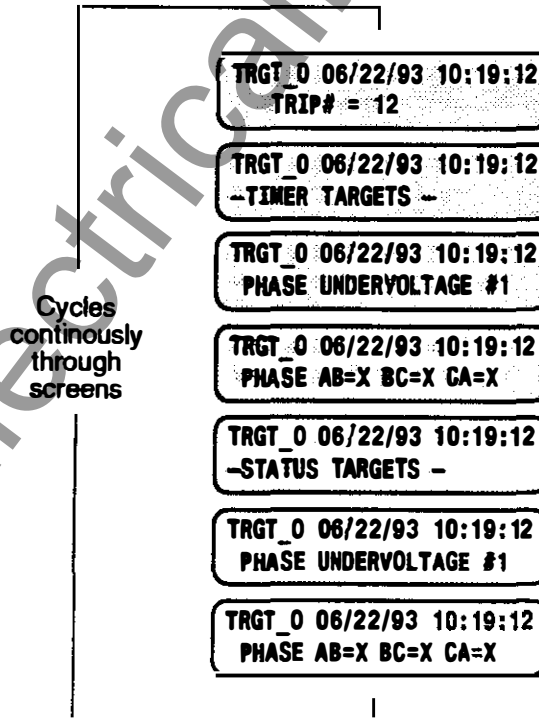


FIGURE 5-20 Example of Target History Screens

FAULT RECORDER

The fault recorder function records comprehensive fault data from the three phase and the neutral voltages and the three phase and the neutral currents at 16 samples per cycle (960 Hz), and from the 52b and 60 FL status inputs at 480 Hz. The **FAULT RECORDER** menu selection enables you to determine the status of the fault recorder (whether armed or not, and if armed, whether triggered or not), and to arm or disarm the recorder. Fault recorder information can be downloaded via the RS-232C ports to an IBM-compatible personal computer running the M-0429A BECOCOM™ Communications Software package. Once downloaded, you can examine the waveform data and output it using the M-0428A BECOPLOT™ Fault Data Analysis Software package. (Refer to the M-0429A BECOCOM™/M-0428A BECOPLOT™ User's Guide for more information on downloading and analyzing fault data.)

The fault recorder can be either armed or disarmed. In the armed condition, the fault recorder will be triggered to freeze the data when a breaker open (52b) signal is present. The status display changes from **ARMED** to **TRIGGERED**.

When armed but not triggered, the recorder continuously records waveform data, keeping the data from the most recent 96 cycles in its memory. When the breaker opens, as indicated by the external contact closure at the 52b status input, the recorder is triggered. It continues recording for a minimum of four to six additional cycles (default value is 5% post-trigger data acquisition) and then goes to disarmed mode, keeping the 95% pre-fault and 5% post-fault snapshot of waveform data in its memory for downloading via the M-0429 software. You can also trigger the fault recorder manually through the M-0429 software.

- **NOTE:** The fault recorder is initially disarmed after power up. To arm the fault recorder, choose the **ARM** menu selection and press **ENTER**; the recorder will be armed.

AUTOMATIC FAULT RECORDER RE-ARMING

The fault recorder can be set to rearm itself automatically under the **FAULT RECORDER** menu selection. When auto-rearming is enabled, the fault recorder is armed when the breaker closes (as indicated by the 52b contact opening input) and triggered when the breaker opens.

- ▲ **CAUTION:** The previous fault record is lost once the recorder is rearmed. When auto-rearming is enabled, the fault record must be downloaded while the breaker is open.

POST TRIGGER DELAY

The post trigger delay function permits you to vary the distribution of data before and after the fault over the range from 5% to 95% of the 96 cycles.

READ COUNTER

READ COUNTER
← COUNT ~~com~~ setup exit

The system counters count the number of trip, close, self-test alarm indications, and power-loss situations. By pressing **ENTER** from the **READ COUNTER** menu, you can determine the present count of each counter, and, if desired, clear them. The second-level menu presents the counters in the following order:

Trip Counter

Close Counter

Alarm Counter

Power Loss Counter

Clear Trip Counter

Clear Close Counter

Clear Alarm Counter

Clear Power Loss Counter

COMMUNICATION

```

COMMUNICATION
← count COMM setup exit

```

You can configure the M-0420 for communication via the RS-232C ports using the **COMMUNICATION** menu. In a typical communications application, the rear-panel communication port is permanently connected to a modem, while the front-panel port is kept free for on-site programming via a laptop PC. The second-level menu selections are described below. Refer to the M-0429A BECOCOM™/M-0428A BECOPLOT™ Software User's Guide, and to Appendix C, **Communications**, of this Instruction Book for detailed information about these functions.

CONFIGURE COM 1/CONFIGURE COM 2

```

CONFIGURE COM1
COM1 com2 com_adr accss→

```

The **CONFIGURE COM1** and **CONFIGURE COM2** menu selections enable you to set the baud rate and parity for the front- and rear-panel RS-232C ports. The M-0420 can communicate at up to 9600 baud and with even parity or no parity (parity disabled).

- **NOTE:** These parameters must match those of the attached modem, computer, or other communications device. The default parameters have been chosen to match the default parameters supplied with the M-0429A BECOCOM™ Communications Software package.

COMMUNICATION ADDRESS

```

COMMUNICATION ADDRESS
com1 com2 COM_ADR accss→

```

The communication address capability allows multiple units (M-0420 or other compatible Beckwith products) to share a phone line or modem. Each M-0420 can be given an individual address ranging from 1–200. All M-0420s have the group address of 230. More information on the use of communication addresses is provided in the Chapter 2, **Application**, of the M-0429A BECOCOM™/M-0428A BECOPLOT™ Software User's Guide.

COMM ACCESS CODE

```
COMM ACCESS CODE
com1 com2 com_adr ACCSS→
```

This function enables you to restrict communications access to the M-0420 function setpoints by establishing a security access code. Setting the access code to 0 will disable this protection.

ISSUE COM 2 MODEM LOG ON

```
ISSUE COM2 MODEM LOG ON
↑ ISSUE enter
```

The **ISSUE COM2 MODEM LOG ON** menu selection enables you to send the predefined COM2 initialization parameters to the attached communication device. These parameters may be used for initializing a modem, and are defined using the **ENTER COM2 MODEM LOG ON** command.

ENTER COM 2 MODEM LOG ON

```
ENTER COM2 MODEM LOG ON
↑ Issue ENTER
```

Using the **ENTER COM2 MODEM LOG ON** menu, you can define a string of initialization parameters to be sent using the **ISSUE COM2 MODEM LOG ON** menu selection. These parameters are also sent on power-up. For a Hayes-compatible modem set as receiver, the following string might be used:

```
AT E0 QV &D0 S0=2 X4 M1
```

If the first character of the **ENTER COM2 MODEM LOG ON** string is a space character, no log-on string will be issued through the COM 2 port, in effect disabling the Log On function.

Many factors are involved in choosing the current characters for the log-on string including manufacture, type, speed and default settings of the modem selected. Some modems allow all parameters to be set up before installation, thereby eliminating the need for the modem string altogether.

Beckwith Electric has a series of application notes relating to communications issues. Please contact the factory at (813) 535-3408 for further information.

SETUP UNIT

```

SETUP UNIT
← count comm SETUP exit

```

The **SETUP UNIT** menu selection enables you to perform tasks necessary to set up the unit for operation. The second-level menu selections are described below.

SOFTWARE VERSION

```

SOFTWARE VERSION
VERS access time dipsw →

```

The **SOFTWARE VERSION** menu selection presents the current software version. This menu selection displays the same software version number that is displayed when system power is turned on.

ALTER ACCESS CODES

```

ALTER ACCESS CODES
vers ACCESS time dipsw →

```

The **ALTER ACCESS CODES** menu selection enables you to define and change access codes. The M-0420 supports three levels of access codes:

Level 3 access	access to all relay functions (including defining or changing access codes)
Level 2 access	read and change setpoints, monitor status, view trip history
Level 1 access	read setpoints, monitor status, view trip history

Each access code is a one- to four-digit number. If the level 3 access code is set to 9999, the access code feature is disabled. Access codes are entered in the same manner as any other value, using the rotary knob and the left- and right-arrow pushbuttons.

- **NOTE:** If access codes are enabled (the level 3 code is set to something other than 9999), you must have level 3 access to alter any access code. *If you forget your access code, you will have to contact the factory for information on resetting the unit.*

DATE & TIME

```
DATE & TIME
vers access TIME dipsw →
```

The **DATE & TIME** menu selection enables you to set the unit's internal clock to the current date and time, to synchronize the clock, to start and stop the clock, and to calibrate the clock's time base.

- **NOTE:** The unit is shipped with the clock stopped.

DIP SWITCH SETTINGS

The **DIP SWITCH SETTINGS** menu enables you to determine the setting of the internal configuration DIP switches. Choosing this menu selection will display the default screen shown below (60 Hz version). For further information about the DIP switches, see Chapter 6, **Installation**.

```
DIP SWITCH SETTINGS
vers access time DIPSW →
```

1X	8 OFF OIPSWITCH
XXXXXX	ON

INPUT USER LOGO

```
USER LOGO LINE 1
←LOG01 logo2 disp okled→
```

The **INPUT USER LOGO** menu selection enables you to enter two alphanumeric lines (User Logo 1 and User Logo 2) to identify the unit. If these lines are defined, they will be displayed instead of the Beckwith Electric Co. screen at certain times. The information on these screens is also automatically transmitted via **COM1** and **COM2** during remote communications in order to aid in identifying the relay. To enter a line, first use the left- and right-arrow keys to move the cursor to the location of the desired character. Next, use the front panel knob to select the desired character from the ASCII character set. Repeat this procedure for each character in the message. When the desired message has been entered, press **ENTER**.

- **NOTE:** The user logo screens will be displayed if the first character of line 1 (the top menu line) is any character *other than a space*. If a space character is present, this feature is disabled.

LCD DISPLAY BLANKING

```
LCD DISPLAY BLANKING
←logo1 logo2 DISP okled→
```

The **LCD DISPLAY BLANKING** menu selection enables you to select the screen-blanking option for the Liquid Crystal Display. When screen-blanking is enabled, the LCD will blank two seconds after **EXIT** is chosen from the top-level menu and after five minutes of unattended operation from *most* other menus. This feature is enabled as shipped from the factory.

RELAY OK LED FLASH

RELAY OK LED FLASH
 ←logo1 logo2 disp OKLED→

If this function is enabled, the RELAY OK LED on the front panel will flash at the rate of about two flashes per second. If disabled, the LED will be on continuously.

V.T. AND C.T. RATIOS

V.T. & C.T. RATIOS ←RATIO	V.T. PHASE RATIO 1.0:1	V.T. NEUTRAL RATIO 1.0:1
	C.T. PHASE RATIO 1.0:1	C.T. NEUTRAL RATIO 1.0:1

In order for the M-0429A BECOCOM™ Communications Software program to properly display primary values for voltages, currents, and power, the program must have available the appropriate VT and CT ratios. For this reason, each M-0420 can be programmed with its VT and CT ratios. During communications, these ratios are transmitted to the BECOCOM program.

- **NOTE:** These ratios are used for BECOCOM display purposes only; they are not used in the M-0420 for any calculations and need not be set if remote communication is not desired.

These ratios are always set as X to 1. For example, if the VT is a 600 V/120 V or 575 V/115 V, the ratio would be input as 5.0 to 1.

- **NOTE:** When the VT secondary voltage has been chosen to be 120 V (via the internal configuration DIP switch), the VT ratios should be calculated as marked on the VT. However, when 69.3 V has been selected, the VT ratio should be divided by $\sqrt{3}$. For example, a 600 V/69.3 V VT has a ratio of $600/(69.3 \times \sqrt{3}) = 5$ or 5.0:1. (When the 69.3 V option is selected, the M-0420 internally scales the input voltages by a factor of $\sqrt{3}$ to provide a nominal 120 V. Hence the $\sqrt{3}$ factor in the above equation.)

When the VT inputs are selected as line-to-ground through DIP switch 5, primary line voltages are displayed as follows:

$$V_{AB} = V_A\sqrt{3} \quad V_{BC} = V_B\sqrt{3} \quad V_{CA} = V_C\sqrt{3}$$

Because of the many connections and ratios available with CTs and VTs, experimentation with various ratios may be required to achieve the proper primary value display.

EXIT LOCAL MODE



Pressing **ENTER** when **EXIT LOCAL MODE** is displayed returns you to the default message screens.

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6 INSTALLATION

INITIAL SETUP PROCEDURE

The M-0420 is shipped with the initial relay settings listed in the Specifications at the front of this book and in Chapter 2, **Application**. Select settings that are unique to your application using the **CONFIGURE RELAYS** menu and then the specific settings for each relay function. Review the front panel operation of the M-0420 described in Chapter 3, **Front Panel Controls**, before you attempt the following procedure.

■ **NOTE:** The following procedure can be performed before the M-0420 is installed. All settings will remain stored in its memory even after power has been removed.

1. Connect power to the M-0420's rear power terminals (as marked on the rear-panel power supply label and as shown in Figure 6-5, External Connections).
2. As described in Chapter 4, **Operation**, the relay performs a power-on self test routine and ends by cycling through a display of all of the functions that are tripped. Assuming that various voltage functions are enabled, and that there are no test voltage inputs connected, you will see various voltage targets identified as having tripped.
3. To set the system clock, proceed as follows:
 - a. Press the **ENTER** pushbutton to go to the beginning of the main menu.
 - b. Rotate the knob clockwise until **SETUP UNIT** appears on the first line of the display.
 - c. Press **ENTER**, and rotate the knob to **TIME**.
 - d. Press **ENTER**. The date and time in the system memory will appear. If the clock is stopped (the as-shipped condition), the seconds digits will not change. If so, press **ENTER**, rotate the knob to **START**, then press **ENTER** again. The **DATE & TIME** menu will return. Push **ENTER**. The selection **SET** will be in capital letters. Press **ENTER** and step through all of the elements of setting the date and time using the rotary knob and saving each entry using the **ENTER** pushbutton. After the last **ENTER**, the **DATE & TIME** menu will appear again. Press **ENTER**, and the new date and time will appear on the display, with the seconds digit incrementing. To synchronize with utility system time, set the time somewhat ahead and use the **SYNC** function. Press **EXIT** to return to the **SETUP UNIT** menu.

The battery-backed clock will maintain system time when system power is removed. However, if the M-0420 is to be taken out of service and stored, it is best to stop the clock.

4. If desired, set the user logo screen to your company name and location of the relay by pressing **ENTER** from **SETUP UNIT** and rotate the knob clockwise to **USER LOGO LINE 1**. Press **ENTER**. The default Beckwith Electric logo will appear, with the underline cursor under the farthest left character. You can change this character through a complete set of capital and small letters, numbers, and symbols by turning the rotary knob. When the desired character is visible, press the right arrow pushbutton. This moves the cursor to the next location. When all characters are correct, push **ENTER**. The screen **-WAIT-** will appear, then the display returns to the **USER LOGO LINE 1** selection. Select **USER LOGO LINE 2**, repeat the process, then **EXIT**.

■ **NOTE:** If the M-0420 is to be used with the M-0429A BECOCOM™ Communications Software package, these lines should be set to an unambiguous identifier; for example, *Beckwith Electric\62nd St. Substation*.

5. If desired, calibrate the unit following the calibration procedure detailed in Chapter 7, **Test Procedures**.

■ **NOTE:** The M-0420 has been fully calibrated at the factory using very precise and accurate test equipment. There is no need to recalibrate the unit before initial installation. Further calibration is only necessary if a component was changed during a repair procedure, and will be only as accurate as the test equipment used.

6. Set the internal configuration DIP switches according to your application. Refer to the **DIP Switches** section following for more information on the location of the DIP switches and for a description of their settings. The default DIP switch configuration is shown on the yellow tag attached to the unit when shipped. The configuration can also be determined at any time by accessing the **DIP SWITCH SETTINGS** portion of the **SETUP UNIT** menu.
7. If remote communication is required, set the baud rate, parity, and other parameters for the **COM1** and **COM2** ports by following the instructions in Appendix C, **Communications**, and in the M-0429A BECOCOM™/M-0428A BECOPLOT™ User's Guide.

8. Enable the desired relay functions under the **CONFIGURATION** menu.

■ **NOTE:** Disabling unused functions improves the response time of the indicators and controls.

9. Enter the desired setpoints for the enabled functions. See Chapter 5, **Menu Reference**.
10. If security is desired, set the user access codes.
11. Install the unit and connect the external input and output signals to the relay according to the rear panel terminal block markings as shown in Figure 6-5, **External Connections**.

COMMISSIONING CHECKOUT

During M-0420 field commissioning, check the following to ensure that the CT and VT connections are correct.

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

2. Turn the rotary knob clockwise until the unit displays

MONITOR STATUS
← setpts STAT config →

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

MONITOR VOLTAGE STATUS
VOLT freq curr powr →

4. Press **ENTER**. The unit should display either V_A , V_B , V_C (line-to-ground connections) or V_{AB} , V_{BC} , V_{CA} (line-to-line connections).

PHASE VOLTAGE (Volts)
A= 0.0 B= 0.0 C= 0.0

Compare these voltages with actual measurements using a voltmeter. If there is a discrepancy, check for loose connections to the rear terminal block of the unit.

5. Display positive, negative and zero sequence voltages. Press **ENTER** until the unit displays

POS SEQUENCE VOLTAGE
0.0 Volts

The positive sequence should be $V_{POS} = V_A = V_B = V_C$ or $V_{AB} = V_{BC} = V_{CA}$

6. Press **ENTER** until the unit displays

NEG SEQUENCE VOLTAGE
0.0 Volts

The negative sequence should be $V_{NEG} \approx 0$

7. Press **ENTER** until the unit displays

ZERO SEQUENCE VOLTAGE
0.0 Volts

The zero sequence should be $V_{ZERO} \approx 0$

If the negative sequence voltage shows a high value and the positive sequence voltage is close to zero, the phase sequence is incorrect and proper phases must be reversed to obtain correct phase sequence. If the phase sequence is incorrect, frequency- and power-related functions will not operate properly and the **MONITOR FREQUENCY STATUS** menu will read **LOW VOLT DISABLE**.

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

8. Press EXIT until the unit displays

MONITOR VOLTAGE STATUS
VOLT freq curr powr →

9. Turn the rotary knob clockwise until the unit displays

MONITOR CURRENT STATUS
volt freq CURR powr →

10. Display line currents (I_A , I_B , I_C). Press ENTER. The unit should display

PHASE CURRENT (Amps)
A= 00.0 B= 00.0 C= 00.0

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.

11. Display negative sequence current. Press ENTER. The unit should display

NEG SEQUENCE CURRENT
0.0 Amps

Negative sequence current should be close to zero amperes. If a significant amount of negative sequence current (greater than 25% of I_A , I_B , I_C .) then either the phase sequence or the polarities are incorrect. Modify connections to obtain proper phase sequence and polarities.

12. Press EXIT until the unit displays

MONITOR VOLTAGE STATUS
VOLT freq curr powr →

Turn the rotary knob clockwise until the unit displays

MONITOR POWER STATUS
volt freq curr POWR →

Display real power and check its sign. Press ENTER. The unit should display

REAL POWER
.00 PU

The sign should be positive for forward power and negative for reverse power. If the sign does not agree with actual conditions, reverse the polarities of all three CTs.

DIP SWITCHES

Certain system conditions and M-0420 operator preferences must be set at the time of installation. These parameters are established using an 8-position DIP switch inside the M-0420.

- **NOTE:** The DIP switch settings can be examined from the front panel by using the **DIPSW** selection under the **SETUP** menu. Appendix E, **Configuration Record Forms**, of this manual contains a form for recording the unit's DIP switch settings.

Accessing the Internal Configuration DIP Switch

Release the four captive screws (two each at the top and bottom of the front panel) and pull the internal assembly from the housing. As shown in Figure 6-1, the DIP switch is accessible from the bottom front of the unit.

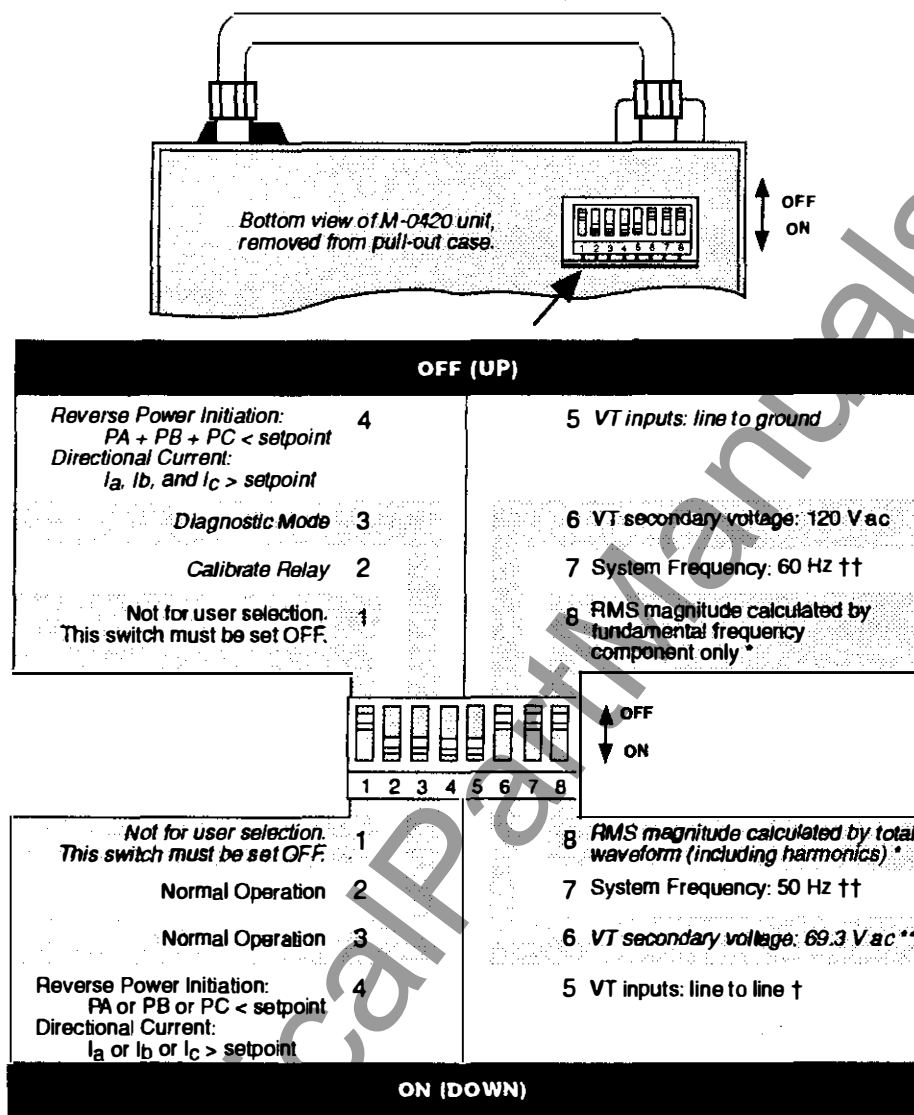
- **NOTE:** Significant force is required to remove and replace the unit in its housing.

Switch	Description	ON (down)	OFF (up)
1	<i>Not for user selection. This switch must be set OFF.</i>		
2	Calibrate Relay	Normal Operation	Calibrate Relay
3	Diagnostic Mode	Normal Operation	Diagnostic Mode
4	Reverse Power	A reversal of power flow in any one phase initiates relay operation (PA or PB or PC < setpoint).	The total 3-phase power must be in the reverse direction for relay initiation (PA + PB + PC < setpoint).
	Directional Current	la or lb or lc > setpoint	la, lb, and lc > setpoint
5	Basic VT Inputs	Line to Line	Line to Ground
6	VT Secondary Voltage	69.3 V ac*	120 V ac
7	System Frequency	60 Hz	60 Hz
8	Basis for rms Magnitude of Voltage and Current	Total Waveform** (including Harmonics)	Fundamental frequency component only

*When the 69.3 V option is selected, the M-0420 internally scales the 69.3 V input to an equivalent 120 V (1 pu) for setting and display purposes.
 ** Neutral voltage functions (59N and 27N) respond to fundamental frequency component only regardless of the setting of DIP switch 8.

- **NOTE:** If line-to-line is chosen for the basic VT inputs (DIP switch 5 is ON), reverse power sensing will respond to total three-phase power regardless of the setting of DIP switch 4.

TABLE 6-1 Internal Configuration DIP Switch



■ NOTES:

- * 59N and 27N functions respond to fundamental frequency component of input waveform only, regardless of the position of switch 8.
- ** When 69.3 V is chosen for the VT secondary voltage, 69.3 V is internally converted to 120 V (1 pu) for all calculations and for setting and display options.
- † If line-to-line is chosen for the basic VT inputs (DIP switch 5 is ON), reverse power sensing will respond to total three-phase power regardless of the setting of switch 4.
- †† If the system frequency selection (DIP switch 7) is changed from the original factory calibration, the unit must be recalibrated (see the self-calibration procedure in Chapter 7, Test Procedures).

FIGURE 6-1 Internal Configuration DIP Switch—60 Hz.

MECHANICAL

The M-0420 is designed as a drawout case for semiflush panel mounting. It will directly mount in a panel prepared for either a General Electric L-2 or Westinghouse FT-41 housing. Dimensions for these mounting configurations are provided in Figures 6-2 and 6-3.

■ **NOTE:** If this is a new installation, choose either mounting configuration and prepare the panel accordingly.

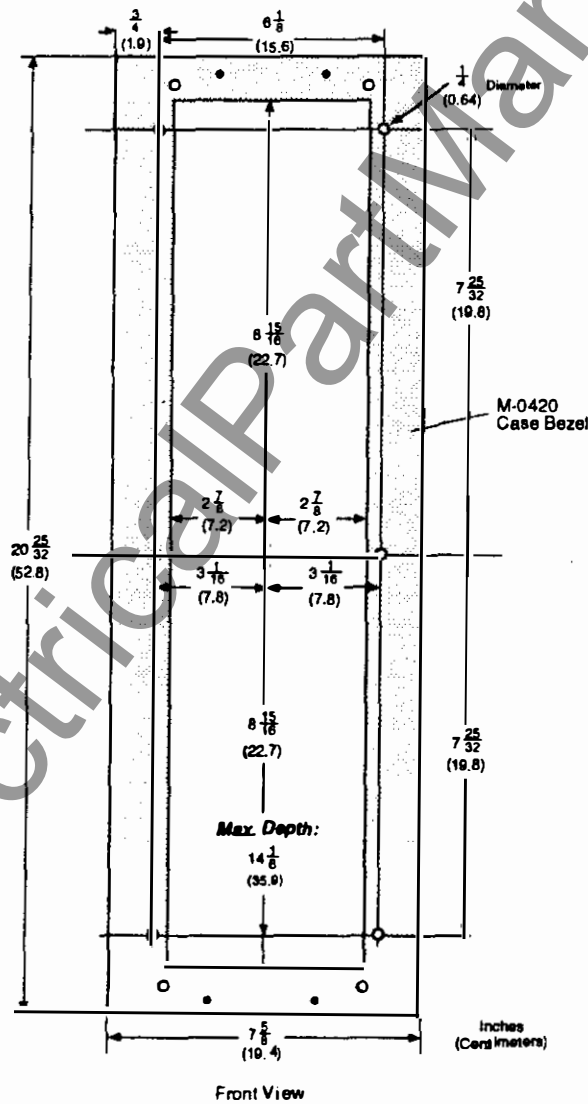


FIGURE 6-2 Mounting Dimensions for GE L-2 Cabinet

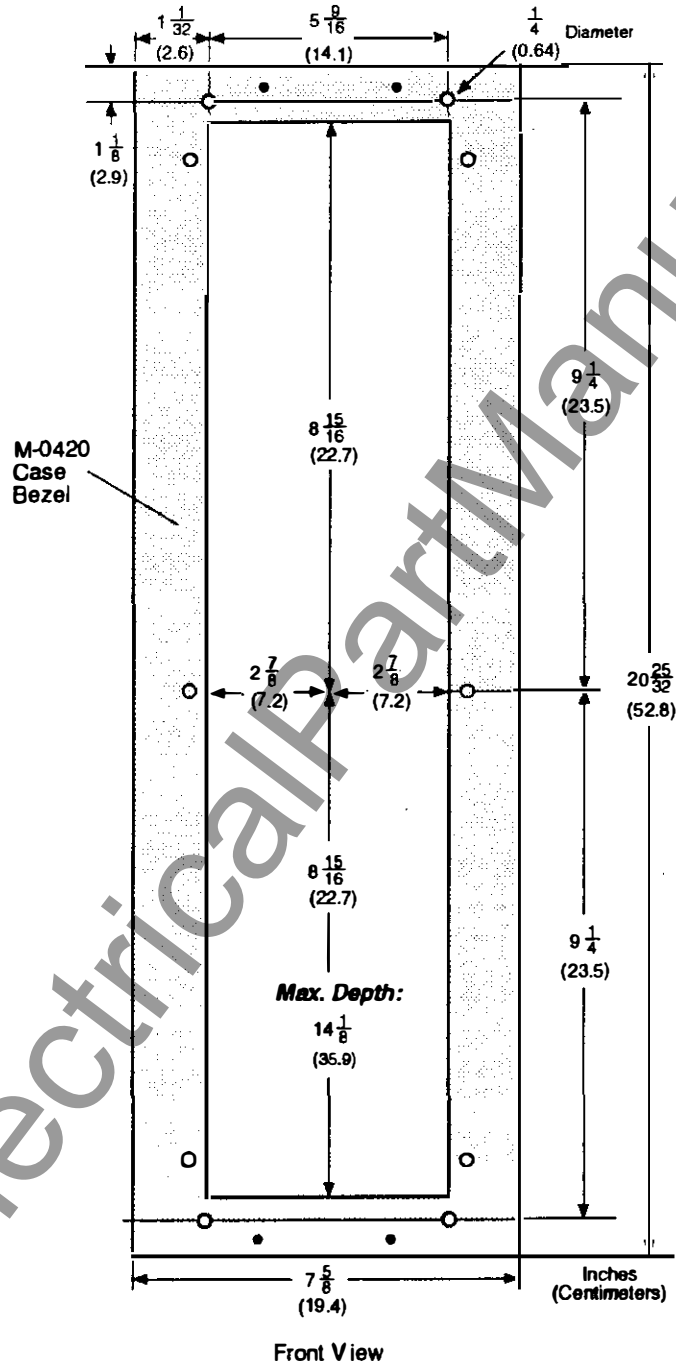
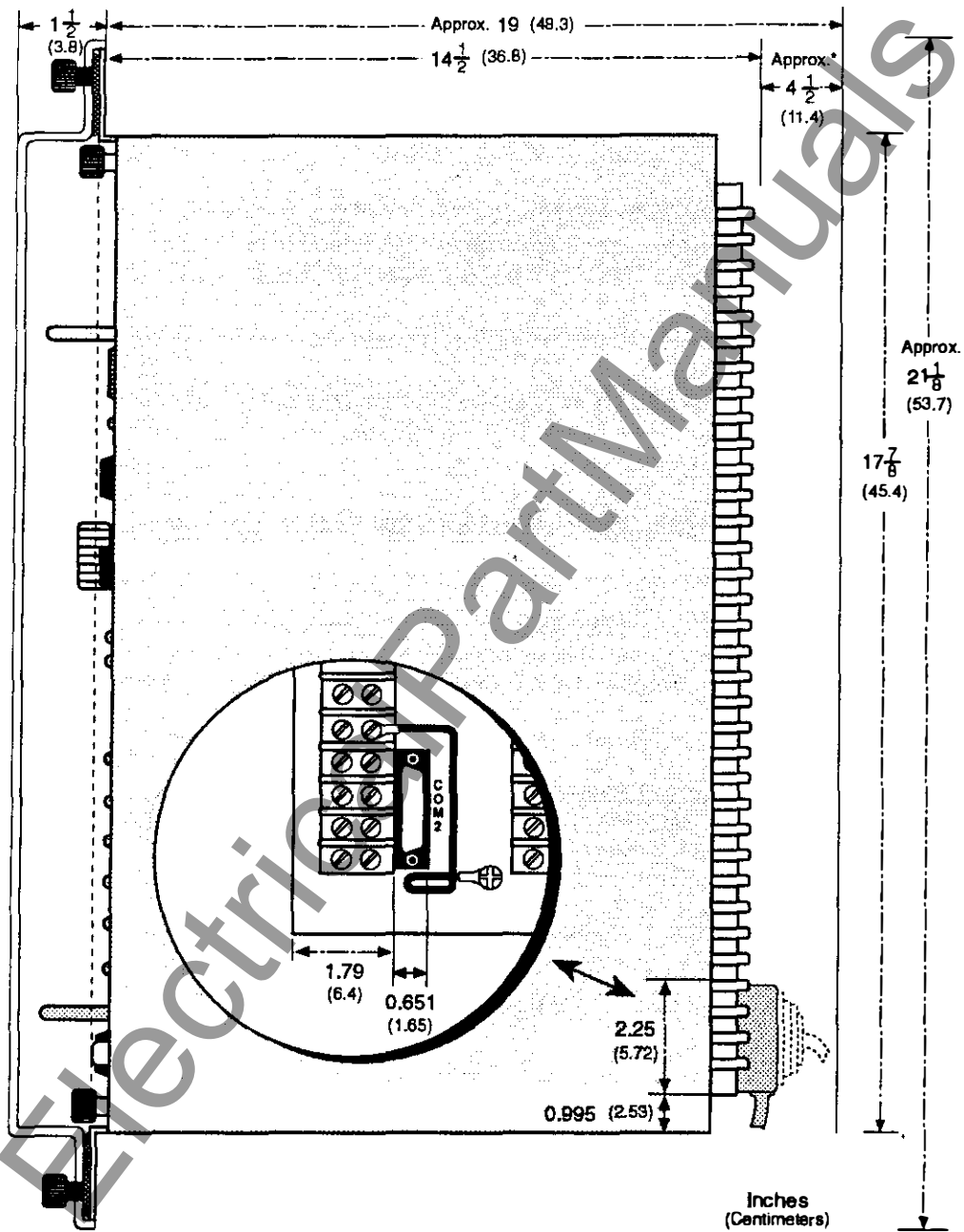


FIGURE 6-3 Mounting Dimensions for Westinghouse FT-41 Cabinet

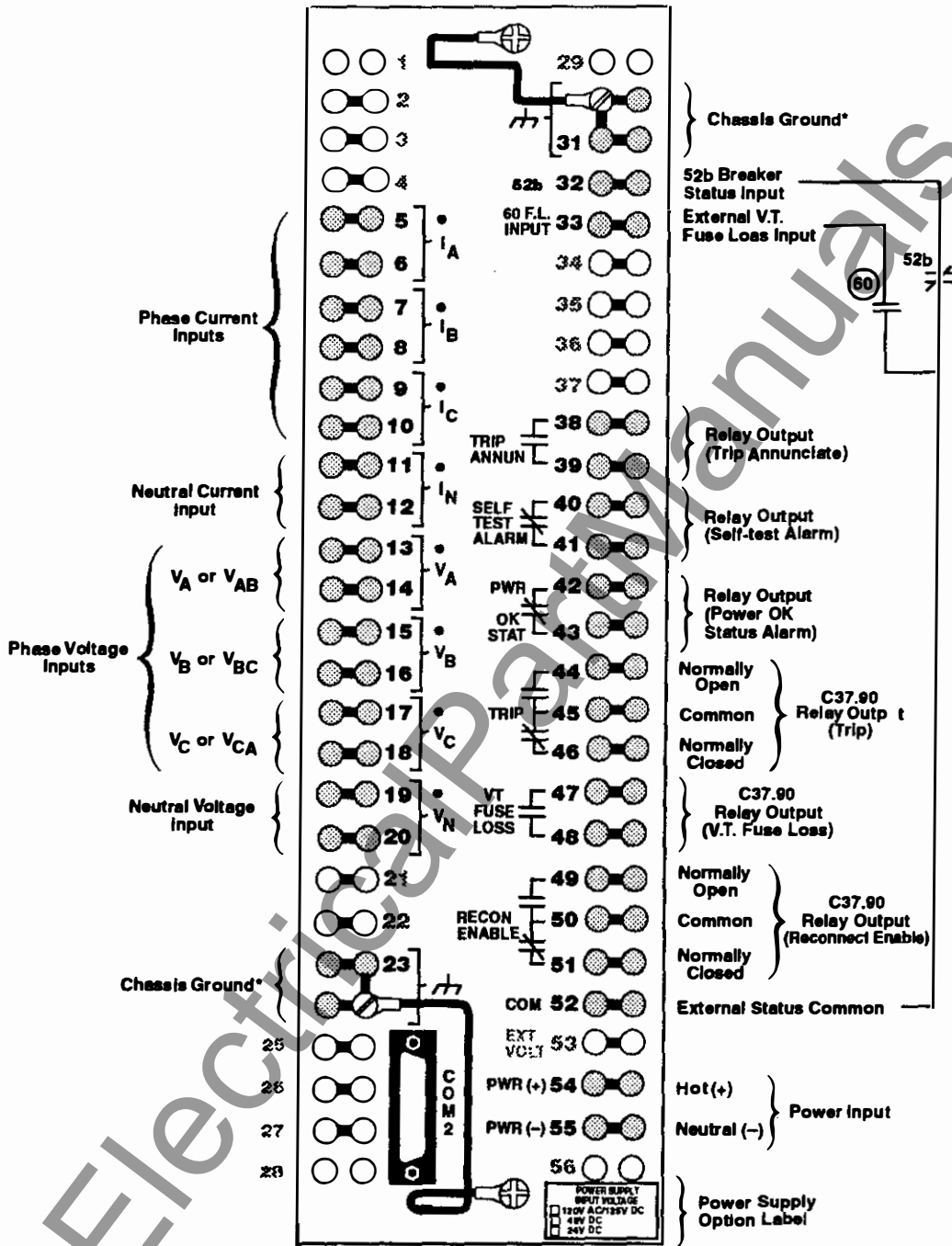
SIDE VIEW



■ **NOTE:** Approximately 2.5" clearance is required when a right-angle connector is used for the rear RS-232C port.

FIGURE 6-4 M-0420 Side View

EXTERNAL CONNECTIONS



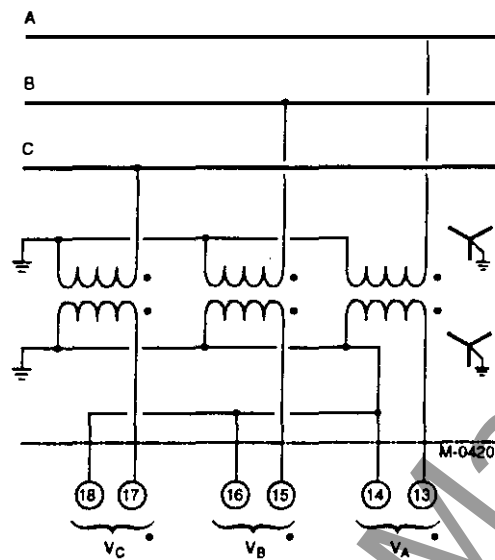
*▲ **CAUTION:** Always connect both locations (terminals 23 and 31) to external chassis ground.

■ **NOTES:**

1. Normally-closed contacts will open when the M-0420 is removed from its pull-out case.
2. Unmarked terminals reserved for future expansion.

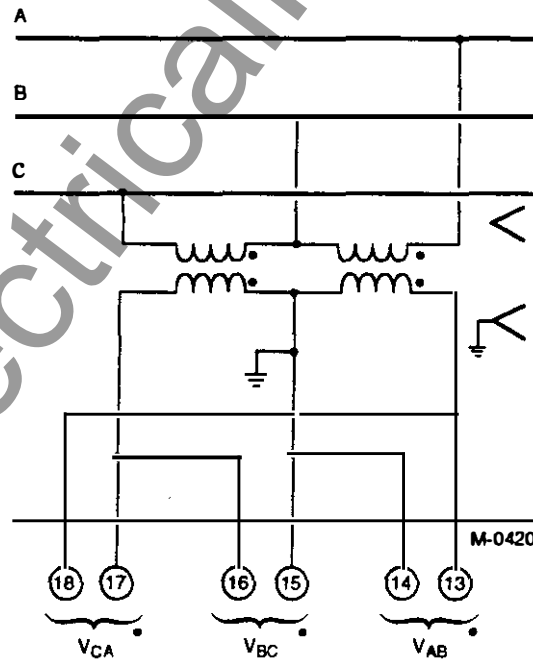
FIGURE 6-5 External Connections

SUGGESTED VT CONNECTIONS



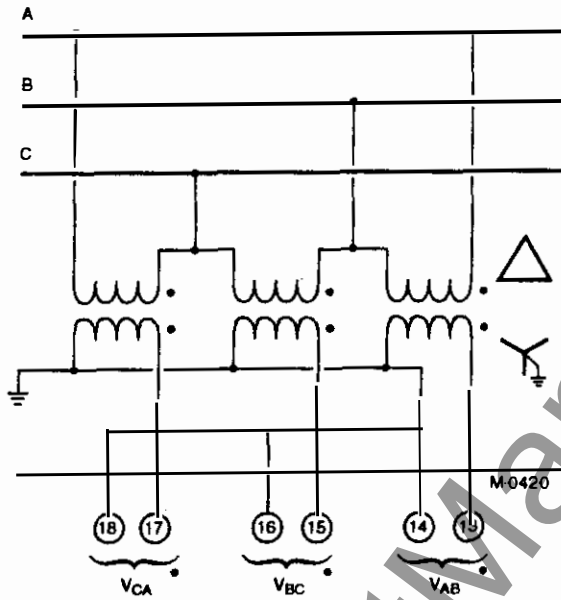
■ **NOTE:** On the internal configuration DIP switch, select line-to-ground for basic VT input and either 69.3 V ac or 120 V ac for VT secondary voltage.

FIGURE 6-6 Connections for Wye-Wye-Connected VTs



■ **NOTE:** On the internal configuration DIP switch, select line-to-line for basic VT input and either 69.3 V ac or 120 V ac for VT secondary voltage.

FIGURE 6-7 Connections for Open-Delta-Connected VTs



■ **NOTE:** On the internal configuration DIP switch, select line-to-line for basic VT input and either 69.3 V ac or 120 V ac for VT secondary voltage.

FIGURE 6-8 Connections for Delta-Wye-Connected VTs

UL-APPROVED TERMINAL BLOCK CONNECTIONS

Serial Numbers 145 and above of the M-0420 are listed to UL Standards for Safety by Underwriters Laboratories Inc. (UL). To fulfill the UL requirements, terminal block connections must be made as illustrated in Figure 6-9: the wire should be No. 12 AWG inserted in an AMP #324915 (or equivalent) connector, and both screws tightened to 20 inch-pounds torque.

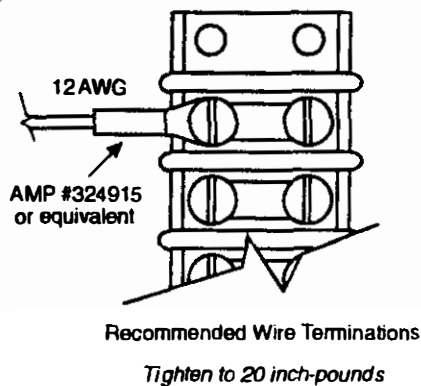


FIGURE 6-9 Wire Terminations for External Connections as Required for UL Listing

7

TEST PROCEDURES

This chapter presents step-by-step test procedures for each M-0420 function as well as the diagnostic mode procedures and the self-calibration procedure. (The diagnostic mode procedures provide a means to check the basic functionality of the relay, including inputs, outputs, the alphanumeric display, LEDs, pushbuttons, and the COM ports.) Refer to Figure 6-5 for the external connections diagram. These tests are based on the three-phase line-to-neutral configuration, with DIP switches 4 and 5 OFF (up).

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UNIT SETUP

No calibration is needed since the unit is calibrated and fully tested at the factory. If calibration is necessary because of a component replacement, follow the self-calibration procedure detailed at the end of this chapter. These test procedures are based on the prerequisite that the functions are enabled and have initial settings as shown in Table 7-1, Initial Settings, the default, as-shipped configuration. (Functions with two available setpoints have only setpoint #1 enabled.)

Before beginning these test procedures, examine the DIP switch settings by going to the **SETUP UNIT** menu and selecting **DIP SWITCH SETTINGS**. If switches 4 and 5 are shown to be **ON** (down), remove the unit from its case and reset them to **OFF**. The applied test voltages and the M-0420 responses defined below are valid only for the three-phase line-to-neutral configuration. If the unit is intended for line-to-line service, reset the DIP switches after completing the tests.

EQUIPMENT REQUIRED

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

1. Two Digital Multimeters (DMM) with 10 A current range
2. 120 V ac or 0 to 125 V dc variable supply for system power
3. Three-phase independent voltage sources (0 to 250 V) to simulate VT inputs*
4. Three-phase variable current sources (0-25 A) to simulate CT inputs*
5. Electronic timer accurate to at least 10 ms.*

* Three Doble F2200 Test Systems or equivalent can be used.

** Doble F2200 or FT-2, or equivalent timer.

TEST AND EQUIPMENT SETUP

1. Connect system power to the power input terminals 54 (hot) and 55 (neutral). The relay can be ordered with a nominal input power supply of 120 V ac, 125 V dc, 48 V dc, or 24 V dc.

■ **NOTE:** The proper power for your relay is clearly marked on the power supply label affixed to the rear panel.

2. Connect the voltage and current inputs according to the configurations shown in Figures 7-1 and 7-2. Before beginning each test, set the test voltage inputs to 120 V ac and the current input to 2 A to simulate normal operating conditions.

OPTIONAL

3. Ohmmeter Connection: The status of the trip contact can be monitored by connecting an ohmmeter to terminals 44 and 45.

Device #	Description	Magnitude #1	Time Delay #1
59	RMS Overvoltage, 3-Phase	132 V (1.10 PU)	30 cycles
59N	RMS Overvoltage, Neutral Circuit or Zero Sequence	150 V (1.25 PU)	30 cycles
59I	Peak Overvoltage	1.10 PU	30 cycles
27	RMS Undervoltage	108 V (0.90 PU)	30 cycles
27N	RMS Undervoltage, Neutral Circuit or Zero Sequence	60 V (0.50 PU)	30 cycles
51O	Over Frequency	60.50 Hz	30 cycles
51U	Under Frequency	59.50 Hz	30 cycles
80	Instantaneous Overcurrent, 3-Phase	10.0 A	—
50N	Instantaneous Overcurrent, Neutral	10.0 A	—
51V	Inverse Time Overcurrent, 3-Phase, with Voltage Control/Voltage Restraint		
	Characteristic Curve		Very Inverse
	Tap Setting		6.0 A
	Time Dial Setting		5
	Voltage Control		Disabled
	Voltage Restraint		Disabled
	Delta-Y Transform		Disabled
51N	Inverse Time Overcurrent, Neutral		
	Characteristic Curve		Very Inverse
	Tap Setting		6.0 A
	Time Dial Setting		5
46	Negative Sequence Overcurrent		
	Tap setting		5.0 A
	Pickup (% of Tap Setting)		50%
	Time Dial Setting		25
	Definite Maximum Time to Trip		10,000 cycles
87	Phase Directional Overcurrent (optional)		
	Overcurrent Element		
	Magnitude		10.0 A
	Time Delay		30 cycles
	Directional Element		
	Maximum Sensitivity (Torque) Angle (MSA)		85°
32	Directional Power, 3-Phase		
	Forward Overpower		3.0 PU
	Time Delay		30 cycles
	Reverse Overpower		-3.0 PU
	Time Delay		30 cycles
	Time Delay, High-Speed setting		Disabled
79	Reconnect Relay		
	Reconnect (close) Time Delay		60 cycles

TABLE 7-1 Initial Settings

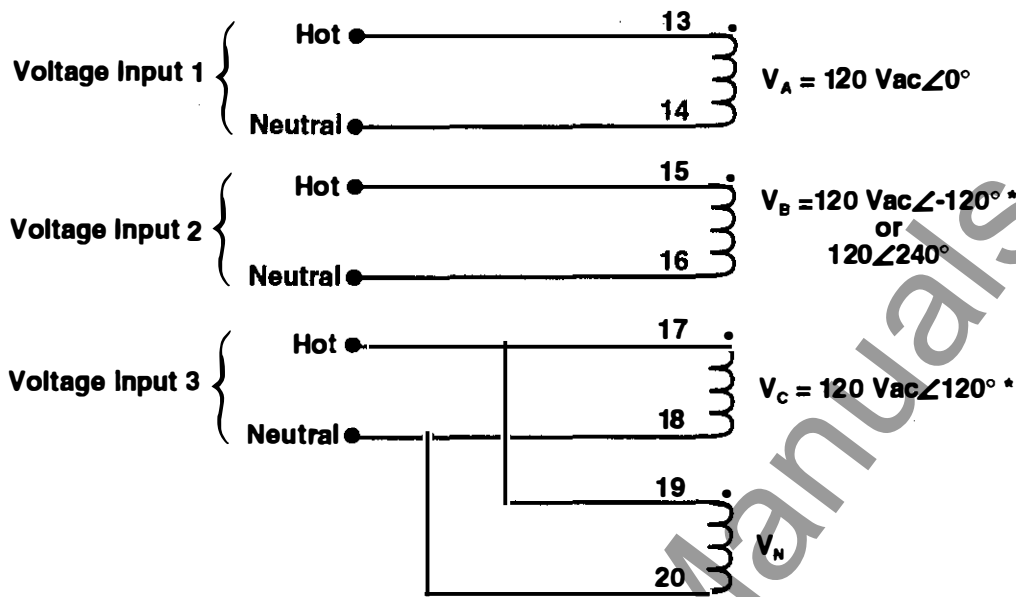


FIGURE 7-1 Voltage Input Configuration

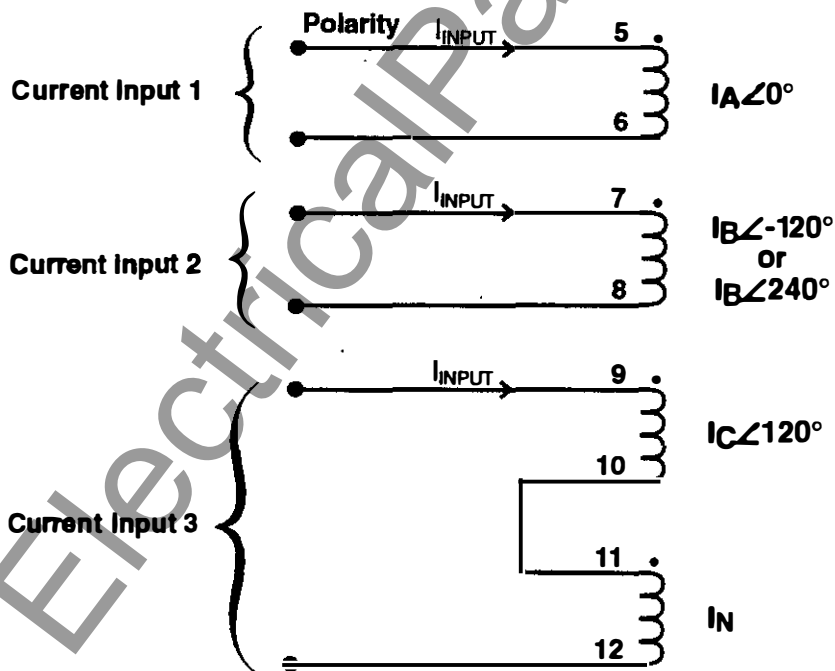


FIGURE 7-2 Current Input Configuration

*■ NOTE: The phase angles shown here use leading angles as positive and lagging angles as negative. Some manufacturers of test equipment have used lagging angles as positive, in which case $V_B = 120 \text{ Vac} \angle 120^\circ$ and $V_C = 120 \text{ Vac} \angle 240^\circ$.

DIAGNOSTIC TEST PROCEDURES

The diagnostic procedures perform basic functional tests to verify the operation of the M-0420 front-panel controls, inputs and outputs, and communication ports. These tests are performed in diagnostic mode, which is entered by setting DIP switch 3 to OFF (up).

To enter diagnostic mode:

1. Power down the unit and remove it from the draw-out case.
2. Set switch 3 of the internal configuration DIP switches to OFF (up).
3. Return the unit to the case and power up the unit. The **DIAGNOSTIC MODE** menu will be displayed.

DIAGNOSTIC MODE

OUTPUT TEST (RELAY)
OUTPUT input led button

Diagnostic mode selections work similar to those of the operational mode, with the exception that after each test is completed and the **EXIT** pushbutton pressed, the word **DONE** is displayed. **EXIT** must be pressed one additional time to return to the **DIAGNOSTIC MODE** main menu.

If you press **EXIT** from the **DIAGNOSTIC MODE** main menu, the following screen will be displayed:

RETURN DIAG MODE DIP SW
PRESS ANY KEY TO RESET

To return the unit to normal operation, power down the unit, reset DIP switch 3 to ON (down), and power up the unit.

To return to the **DIAGNOSTIC MODE** main menu, press any pushbutton except **TARGET RESET/LAMP TEST**.

OUTPUT TEST

The **OUTPUT TEST** menu selection enables you to check the individual relay outputs. Individual relay outputs can be selected by relay number using the rotary knob. The selected output can then be turned on or off using the left- and right-arrow pushbuttons.

RELAY NUMBER	RELAY NAME	NORMALLY OPEN CONTACT*	NORMALLY CLOSED CONTACT*
1	TRIP	44-45	45-46
2	VT FUSE LOSS	47-48	—
3	N/A	—	—
4	SELF-TEST ALARM	—	40-41
5	TRIP ANNUNCIATE	38-39	—
6	RECONNECT ENABLE	49-50	50-51
7	N/A	—	—
8	N/A	—	—

* "Normal" position of the contact corresponds to the OFF (de-energized) state of the relay.

TABLE 7-2 Output Test Terminal Contacts

1. Turn the rotary knob (if necessary) until the unit displays

OUTPUT TEST (RELAY)
OUTPUT input led button

2. Press ENTER.

The unit should display

RELAY NUMBER
1

3. Press ENTER.

The unit should display

RELAY NUMBER
OFF on

4. Referring to Table 7-2, connect a DMM between the normally open contacts for relay 1 (terminals 44 and 45 of the TRIP relay). The output contacts should be open; the DMM should read $\infty \Omega$.

Connect the DMM between the normally closed contacts for relay 1 (terminals 45 and 46 of the TRIP relay). The output contacts should be closed; the DMM should read 0Ω .

5. Use the right-arrow pushbutton to highlight **ON**. The unit should display

RELAY NUMBER
off ON

6. Press **ENTER**. The unit should display

RELAY NUMBER
1

The normally open output contacts should close: the DMM should read 0Ω between terminals 44 and 45.

The normally closed output contacts should open: the DMM should read $\infty \Omega$ between terminals 45 and 46.

7. Press **ENTER**.

The unit should display

RELAY NUMBER
off ON

8. Use the left-arrow pushbutton to highlight **OFF**. The unit should display

RELAY NUMBER
OFF on

9. Press **ENTER**. The unit should display

RELAY NUMBER
1

The normally open output contacts should open: the DMM should read $\infty \Omega$ between terminals 44 and 45.

The normally closed output contacts should close: the DMM should read 0Ω between terminals 45 and 46.

10. Turn the rotary knob clockwise to select relay number 2. The unit should display

RELAY NUMBER
2

11. Repeat steps 3 through 9 for relay 2 and the remainder of the relays being used. When finished, press **EXIT** twice to return to the **DIAGNOSTIC MODE** main menu.

■ **NOTE:** Relays 7 and 8 are not currently used.

- END -

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INPUT TEST

The **INPUT TEST** menu selection enables you to determine the status of the individual status inputs. Individual inputs can be selected by input number using the rotary knob. The status of the input will then be displayed.

INPUT NUMBER	DESIGNATION	TERMINAL
1	52b	32
2	60 FL Input	33
3	not used	---
4	not used	---
5	not used	---
6	not used	---

TABLE 7-3 Input Test Terminal Contacts

1. Turn the rotary knob until the unit displays

INPUT TEST
output INP T led button

2. Press **ENTER**.

The unit should display

INPUT NUMBER
1

3. Press **ENTER**.

The unit should display

INP T NUMBER
CIRCUIT OPEN

4. Simulate closure of the 52b breaker status input contact by making a temporary connection between terminals 52 (**EXT COM**) and 32 (**52b**).

The unit should display

INPUT NUMBER
CIRCUIT CLOSED

5. Press **ENTER**.

The unit should display

INPUT NUMBER
1

Disconnect the temporary contact.

6. Turn the rotary knob clockwise until the unit displays

INPUT NUMBER
2

7. Referring to Table 7-3, repeat steps 2 through 5 for input 2, making the connection from terminal 52 to terminal 33 (**60 F.L INPUT**). When finished, press **EXIT** three times to return to the **DIAGNOSTIC MODE** main menu.

■ **NOTE:** Inputs 3 through 6 are not currently used.

— END —

LED TEST

The **LED TEST** menu selection enables the user to check the front-panel LEDs individually.

LED	DESIGNATION	LED	DESIGNATION
1	59 OVERVOLTAGE	8	51/67 OVERCURRENT
2	27 UNDERVOLTAGE	9	50 INSTANTANEOUS OVERCURRENT
3	59 N OVERVOLTAGE	10	51 N OVERCURRENT
4	27 N UNDERVOLTAGE	11	50 N INSTANTANEOUS OVERCURRENT
5	81 OVER- FREQUENCY	12	46 NEGATIVE SEQUENCE OVERCURRENT
6	81 UNDER- FREQUENCY	13	32 DIRECTIONAL OVERPOWER
7	FAULT RECORDED	14	BREAKER CLOSED

NOTE: LEDs 15 and 16 are not used. The SELECT FUNCTION and ENTER SETPOINT LEDs are referred to by name during the test procedure. The POWER LED should be on continuously when power is applied to the unit. The RELAY OK LED should flash or stay on continuously (as programmed in the SETUP UNIT menu) when power is applied to the unit.

TABLE 7-4 LED Designations

1. Turn the rotary knob until the unit displays

LED TEST
output input LED button

2. Press **ENTER**.

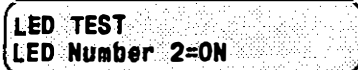
The unit should display

LED TEST
LED Number 1=ON

and LED 1, **59 OVERVOLTAGE**, should turn on.

3. Press **ENTER**.

The unit should display



LED TEST
LED Number 2=ON

and LED 2, **27 UNDERVOLTAGE**, should turn on.

4. Referring to Table 7-4, repeat step 2 for each LED. When all LEDs have been tested, press **EXIT** twice to return to the **DIAGNOSTIC MODE** main menu.

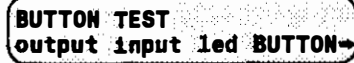
■ **NOTE:** LEDs 15 and 16 are not currently used.

—END—

BUTTON TEST

The **BUTTON TEST** menu selection enables you to check the front-panel pushbuttons. As each pushbutton is pressed, its name is displayed. The rotary knob should cause the displayed number to increment.

1. Turn the knob until the unit displays



BUTTON TEST
output input led BUTTON→

2. Press **ENTER**.

The unit should display



BUTTON TEST
0

3. Turn the knob clockwise. The number should increment.
4. Turn the knob counterclockwise. The number should decrement.
5. Press and hold **ENTER**.

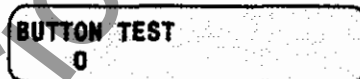
The unit should display



BUTTON TEST
0 ENTER

6. Release **ENTER**.

The unit should display



BUTTON TEST
0

7. Repeat steps 5 and 6 for each front-panel button (left- and right-arrow, **TARGET RESET/LAMP TEST**, and **EXIT**). The name of the button should be displayed while it is held down. When finished, press **EXIT** twice to return to the **DIAGNOSTIC MODE** main menu.

■ **NOTE:** Since pressing the **EXIT** pushbutton will exit from this test, it should be checked last.

—END—

DISPLAY TEST

The **DISPLAY TEST** menu selection enables you to check the Liquid Crystal Display (LCD). This test cycles through varying test patterns until **EXIT** is pressed.

1. Turn the rotary knob until the unit displays



DISPLAY TEST
←DISP backlit com1 com2→

2. Press **ENTER**.

The unit should display a sequence of test characters.

3. After the test has cycled through completely, press **EXIT** twice to return to the **DIAGNOSTIC MODE** main menu.

—END—

BACKLIGHT TEST

The **BACKLIGHT TEST** menu selection enables you to check the LCD backlight by turning it on and off under manual control. The backlight will be turned on for normal operation regardless of whether it is turned on or off when the **DIAGNOSTIC MODE** main menu is exited.

1. Turn the rotary knob until the unit displays

```

BACKLITE TEST
←disp BACKL T COM1 COM2→
  
```

2. Press **ENTER**.

The unit should display

```

BACKLITE TEST
OFF on
  
```

3. Press **ENTER**.

The unit should display

```

BACKLITE TEST
BACKLIGHT OFF
  
```

and the backlight should turn off.

3. Press **ENTER**.

The unit should display

```

BACKLITE TEST
OFF on
  
```

3. Press the right-arrow pushbutton to highlight **ON**. The unit should display

```

BACKLITE TEST
off ON
  
```

4. Press **ENTER**.

The unit should display

```

BACKLITE TEST
BACKLIGHT ON
  
```

and the backlight should turn on.

5. Press **EXIT** twice to return to the **DIAGNOSTIC MODE** main menu.

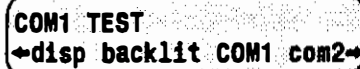
—END—

COM1 TEST

The **COM1 TEST** menu selection enables you to check the front-panel RS-232C port. A loop-back plug is required for this test.

- **NOTE:** The loopback plug required for COM1 consists of a DB9P connector (male) with pin 2 (**RX**) connected to pin 3 (**TX**) and pin 7 (**RTS**) connected to pin 8 (**CTS**). No other connections are necessary.

1. Turn the rotary knob until the unit displays



COM1 TEST
←disp backlit COM1 com2→

2. Press **ENTER**.

The unit should display



COM1 TEST
CONNECT LOOPBACK PLUG

3. Connect the loop-back plug to **COM1**, the front-panel RS-232C connector.
4. Press **ENTER**.

The test will run; when complete the unit should display



COM1 TEST
PASS

5. Press **ENTER** to return to the **DIAGNOSTIC MODE** main menu.

—END—

COM2 TEST

The **COM2 TEST** menu selection enables you to check the rear-panel RS-232C port. A loop-back plug is required for this test.

- **NOTE:** The loopback plug required for COM2 consists of a DB25P connector (male) with pin 2 (**TX**) connected to pin 3 (**RX**) and pin 4 (**RTS**) connected to pin 5 (**CTS**). No other connections are necessary.

1. Turn the rotary knob until the unit displays

```
COM2 TEST
←disp backlit com1 COM2→
```

2. Press **ENTER**.

The unit should display

```
CO TEST
CONNECT LOOPBACK PLUG
```

3. Connect the loop-back plug to **COM2**, the rear-panel RS-232C port.
4. Press **ENTER**.

The test will run; when complete the unit should display

```
COM2 TEST
PASS
```

5. Press **ENTER** to return to the **DIAGNOSTIC MODE** main menu.

—END—

OTHER DIAGNOSTIC MODE COMMANDS

The following diagnostic mode commands are not part of the diagnostic procedures, but are included here for completeness.

Clear Battery Backed RAM

The **CLEAR BATTERY RAM** menu selection enables you to clear the internal battery-backed RAM. This will clear all currently stored trip data, along with the counters and other internal data.

1. Turn the rotary knob until the unit displays



CLEAR BATTERY RAM
←BDRAM clock init →

2. Press **ENTER**. The unit will display the following screens:



CLEAR BATTERY RAM
-WAIT-



CLEAR BATTERY RAM
-DONE-

3. Press **EXIT** to return to the **DIAGNOSTIC MODE** main menu.

—END—

Clear Date and Time

The **CLEAR DATE AND TIME** menu selection enables you to reset the unit's internal clock to 01/01/01 01:01:00.

1. Turn the rotary knob until the unit displays



CLEAR DATE & TIME
←bbram CLOCK init →

2. Press **ENTER**. The unit will display the following screens:



CLEAR DATE & TIME
-WAIT-



CLEAR DATE & TIME
-DONE-

3. Press **EXIT** to return to the **DIAGNOSTIC MODE** main menu.

—END—

Initialize Setpoints

The **INITIALIZE SETPOINTS** menu selection enables you to reset all setpoints to their initial settings as defined in Chapter 2, Application, and the Specifications at the front of this book.

■ **NOTE:** This selection will also reset all access codes.

1. Turn the rotary knob until the unit displays

```
INITIALIZE SETPOINTS
←bbran clock INIT →
```

2. Press **ENTER**. The unit will display

```
INIT SETPOINTS & ACCESS
CODE TO DEFAULT VALUES?
```

■ **NOTE:** If you do not wish to initialize the setpoints at this time, press **EXIT** to return to the **DIAGNOSTIC MODE** main menu.

3. Press **ENTER** to initialize the setpoints. The unit will display

```
INITIALIZING SETPOINTS
-WAIT-
```

```
INITIALIZING SETPOINTS
CSUM S=10 EE=E7 IN=01
```

The **CSUM** (checksum) values are for information only and will vary from unit to unit.

4. Press **EXIT** to return to the **DIAGNOSTIC MODE** main menu.
5. Set switch 3 of the internal configuration DIP switches to **ON** (down).

—END—

Factory Use Only

The **FACTORY USE ONLY** menu selection provides access to diagnostic information and routines of use only to factory personnel. A factory access code is required to proceed beyond this selection.

```
FACTORY USE ONLY
←FACTORY
```

POWER-ON SELF-TEST

1. Apply system power to the unit, but do not connect any test voltage or current inputs.
2. The unit should display

**POWER ON SELFTESTS
XXXXXXXX**

3. All LEDs should turn on for 1 sec. The **POWER LED** and **RELAY OK LED** should remain on, and the rest of the LEDs should turn off.

The unit should display

**POWER ON SELFTESTS
PASS**

4. The unit should trip, as indicated by the internal trip relay changing state.

27 UNDERVOLTAGE LED should turn on

and

27N UNDERVOLTAGE LED should turn on.

5. The unit should display

**BECKWITH ELECTRIC CO.
D-0020Vxx.xx-x**

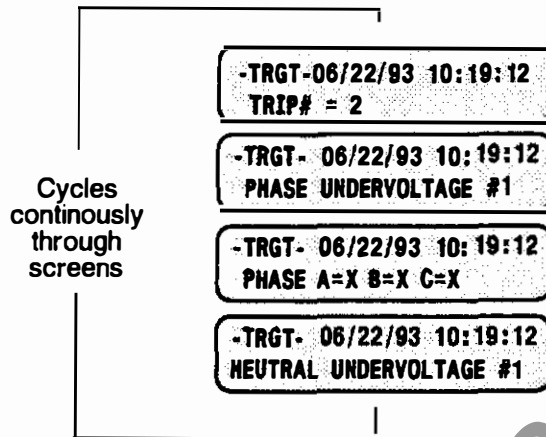
“xx.xx-x” signifies the software revision.

**BECKWITH ELECTRIC CO.
SERIAL NUMBER xxx**

“xxx” signifies the unit serial number.

6. The **POWER LED** should turn on. The **RELAY OK LED** should flash (or stay on as programmed in the setup menu) and the **BREAKER CLOSED LED** should be on. The power-on self-tests ends with the system date and time and the default logo, and then presents the default message screens. These are the target history screens when a trip has occurred, which will have occurred if the voltage and frequency relays are enabled, but there is no input voltage.

7. The display should cycle through the target history screens, as in the following example:



- **NOTE:** Date, time and trip numbers will vary according to the individual relay history, since the target history, the trip counter, and the date and time can be reset from the front panel.

8. Press and hold **TARGET RESET/LAMP TEST** pushbutton. All LEDs should turn on for 1 second.

—END—

59 RMS OVERVOLTAGE, 3-PHASE**MAGNITUDE ACCURACY TEST**

TEST SETTINGS: **Magnitude #1** **126 V (1.05 pu)**
 Time Delay #1 **1 cycle**

1. Press **ENTER**. **SELECT FUNCTION LED** should turn on and the unit should display

VOLTAGE RE Y
 VOLT freq curr powr →

2. Press **ENTER**. The unit should display

OVERVOLTAGE SETPOINTS
 PHASE_OVER phase_under →

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

PHASE OVERVOLTAGE #1
 132 Volts (1.10PU)

4. Change the voltage setpoint by turning the knob counterclockwise to 126 V. The unit should display

PH SE OVERVOLTAGE #1
 126 Volts (1.05PU)

5. Press **ENTER**. The unit should display

DELAY PHASE OVERVOLT #1
 30 CYCLES

6. Change the timer setpoint by turning the knob counterclockwise to 1 cycle. This will cause the relay to trip without delay when the voltage reaches the setpoint.

7. Press **ENTER** once and then **EXIT** until the unit displays

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8. Starting at 120 V ac, slowly increase the input voltage on Phase A until the relay trips.

9. The unit should trip at 126 V ac ± 0.5 V ac.

10. 59 OVERVOLTAGE LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 2

-TRGT- 06/22/93 10:19:12
PHASE OVERVOLTAGE #1

-TRGT- 06/22/93 10:19:12
PHASE A=X B= C=

11. Return the test input voltage to 120 V ac.
12. Press TARGET RESET/LAMP TEST. 59 OVERVOLTAGE LED should turn off. The unit should display

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TIME DELAY ACCURACY TEST

TEST SETTINGS: Magnitude #1 126 V (1.05 pu)
 Time Delay #1 300 cycles

13. Press ENTER. SELECT FUNCTION LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

14. Press ENTER. The unit should display

OVERVOLTAGE SETPOINTS
PHASE_OVER phase_under →

15. Press ENTER. The unit should display

PHASE OVERVOLTAGE #1
126 VOLTS (1.05P.U.)

16. Press ENTER once. Change the timer setpoint by turning the knob counterclockwise to 300 cycles. The unit should display

DELAY PHASE OVERVOLT #1
300 CYCLES

17. Press ENTER once and then EXIT until the unit displays

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18. Replace the ohmmeter connection to the trip relay output with a connection to the timer stop function.

19. Create a step increase in input voltage to 130 V ac and start timing.
20. The unit should trip after 300 cycles (± 1 cycle) time delay. (If using a conventional electronic timer, 300 cycles is the same as 5,000 ms at 16.67 ms per cycle at 60 Hz.)
21. The 59 OVERVOLTAGE LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 3

-TRGT- 06/22/93 10:19:12
PHASE OVERVOLTAGE #1

-TRGT- 06/22/93 10:19:12
PHASE A=X B= C=

22. Return the test input voltage to 120 V ac.
23. Press TARGET RESET/LAMP TEST. The 59 OVERVOLTAGE LED should turn off. The unit should display

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—END—

59N RMS OVERVOLTAGE, NEUTRAL CIRCUIT OR ZERO SEQUENCE**MAGNITUDE ACCURACY TEST**

TEST SETTINGS:	Magnitude #1	150 V (1.25 pu)
	Time Delay #1	1 cycle
	Function 59, Phase Overvoltage	Disable
	Function 59I, Peak Overvoltage	Disable

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

```
VOLTAGE RELAY
VOLT freq curr pow →
```

2. Press **ENTER**. The unit should display

```
OVERVOLTAGE SETPOINTS
PHASE_OVER phase_under↔
```

3. Turn the knob clockwise to highlight **NUTRL_OVER**. Press **ENTER** until the unit displays

```
DELAY NEUTRL OVERVOLT #1
30 Cycles
```

4. Change the timer setpoint by turning the knob counterclockwise to 1 cycle. This will cause the relay to trip without delay when the voltage reaches the setpoint. The unit should display

```
DELAY NEU RL OVERVOLT #1
1 Cycles
```

5. Press **ENTER** once and then **EXIT** two times. The unit should display

```
BECKWITH ELECTRIC CO.
M-0420
```

6. Starting at 120 V ac, slowly increase voltage input 3 (Phase C and neutral) until the trip relay changes state.
7. The unit should trip after 150 V ac ± 0.5 V ac, its default setpoint.
8. The **59N OVERVOLTAGE** LED should turn on and the unit should rotate displays

```
-TRGT- 06/22/93 10:19:12
Trip# = 4
```

```
-TRGT- 06/22/93 10:19:12
NEUTRAL OVERVOLTAGE #1
```

- 9. Set the test input voltage to 120 V.
- 10. Press TARGET RESET/LAMP TEST. The 59 N OVERVOLTAGE LED should turn off. The unit should display

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TIME DELAY ACCURACY TEST

TEST SETTINGS: Magnitude #1 150 V (1.25 pu)
 Time Delay #1 5 cycles

- 11. Press ENTER. The SELECT FUNCTION LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr pow →

- 12. Press ENTER. The unit should display

OVERVOLTAGE SETPOINTS
PHASE_OVER phase_under →

- 13. Turn the rotary knob clockwise until the unit displays

OVERVOLTAGE SETPOINTS
← NUTRL_OVER nutr1_under

- 14. Press ENTER until the unit displays

DELAY NEUTRL OVERVOLT #1
1 Cycles

- 15. Change the timer setpoint by turning the knob clockwise to 5 cycles. This will cause the relay to trip with a delay (to be measured) when the voltage steps above the setpoint. The unit should display

DELAY NEUTRL OVERVOLT #1
5 Cycles

- 16. Press ENTER once and then EXIT until the unit displays

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- 17. Create a step increase in input voltage to 155 V ac and start timing.
- 18. The unit should trip after 5 cycles ±1 cycle time delay.

19. The 59 N OVERVOLTAGE LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 5

-TRGT- 06/22/93 10:19:12
NEUTRAL OVERVOLTAGE #1

20. Set the input voltage to 120 V.

21. Press TARGET RESET/LAMP TEST. The 59 N OVERVOLTAGE LED should turn off. The unit should display

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22. Return to the CONFIGURE RELAYS menu and enable the phase overvoltage and peak overvoltage functions.

—END—

59I PEAK OVERVOLTAGE

MAGNITUDE ACCURACY TEST

TEST SETTINGS:	Magnitude #1	1.10 pu (132 V rms for a sinusoidal input)
	Time Delay #1	1 cycle
	Function 59, Phase Overvoltage	Disable

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

2. Press **ENTER**. The unit should display

OVERDLTAGE SETPOINTS
PHASE_OVER phase_under →

3. Press **ENTER** until the unit displays

DELAY PEAK OVERVOLT #1
30 Cycles

4. Change the setpoint by turning the knob counterclockwise to 1 cycle. The unit should display

DELAY PEAK OVERVOLT #1
1 Cycles

5. Press **ENTER** once and then press **EXIT** until the unit displays

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6. Starting at 120 V ac, slowly increase the test input voltage on Phase A until the relay trips. The unit should trip at 132 V ac \pm 3.6 V ac.

7. The **59 OVERVOLTAGE** LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 6

-TRGT- 06/22/93 10:19:12
PEAK OVERVOLTAGE #1

-TRGT- 06/22/93 10:19:12
PHASE A=X B= C=

8. Set the input voltage to 120 V.

9. Press **TARGET RESET/LAMP TEST**. The **59 OVERVOLTAGE** LED should turn off. The unit should display

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TIME DELAY ACCURACY TEST

TEST SETTINGS:	Magnitude #1	1.10 pu (132 V rms for a sinusoidal input)
	Time Delay #1	5 cycles
	Function 59, Phase Overvoltage	Disable

10. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

11. Press **ENTER**. The unit should display

OVERVOLTAGE SETPOINTS
PHASE_OVER phase_under →

12. Press **ENTER** until the unit displays

DELAY PEAK OVERVOLT #1
1 Cycles

13. Change the setpoint by turning the knob counterclockwise to 5 cycles. The unit should display

DELAY PEAK OVERVOLT #1
5 Cycles

14. Press **ENTER** once and then **EXIT** until the unit displays

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15. Increase the input voltage on Phase A to 136 V ac and start timing. The unit should trip after 5 cycles \pm 1 cycle time delay.

16. The **59 OVERVOLTAGE** LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 7

-TRGT- 06/22/93 10:19:12
PEAK OVERVOLTAGE #1

-TRGT- 06/22/93 10:19:12
PHASE A=X B= C=

17. Set the input voltage to 120 V.

18. Press **TARGET RESET/LAMP TEST**. The **59 OVERVOLTAGE LED** should turn off. The unit should display

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M-0420

—END—

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27 RMS UNDERVOLTAGE, 3-PHASE

DAP 9D

MAGNITUDE ACCURACY TEST

TEST SETTINGS: **Magnitude #1** **108 V (0.90 pu)**
 Time Delay #1 **1 cycle**

1. Press ENTER. The SELECT FUNCTION LED should turn on and the unit should display

VOLTAGE RELAY
 VOLT freq curr powr →

2. Press ENTER. The unit should display

OVERVOLTAGE SETPOINTS
 PHASE_OVER phase_under →

3. Turn the knob clockwise to highlight PHASE_UNDER. Press ENTER. The unit should display

PHASE UNDERVOLTAGE #1
 108 Volts (.90PU)

4. Press ENTER. The unit should display

DELAY PHASE UNDERVOLT #1
 30 CYCLES

5. Change the setpoint by rotating the knob counterclockwise to 1 cycle. The unit should display

DELAY PHASE UNDERVOLT #1
 1 CYCLES

6. Press ENTER once and then EXIT until the unit displays

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 M-0420

7. Starting at 120 V ac, slowly decrease the test input voltage on Phase A until the relay trips. The unit should trip at 108 V ac ± 0.5 V ac.

8. The 27 UNDERVOLTAGE LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
 Trip# = 8

-TRGT- 06/22/93 10:19:12
 PHASE UNDERVOLTAGE #1

-TRGT- 06/22/93 10:19:12
 PHASE A=X B= C=

9. Set the input voltage to 120 V.

10. Press **TARGET RESET/LAMP TEST**. The 27 **UNDERVOLTAGE** LED should turn off. The unit should display

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M-0420

TIME DELAY ACCURACY TEST

TEST SETTINGS: **Magnitude #1** 108 V (0.90 pu)
 Time Delay #1 300 cycles

11. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

12. Press **ENTER**. The unit should display

OVERVOLTAGE SETPOINTS
PHASE_OVER phase_under →

13. Turn the knob clockwise to highlight **PHASE_UNDER**. Press **ENTER**. The unit should display

PHASE UNDERVOLTAGE #1
108 Volts (.90PU)

14. Press **ENTER**. The unit should display

DELAY PHASE UNDERVOLT #1
30 CYCLES

15. Change the setpoint by rotating the knob clockwise to 300 cycles. The unit should display

DELAY PHASE UNDERVOLT #1
1 CYCLES

16. Press **ENTER** once and then **EXIT** until the unit displays

BECKWITH ELECTRIC CD.
M-0420

17. Decrease the test voltage input on Phase A to 107 V ac and start timing. The unit should trip after 300 cycles ± 1 cycle time delay.

18. The 27 UNDERVOLTAGE LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 9

-TRGT- 06/22/93 10:19:12
PHASE UNDERVOLTAGE #1

-TRGT- 06/22/93 10:19:12
PHASE A=X B= C=

19. Reset the input voltage to 120 V ac.

20. Press TARGET RESET/LAMP TEST. The 27 UNDERVOLTAGE LED should turn off. The unit should display

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—END—

27N RMS UNDERVOLTAGE, NEUTRAL CIRCUIT OR ZERO SEQUENCE

MAGNITUDE ACCURACY TEST

TEST SETTINGS:	Magnitude #1	60 V (0.50 pu)
	Time Delay #1	1 cycle
	Function 27, Phase Undervoltage	Disable

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr pow →

2. Press **ENTER**. The unit should display

OVERVOLTAGE SETPOINTS
PHASE_OVER phase_under →

3. Turn the knob clockwise to highlight **NUTRL_UNDER**. Press **ENTER**. The unit should display

NEUTRAL UNDERVOLTAGE #1
60 Volts (.50PU)

4. Press **ENTER**. The unit should display

DELAY NEUTRL UNDERVOLT#1
30 Cycles

5. Change the setpoint by rotating the knob counterclockwise to 1 cycle. The unit should display

DELAY NEUTRL UNDERVOLT#1
1 Cycles

6. Press **ENTER** once and then **EXIT** until the unit displays

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7. Starting at 120 V ac, slowly decrease the test input voltage until the relay trips. The unit should trip at 60 V ac ± 0.5 V ac.

8. The **27N UNDERVOLTAGE** LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 10

-TRGT- 06/22/93 10:19:12
NEUTRAL UNDERVOLT #1

9. Set the input voltage to 120 V.

10. Press **TARGET RESET/LAMP TEST**. The **27N UNDERVOLTAGE** LED should turn off. The unit should display the default logo continuously, or else briefly and then go blank in accordance with the display setup configuration.

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TIME DELAY ACCURACY TEST

TEST SETTINGS:

Magnitude #1	60 V (0.50 pu)
Time Delay #1	5 cycles
Function 27, Phase Undervoltage	Disable

11. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RE AY
VOLT freq curr powr →

12. Press **ENTER**. The unit should display

OVERVOLTAGE SETPOINTS
PHASE_OVER phase_under→

13. Turn the knob clockwise to highlight **NUTRL_UNDER**. Press **ENTER**. The unit should display

NEUTRAL UNDERVOLTAGE #1
60 Volts (.50PU)

14. Press **ENTER**. The unit should display

DELAY NEUTRL UNDERVOLT#1
30 Cycles

15. Change the setpoint by rotating the knob counterclockwise to 5 cycles. The unit should display

DELAY NEUTRL UNDERVOL #1
5 Cycles

16. Press **ENTER** once and then **EXIT** until the unit displays

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17. Decrease the test voltage input to 55 V ac and start timing. The unit should trip after 5 cycles ±1 cycle time delay.

18. The 27N UNDERVOLTAGE LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 11

-TRGT- 06/22/93 10:19:12
NEUTRAL UNDERVOLT #1

19. Reset the input voltage to 120 V ac.

20. Press TARGET RESET/LAMP TEST. The 27N UNDERVOLTAGE LED should turn off. The unit should display

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—END—

60 FL V.T. FUSE-LOSS DETECTION

1. Apply three-phase voltages as shown in Figure 7-1.
2. Set input current to 5.00 A with phase angles as shown in Figure 7-2.
3. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

4. Turn the knob clockwise on the unit until the unit displays

MONITOR STATUS
← setpts STAT config →

5. Press **ENTER**. The unit should display

MONITOR VOLTAGE STATUS
VOLT freq curr powr →

6. Turn the knob clockwise until the unit displays

MONITOR FUSE STATUS
← FUSE temp powerup

7. Press **ENTER**. The **SELECT FUNCTION** LED should turn off and the unit should display

V.T. FUSE STATUS
--OK--

8. Connect a digital multimeter (DMM) across the **V.T. FUSE LOSS** contacts 47 and 48. The DMM should read $\infty \Omega$ (open contacts).
9. Simulate the VT fuse blown condition by removing the voltage input from Phase A ($V_A = 0$ V).

■ **NOTE:** In the default condition, the phase undervoltage relay is blocked when the VT Fuse Loss relay is enabled. Thus, removing the phase voltage simulates a fuse loss without causing a trip.

10. The unit should display

V.T. FUSE STATUS
--BLOWN--

11. The **V.T. FUSE LOSS** contacts should close. The DMM should read 0.00Ω (closed contacts).
12. Verify that the unit did not call for an undervoltage trip.

13. Reconnect the input voltage to Phase A.
14. The **V.T. FUSE LOSS** contacts should open. The DMM should read $\infty \Omega$ (open contacts).
15. The unit should display

V.T. FUSE STATUS
--OK--

16. Check the fuse status on Phase B and Phase C by following steps 9 through 15 above. (Having the neutral in series with Phase C will not affect the VT fuse-loss function. However, the unit will trip on neutral undervoltage when the source voltage is removed.)

—END—

810 OVER FREQUENCY

U1 61.0 Hz @ 60 Hz
 U2 61.5 Hz @ 60 Hz

MAGNITUDE ACCURACY TEST

TEST SETTINGS: **Magnitude #1** **60.50 Hz**
 Time Delay #1 **2 cycles**

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
 VOLT freq curr powr →

2. Turn the knob clockwise to highlight **FREQ**. Press **ENTER** until the unit displays

DELAY OVERFREQUENCY #1
 30 CYCLES

3. Change the timer setpoint by turning the knob counterclockwise to 2 cycles. The unit should display

DELAY OVERFREQUENCY #1
 2 CYCLES

4. Press **ENTER** once and then **EXIT** until the unit displays

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5. Slowly increase the frequency of the three-phase test set until the relay trips. The unit should trip at 60.50 Hz \pm 0.02 Hz.

6. The **81 OVERFREQUENCY** LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
 Trip# = 12

-TRGT- 06/22/93 10:19:12
 OVERFREQUENCY #1

7. Set the frequency to 60.00 Hz.

8. Press **TARGET RESET/LAMP TEST**. The **81 OVERFREQUENCY** LED should turn off. The unit should display

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81U UNDER FREQUENCY

#1 59.5 Hz @ 50 (50%)
 #2 56.0 Hz @ 50

MAGNITUDE ACCURACY TEST

TEST SETTINGS: Magnitude #1 59.50 Hz
Time Delay #1 2 cycles

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
 VOLT freq curr powr →

2. Turn the knob clockwise to highlight **FREQ**. Press **ENTER** and then the right arrow pushbutton, and then **ENTER** until the unit displays

DELAY UNDERFREQUENCY #1
 30 CYCLES

3. Change the timer setpoint by turning the knob counterclockwise to 2 cycles. The unit should display

DELAY UNDERFREQUENCY #1
 2 CYCLES

4. Press **ENTER** once and then **EXIT** until the unit displays

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5. Slowly decrease the frequency of the three-phase test set until the relay trips. The unit should trip at 59.50 Hz ±0.02 Hz.

6. The **81 UNDERFREQUENCY** LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
 Trip# = 14

-TRGT- 06/22/93 10:19:12
 UNOERFREQUENCY #1

7. Set the frequency to 60.00 Hz.

8. Press **TARGET RESET/LAMP TEST**. The **81 UNDERFREQUENCY** LED should turn off. The unit should display

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TIME DELAY ACCURACY TEST

TEST SETTINGS: Magnitude #1 59.50 Hz
 Time Delay #1 30 cycles

9. Press ENTER. The SELECT FUNCTION LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

10. Turn the knob clockwise to highlight FREQ. Press ENTER and then the right arrow pushbutton, and then ENTER until the unit displays

DELAY UNDERFREQUENCY #1
2 CYCLES

11. Change the timer setpoint by turning the knob clockwise to 30 cycles. The unit should display

DELAY UNDERFREQUENCY #1
30 CYCLES

12. Rapidly decrease the frequency of the three-phase test set to 59.00 Hz and start timing. The unit should trip after 30 cycles ±1 cycle time delay.

13. The 01 UNDERFREQUENCY LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 15

-TRGT- 06/22/93 10:19:12
UNDERFREQUENCY #1

14. Set the frequency to 60.00 Hz.

15. Press TARGET RESET/LAMP TEST. The 01 UNDERFREQUENCY LED should turn off. The unit should display

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—END—

50N INSTANTANEOUS OVERCURRENT, NEUTRAL**MAGNITUDE ACCURACY TEST**

TEST SETTINGS: Magnitude #1 9 A
Function 46,
Negative Sequence Overcurrent Disable

1. Press ENTER. The SELECT FUNCTION LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr ←

2. Turn the knob clockwise to highlight CURR. The unit should display

CURRENT RELAY
volt freq CURR powr ←

3. Press ENTER until the unit displays

PHASE INST OVERCURRENT
9.0 Amps

The ENTER SETPOINT LED should be on.

4. Turn the knob clockwise until the unit displays

PHASE INST OVERCURRENT
15.0 Amps

5. Press ENTER and then EXIT until the unit displays

OVERCURRENT SETPOINTS
PHASE_OVER nutr1_over →

6. Turn the knob clockwise until the unit displays

OVERCURRENT SETPOINTS
phase_over NUTRL_OVER →

7. Press ENTER until the unit displays

NUTRL INST OVERCURRENT
10.0 Amps

The ENTER SETPOINT LED should be on.

8. Turn the knob counterclockwise until the unit displays

NUTRL INST OVERCURRENT
9.0 Amps

9. Press ENTER once and then EXIT until the unit displays

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10. Slowly increase the current on Phase C (and neutral) until the relay trips. The unit should trip at 9.00 A ± 0.27 A.

11. The 50 N INSTANTANEOUS OVERCURRENT LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 18

-TRGT- 06/22/93 10:19:12
NUTRL INST OVERCURRENT

12. Reduce the current to 8.50 A.

13. Press TARGET RESET/LAMP TEST. The 50 N INSTANTANEOUS OVERCURRENT LED should turn off. The unit should display

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TIME DELAY ACCURACY TEST

TEST SETTINGS: Magnitude #1 9 A
Function 46,
Negative Sequence Overcurrent Disable

14. Rapidly increase the current on Phase C to 9.50 A. The unit should trip instantaneously (2 cycles).

15. The 50 N INSTANTANEOUS OVERCURRENT LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 19

-TRGT- 06/22/93 10:19:12
NUTRL INST OVERCURRENT

16. Reduce the current to 0.00 A.

17. Press **TARGET RESET/LAMP TEST**. The **50 N INSTANTANEOUS OVERCURRENT LED** should turn off. The unit should display

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—END—

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51 INVERSE TIME OVERCURRENT, 3-PHASE

TIME DELAY ACCURACY TEST—PHASE A

TEST SETTINGS:	Characteristic Curve	Very Inverse
	Tapsetting	1 A
	Time Dial Setting	5.0
	Voltage Control	Disable
	Voltage Restraint	Disable
	Delta-Wye Transform	Disable

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

2. Turn the knob clockwise to highlight **CURR**. The unit should display

CURRENT RELAY
volt freq CURR powr →

3. Press **ENTER** until the unit displays

OVERCURRENT SETPOINTS
PHASE_OVER nutr1_over →

4. Press **ENTER** until the unit displays

TAP PHASE OVERCURRENT
6.0 Amps

The **ENTER SETPOINT** LED should be on.

5. Turn the knob counterclockwise until the unit displays

TAP PHASE OVERCURRENT
1.0 Amps

6. Press **ENTER** once and **EXIT** until the unit displays

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7. Set the input current on Phase A to just below 1.00 A, then rapidly increase it to 2.00 A and start timing.

■ **NOTE:** Commercial test equipment may have a “jump initiate” function that could be used to create a step function to a specific value.

8. The unit should trip within the range 7.14 to 7.59 seconds time delay.
9. The 51/67 OVERCURRENT LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 20

-TRGT- 06/22/93 10:19:12
PHASE TIME OVERCURRENT

-TRGT- 06/22/93 10:19:12
PHASE A=X B= C=

10. Reduce the input current to 0.00 A.
11. Press TARGET RESET/LAMP TEST. The 51/67 OVERCURRENT LED should turn off. The unit should display

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TIME DELAY ACCURACY TEST—PHASE B

TEST SETTINGS:	Characteristic Curve	Very Inverse
	Tapsetting	1 A
	Time Dial Setting	5.0
	Voltage Control	Disable
	Voltage Restraint	Disable
	Delta-Wye Transform	Disable

12. Set the input current on Phase B to just below 1.00 A, then rapidly increase it to 4.00 A and start timing.
13. The unit should trip within the range 1.65 to 1.76 seconds time delay.
14. The 51/67 OVERCURRENT LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 21

-TRGT- 06/22/93 10:19:12
PHASE TIME OVERCURRENT

-TRGT- 06/22/93 10:19:12
PHASE A= B=X C=

15. Set the input current to 0.00 A.
16. Press TARGET RESET/LAMP TEST. The 51/67 OVERCURRENT LED should turn off. The unit should display

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TIME DELAY ACCURACY TEST—PHASE C

TEST SETTINGS:	Characteristic Curve	Very Inverse
	Tapsetting	1 A
	Time Dial Setting	5.0
	Voltage Control	Disable
	Voltage Restraint	Disable
	Delta-Wye Transform	Disable

17. Set the input current on Phase C to just below 1.00 A, then increase it rapidly to 8.00 A and start timing.

18. The unit should trip within the range 0.79 to 0.85 seconds time delay.

19. The **51/67 OVERCURRENT** LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 22

-TRGT- 06/22/93 10:19:12
PHASE TIME OVERCURRENT

-TRGT- 06/22/93 10:19:12
PHASE A= B= C=X

20. Set the input current to 0.00 A.

21. Press **TARGET RESET/LAMP TEST**. The **51/67 OVERCURRENT** LED should turn off. The unit should display

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—END—

51VC / INVERSE TIME OVERCURRENT WITH VOLTAGE CONTROL, 3-PHASETAP 25 TD 20 I₁ 12.5A @ 0.5s PH. In 28.0A**TIME DELAY ACCURACY TEST**

TEST SETTINGS:	Characteristic Curve	Very Inverse
	Tapsetting	1 A
	Voltage Control	132 V (1.10 pu)
	Voltage Restraint	Disable
	Delta-Wye Transform	Disable
	Phase Overvoltage	Disable
	Peak Overvoltage	Disable
	Phase Directional Overcurrent	Disable

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

2. Turn the knob clockwise to highlight **CURR**. The unit should display

CURRENT RELAY
volt freq CURR powr →

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

OVERCURRENT SETPOINTS
PHASE_OVER nutr1_over →

4. Press **ENTER**. The unit should display

TAP PHASE OVERCURRENT
6.0 Amps

The **ENTER SETPOINT** LED should be on.

5. Turn the knob counterclockwise until the unit displays

TAP PHASE OVERCURRENT
1.0 Amps

6. Press **ENTER** once and **EXIT** until the unit displays

VOLTAGE RELAY
VOLT freq curr powr →

7. Turn the knob clockwise until the unit displays

CONFIGURE RELAYS
← setpts stat CONFIG →

8. Press ENTER. The unit should display

CONFIGURE RELAYS
VOLTAGE_RELAY →

9. Press ENTER. The unit should display

PHASE OVERVOLTAGE #1
disable ENABLE

10. Turn the knob counterclockwise until the unit displays

PHASE OVERVOLTAGE #1
DISABLE enable

11. Press ENTER twice. The unit should display

PEAK OVERVOLTAGE #1
disable ENABLE

12. Turn the knob counterclockwise until the unit displays

PEAK OVERVOLTAGE #1
DISABLE enable

13. Press ENTER once and EXIT once. The unit should display

CONFIGURE RELAYS
VOLTAGE_RELAY →

14. Turn the knob clockwise until the unit displays

CONFIGURE RELAYS
← CURRENT_RELAY →

15. Press ENTER twice. The unit should display

VOLTAGE CONTROL OVERCURR
DISABLE v_cntrl v_rstrnt

16. Turn the knob clockwise until the unit displays

VOLTAGE CONTROL OVERCURR
disable V_CNTL v_rstrnt

17. Press ENTER once and EXIT until the unit displays

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18. Increase the input voltage to 133 volts on all phases.
19. Increase the input current to 2.00 A on all phases.
20. Decrease the input voltage to 131 volts on all phases and start timing.
21. The unit should trip within the range 7.14 to 7.59 seconds time delay.
22. The 51/67 OVERCURRENT LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 23

-TRGT- 06/22/93 10:19:12
PHASE TIME OVERCURRENT

-TRGT- 06/22/93 10:19:12
PHASE A=X B=X C=X

23. Set the input current to 0.00 A.
24. Press TARGET RESET/LAMP TEST. The 51/67 OVERCURRENT LED should turn off. The unit should display

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~~END~~

51VR INVERSE TIME OVERCURRENT WITH VOLTAGE RESTRAINT, 3-PHASE

TIME DELAY ACCURACY TEST

TEST SETTINGS:	Characteristic Curve	Very Inverse
	Tapsetting	1 A
	Time Dial Setting	5.0
	Voltage Control	Disable
	Voltage Restraint	Enable
	Delta-Wye Transform	Disable
	Phase Undervoltage	Disable
	Neutral Undervoltage	Disable

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

2. Turn the knob clockwise to highlight **CURR**. The unit should display

CURRENT RELAY
volt freq CURR powr →

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

OVERCURRENT SETPOINTS
PHASE_OVER nutr1_over ↔

4. Press **ENTER**. The unit should display

TAP PHASE OVERCURRENT
8.0 Amps

The **ENTER SETPOINT** LED should be on.

5. Turn the knob counterclockwise until the unit displays

TAP PHASE OVERCURRENT
1.0 Amps

6. Press **ENTER**. The unit should display

TIMING PHASE OVERCURRENT
OEF inv vinv einv

7. Turn the knob clockwise until the unit displays

TIMING PHASE OVERCURRENT
def inv VINV @inv

8. Press ENTER. The unit should display

TIME DIAL PHASE OVERCURR
5.0

9. If the display does not default to 5.0, turn the knob clockwise or counterclockwise until the unit displays

TIME DIAL PHASE OVERCURR
5.0

10. Press ENTER once and EXIT until the unit displays

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11. Press ENTER. The SELECT FUNCTION LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

12. Turn the knob clockwise until the unit displays

CONFIGURE RELAYS
← setpts stat CONFIG →

13. Press ENTER. The unit should display

CONFIGURE RELAYS
VOLTAGE_RELAY →

14. Press ENTER until the unit displays

PHASE UNDERVOLTAGE #1
disable ENABLE

15. Turn the knob counterclockwise until the unit displays

PHASE UNDERVOLTAGE #1
DISABLE enable

16. Press ENTER until the unit displays

NEUTRAL UNDERVOLTAGE #1
disable ENABLE

17. Turn the knob counterclockwise until the unit displays

NEUTRAL UNDERVOLTAGE #1
DISABLE enable

18. Press **ENTER** once and **EXIT** until the unit displays

CONFIGURE RELAYS
VOLTAGE_RELAY →

19. Turn the knob clockwise until the unit displays

CONFIGURE RELAYS
← CURRENT_RELAY →

20. Press **ENTER** until the unit displays

VOLTAGE CONTROL OVERCURR
DISABLE v_cntl v_rstrnt

21. Turn the knob clockwise until the unit displays

VOLTAGE CONTROL OVERCURR
disable v_cntl V_RSTRNT

22. Press **ENTER** once and **EXIT** until the unit displays

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23. Set the input voltage to 25 volts (V_A , V_B , and V_C). (This changes the current tap setting from 1.00 A to 0.25 A.)

24. Increase the input current to 1.00 A and start timing.

25. The unit should trip at $1.71 \pm 5\%$ seconds time delay.

26. The 51/67 OVERCURRENT LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 24

-TRGT- 06/22/93 10:19:12
PHASE TIME OVERCURRENT

-TRGT- 06/22/93 10:19:12
PHASE A=X B=X C=X

27. Set the input current to 0.00 A.

28. Press **TARGET RESET/LAMP TEST**. The 51/67 OVERCURRENT LED should turn off. The unit should display

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29. Set the input voltage to 60 volts (V_A , V_B , and V_C). (This changes the 51 V tap setting to 0.50 A.)
30. Increase the input current to 1.00 A and start timing.
31. The unit should trip at $7.36 \pm 5\%$ seconds time delay.
32. The unit should rotate displays as in step 26.
33. Set the input current to 0.00 A.
34. Press **TARGET RESET/LAMP TEST**. The 51/67 OVERCURRENT LED should turn off. The unit should display

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35. Set the input voltage to 120 volts (V_A , V_B , and V_C).
36. Increase the input current to 5.00 A and start timing.
37. The unit should trip at $1.22 \pm 5\%$ seconds.
38. The unit should rotate displays as in step 26.
39. Set the input current to 0.00 A.
40. Press **TARGET RESET/LAMP TEST**. The 51/67 OVERCURRENT LED should turn off. The unit should display

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—END—

51N INVERSE TIME OVERCURRENT, NEUTRAL

48 TD 20 2019 5: 28:09

TIME DELAY ACCURACY TEST

TEST SETTINGS:	Characteristic Curve	Very Inverse
	Tapsetting	1 A
	Time Dial Setting	5 A

1. Press ENTER. The SELECT FUNCTION LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr pow →

2. Turn the knob clockwise to highlight CURR. The unit should display

CURRENT RELAY
volt freq CURR pow →

3. Press ENTER. The unit should display

OVERCURRENT SETPOINTS
PHASE_OVER nutr1_over →

4. Press ENTER. The unit should display

TAP PHASE OVERCURRENT
1.0 Amps

The ENTER SETPOINT LED should be on.

5. Turn the knob clockwise until the unit displays

TAP PHASE OVERCURRENT
6.0 Amps

6. Press ENTER once and then EXIT until the unit displays

OVERCURRENT SETPOINTS
PHASE_OVER nutr1_over →

7. Turn the knob clockwise until the unit displays

OVERCURRENT SETPOINTS
phase_over NUTRL_OVER →

8. Press ENTER. The unit should display

TAP NEUTRAL OVERCURRENT
6.0 Amps

The ENTER SETPOINT LED should be on.

9. Turn the knob counterclockwise until the unit displays

TAP NEUTRAL OVERCURRENT
1.00 Amps

10. Press **ENTER** once and **EXIT** until the unit displays

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11. Set the input current on Phase C (and neutral) to just below 1.00 A, then increase it to 2.00 A and start timing. The unit should trip within 7.14 to 7.59 seconds time delay.

12. The 51 N OVERCURRENT LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 25

-TRGT- 06/22/93 10:19:12
NUTRL TIME OVERCURRENT

13. Set the input current to 0.00 A.

14. Press **TARGET RESET/LAMP TEST**. The 51 N OVERCURRENT LED should turn off. The unit should display

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—END—

46. NEGATIVE SEQUENCE OVERCURRENT

Tap 20 TB 30 50% 7.20/1.2

TIME DELAY ACCURACY TEST

TEST SETTINGS:	Tapsetting	5 A
	Pickup (% Tap Setting)	50%
	Time Dial Setting ($K=I_2^2t$)	25
	Definite Max Time to Trip	10,000 Cycles
	Function 46, Negative Sequence Overcurrent	Enable

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr pow →

2. Turn the knob clockwise to highlight **STAT**. The unit should display

MONITOR STATUS
← setpts STAT config →

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

MONITOR VOLTAGE STATUS
VOLT freq curr pow →

4. Turn the knob clockwise to highlight **CURR**. The unit should display

MONITOR CURRENT STATUS
volt freq CURR pow →

5. Press **ENTER** until the unit displays

NEG SEQUENCE CURRENT
0.00 Amps

6. Turn on and set input current to: $I_A=5A -0^\circ$, $I_B=5A -180^\circ$, $I_C=5A -0^\circ$. The display should read "3.33 Amps, Neg.Sequence Current (I_2') = $2/3 I_{INPUT}$."

Check at input currents of 10 A and 15 A:

$I_{INPUT} = 10$ A, $I_2' = 2/3 (10) = 6.67$ Amps on display

$I_{INPUT} = 15$ A, $I_2' = 2/3 (15) = 10$ Amps on display

7. Set input current to 0.00 A.

8. Press **EXIT** until the unit displays

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9. Timing Accuracy Calculations

Tapsetting 5 A
 Pickup 50%
 Time Dial (k) 25
 Definite maximum time to trip 10,000 cycles (166.67 sec.)

$I_2' = 10 \text{ A}$

$I_2 = I_2'/\text{Tapsetting} = 10/5 = 2$, where I_2 = Negative Sequence Current in multiples of the tap setting.

$K = I_2^2 t$

$t = k/I_2^2 = 25/(2)^2 = 25/4 = 6.25 \text{ sec.}$

Input Current Setting = $10(3/2) = 15 \text{ A}$, for example: $I_A=15\text{A } -0^\circ$, $I_B=15\text{A } -180^\circ$, $I_C=15\text{A } -0^\circ$.

$k = 25$
 $I_2 = 2$
 $t = 6.25$
 $I_{\text{reg}} = \frac{10}{5} = 2$
 Tap

10. Set the input current to 15.00 A and start timing. The unit should trip after $6.25 \pm 3\%$ seconds.
 11. The 46 NEGATIVE SEQUENCE OVERCURRENT LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
 Trip# = 26

-TRGT- 06/22/93 10:19:12
 NEG SEQ OVERCURRENT

12. Set the input current to 0.00 A.
 13. Press TARGET RESET/LAMP TEST. The 46 NEGATIVE SEQUENCE OVERCURRENT LED should turn off. The unit should display

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■ NOTE: The negative sequence overcurrent function has a linear reset characteristic that takes four minutes to reset. If you wish to retest this function, you must wait four minutes or power down the unit.

—END—

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67 PHASE DIRECTIONAL OVERCURRENT

TIME DELAY ACCURACY TEST

TEST SETTINGS:	Angle Directional Element (MSA)	0°
	Pickup, Phase Directional Overcurrent	5 A
	Delay, Phase Directional Overcurrent	30 Cycles
	Tap Neutral Overcurrent	10 A
	Function 51V, Phase Time Overcurrent	Disable
	Function 67, Phase Directional Overcurrent	Enable
	Function 46, Negative Sequence Overcurrent	Disable

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr pow →

2. Turn the knob clockwise until the unit displays

CONFIGURE RELAYS
← setpts stat CONFIG →

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

CONFIGURE RELAYS
VOLTAGE_RELAY →

4. Turn the knob clockwise until the unit displays

CONFIGURE RELAYS
← CURRENT RELAY →

5. Press **ENTER** once. The unit should display

PHASE TIME OVERCURRENT
disable NONDIRECTIONAL →

6. Turn the knob counterclockwise until the unit displays

PHASE TIME OVERCURRENT
DISABLE nondirectional →

7. Press **ENTER** once. The unit should display

```
PHASE DIRECTIONAL OVRCUR
DISABLE enable high_spd
```

8. Turn the knob clockwise until the unit displays

```
PHASE DIRECTIONAL OVRCUR
disable ENABLE high_spd
```

9. Press **ENTER** once and **EXIT** until the unit displays

```
CONFIGURE RELAYS
← setpts stat CONFIG →
```

10. Turn the knob counterclockwise until the unit displays

```
CURRENT RELAY
volt freq CURR powr →
```

11. Press **ENTER**. The unit should display

```
OVERCURRENT SETPOINTS
PHASE_OVER nutr1_over →
```

12. Press **ENTER**. The unit should display

```
ANGLE DIR ELEMENT
85 Degrees
```

13. Turn the knob counterclockwise until the unit displays

```
ANGLE DIR ELEMENT
0 Degrees
```

14. Press **ENTER**. The unit should display

```
PICKUP PHASE DIR OVERCUR
10.0 Amps
```

15. Turn the knob counterclockwise until the unit displays

```
PICKUP PHASE DIR OVERCUR
5.0 Amps
```

16. Press **ENTER** once and **EXIT** until the unit displays

```
OVERCURRENT SETPOINTS
PNASE_OVER nutr1_over →
```

17. Turn the knob clockwise until the unit displays

```
OVERCURRENT SETPOINTS
phase_over NUTRL_OVER →
```

18. Press **ENTER**. The unit should display

TAP NEUTRAL OVERCURRENT
1.0 Amps

19. Turn the knob clockwise until the unit displays

TAP NEUTRAL OVERCURRENT
10.0 Amps

20. Press **ENTER** once and **EXIT** until the unit displays

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21. Increase the input current to 6.00 A and start timing. The unit should trip after 30 cycles time delay.

22. The **51/67 OVERCURRENT** LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 27

-TRGT- 06/22/93 10:19:12
DIR PHASE OVERCURRENT

23. Press **TARGET RESET/LAMP TEST**. The **51/67 OVERCURRENT** LED should turn off. The unit should display

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24. Set the phase angle between the voltage and current inputs to 180°:

$$V_A=120\text{Vac}\angle 0^\circ; V_B=120\text{Vac}\angle 240^\circ; V_C=120\text{Vac}\angle 120^\circ;$$

$$I_A=6\text{A}\angle 180^\circ, I_B=6\text{A}\angle 60^\circ, I_C=6\text{A}\angle 300^\circ.$$

The unit should now be in the blocking direction, and should not trip.

25. Set the phase angle between the voltage and current inputs to 45° and **start timing**. The unit should trip after 30 cycles time delay.

26. The **51/67 OVERCURRENT** LED should turn on and the unit should rotate displays

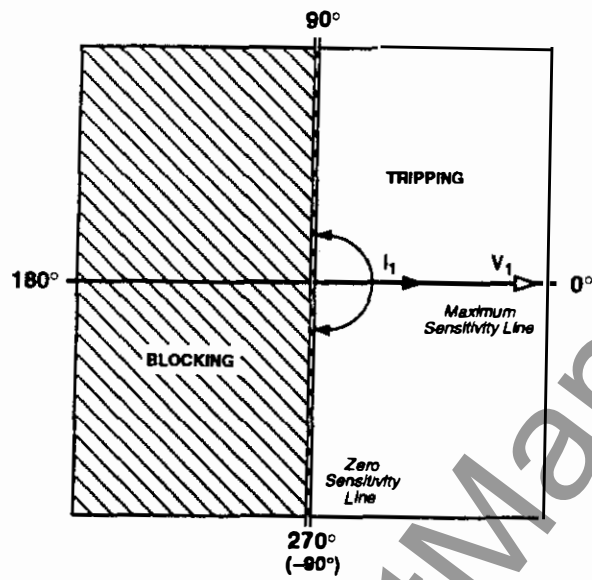
-TRGT- 06/22/93 10:19:12
Trip# = 28

-TRGT- 06/22/93 10:19:12
DIR PHASE OVERCURRENT

27. Press **TARGET RESET/LAMP TEST**. The **51/67 OVERCURRENT** LED should turn off. The unit should display

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28. The tripping and blocking regions of the directional elements are shown in the following figure.



-END-

32F DIRECTIONAL POWER, FORWARD POWER, 3-PHASE

15.1 @ 30.2 cycle

MAGNITUDE ACCURACY TEST

**TEST SETTINGS: Forward Power Flow Magnitude 3.0 pu
Time Delay 1 Cycle**

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

2. Turn the knob clockwise until the unit displays

POWER RELAY
volt freq curr POWER →

3. Press **ENTER** until the unit displays

DELAY FORWARD POWER
30 Cycles

4. Turn the knob counterclockwise until the unit displays

DELAY FORWARD POWER
1 Cycles

5. Press **ENTER** once and then **EXIT** until the unit displays

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6. Slowly increase the input current until the relay trips. The unit should trip at 15 A \pm 0.1 A.

7. The **32 DIRECTIONAL OVERPOWER** LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 29

-TRGT- 06/22/93 10:19:12
FORWARD OVERPOWER

8. Set the input current to 5.00 A.

9. Press **TARGET RESET/LAMP TEST**. The **32 DIRECTIONAL OVERPOWER** LED should turn off. The unit should display

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M-0420

TIME DELAY ACCURACY TEST

TEST SETTINGS: Forward Power Flow Magnitude 3.0 pu
Time Delay 30 Cycles

10. Press ENTER. The SELECT FUNCTION LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

11. Turn the knob clockwise until the unit displays

POWER RELAY
volt freq curr POWER →

12. Press ENTER until the unit displays

DELAY FORWARD POWER
1 Cycles

13. Turn the knob clockwise until the unit displays

DELAY FORWARD POWER
30 Cycles

14. Press ENTER once and then EXIT until the unit displays

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15. Increase the input current to 16.00 A and start timing. The unit should trip after 30 cycles time delay.

16. The 32 DIRECTIONAL OVERPOWER LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 30

-TRGT- 06/22/93 10:19:12
FORWARD OVERPOWER

17. Set the input current to 0.00 A.

18. Press TARGET RESET/LAMP TEST. The 32 DIRECTIONAL OVERPOWER LED should turn off. The unit should display

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—END—

32R DIRECTIONAL POWER, REVERSE POWER, 3-PHASE

WARRANTY

MAGNITUDE ACCURACY TEST

TEST SETTINGS: Reverse Power Flow Magnitude -3.0 pu
Time Delay 1 Cycle

1. Press **ENTER**. The **SELECT FUNCTION** LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr pow →

2. Turn the knob clockwise until the unit displays

POWER RELAY
volt freq curr POWER →

3. Press **ENTER** until the unit displays

FORWARD POWER SETPOINTS
FORWARD reverse

4. Turn the knob clockwise until the unit displays

REVERSE POWER SETPOINTS
forward REVERSE

5. Press **ENTER** until the unit displays

DELAY REVERSE POWER
30 Cycles

6. Turn the knob counterclockwise until the unit displays

DELAY REVERSE POWER
1 Cycles

7. Press **ENTER** once and then **EXIT** until the unit displays

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8. Set the phase angle between the voltage and current inputs to 180°:

$$V_A=120\text{Vac}\angle 0^\circ; V_B=120\text{Vac}\angle 240^\circ; V_C=120\text{Vac}\angle 120^\circ;$$

$$I_A=2\text{A}\angle 180^\circ, I_B=2\text{A}\angle 60^\circ, I_C=2\text{A}\angle 300^\circ.$$

9. Slowly increase the input current until the relay trips. The unit should trip at 15.00 A ±0.10 A.

10. The 32 DIRECTIONAL OVERPOWER LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 31

-TRGT- 06/22/93 10:19:12
REVERSE OVERPOWER

11. Set the input current to 5.00 A.

12. Press TARGET RESET/LAMP TEST. The 32 DIRECTIONAL OVERPOWER LED should turn off. The unit should display

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TIME DELAY ACCURACY TEST

TEST SETTINGS: Reverse Power Flow Magnitude -3.0 pu
Time Delay 30 Cycles

13. Press ENTER. The SELECT FUNCTION LED should turn on and the unit should display

VOLTAGE RELAY
VOLT freq curr powr →

14. Turn the knob clockwise until the unit displays

POWER RELAY
volt freq curr POWR →

15. Press ENTER until the unit displays

FORWARD POWER SETPOINTS
FORWARD reverse

16. Turn the knob clockwise until the unit displays

REVERSE POWER SETPOINTS
forward REVERSE

17. Press ENTER until the unit displays

DELAY REVERSE POWER
1 Cycles

18. Turn the knob clockwise until the unit displays

DELAY REVERSE POWER
30 Cycles

19. Press **ENTER** once and then **EXIT** until the unit displays

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M-0420

20. Increase the input current to 16.00 A and start timing. The unit should trip after 30 cycles time delay.

21. The 32 DIRECTIONAL OVERPOWER LED should turn on and the unit should rotate displays

-TRGT- 06/22/93 10:19:12
Trip# = 32

-TRGT- 06/22/93 10:19:12
REVERSE OVERPOWER

22. Set the input current to 0.00 A.

23. Press **TARGET RESET/LAMP TEST**. The 32 DIRECTIONAL OVERPOWER LED should turn off. The unit should display

BECKWITH ELECTRIC CO.
M-0420

—END—

79 RECONNECT TIME DELAY**TIME DELAY ACCURACY TEST****TEST SETTINGS: Time Delay 60 Cycles**

1. Connect an ohmmeter across reconnect contacts terminals 49 and 50. Contacts should be closed. The voltmeter should read 0.0000 Ω .
2. Increase the input voltage to 132 V.
3. The unit should trip after 30 cycles ± 1 cycle time delay.
4. The reconnect contacts should open. The Digital Multimeter (DMM) reading should indicate open contacts.
5. Decrease the input voltage to 120 V and start timing.
6. The reconnect contacts should close after 60 cycles ± 1 cycle time delay. The ohmmeter should read 0.0000 Ω .

—END—

SELF-CALIBRATION PROCEDURE

The M-0420 has been fully calibrated at the factory. There is no need to re-calibrate the unit prior to initial installation. Further calibration is only necessary if a component was changed during a repair procedure.

TEST EQUIPMENT

The following equipment* is required to perform self-calibration:

- a. Two digital multimeters (DMM) with 10 A current range.
- b. A source of 24 V dc, 48 V dc, 125 V dc, and 120 V ac conforming to the power input specifications.
- c. A source of variable ac voltage from zero to 240 V ac.
- d. A source of variable current from zero to 20 amperes.

*The Doble, AVO, and PowerTec family of test equipment may be used.

TEST SETUP

- a. Disconnect system power (if connected) and pull the unit out of its housing.
- b. Set DIP switch 2 (see Figure 6-1) to OFF (up). For self-calibration, all DIP switches should be OFF except for switch 3.
- c. Place the unit back in the case and verify that the unit assembly is secured properly to the housing.
- d. Connect and configure the voltage inputs (V_A , V_B , V_C and V_N) according to Figure 7-3.

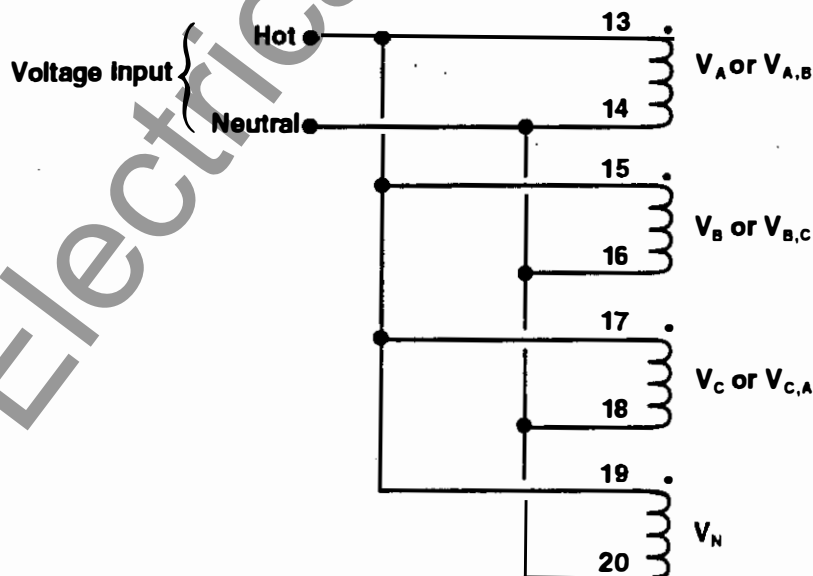


FIGURE 7-3 Single-Phase Voltage Input Configuration for Calibration

- e. Connect and configure the current inputs (I_A , I_B , I_C and I_N) according to Figure 7-4.

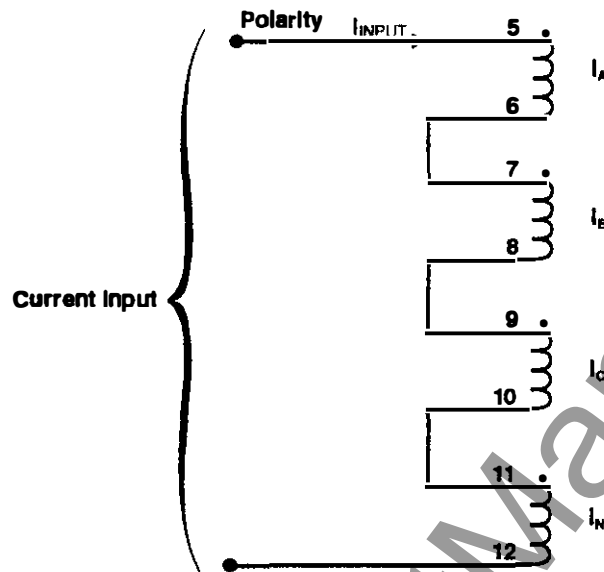


FIGURE 7-4 Single-Phase Current Input Configuration for Calibration

- f. Verify that the system power supply's rating meets specification requirements, and connect it to terminals 54 and 55.
- g. Set the test equipment voltage to 120 V ac, 0.00 degrees phase angle, 60 Hz. Connect the test voltage output to terminals 13 and 14, but do not turn the system power on.
- h. Set the test equipment current source to 5.0 amperes, 0.00 degrees phase angle, 60 Hz. Connect the current source output to terminals 5 and 6, but do not turn the system power on.
- i. Connect a DMM to measure the test equipment output voltage.
- j. Connect a DMM to measure the test equipment output current.

CALIBRATION PROCEDURE

- a. Apply nominal system power to the unit on terminals 54 and 55.
- b. The unit will turn on and display the following:

CALIBRATION MODE

CONNECT REFERENCE INPUTS
PRESS ENTER TO RECAL

- c. Apply 120 V ac test input voltage to terminals 13 (hot) and 14 (neutral).

d. Apply 5 A current input to terminals 5 (polarity) and 12.

e. Press **ENTER**. The unit will enter calibration mode and display

CONNECT REFERENCE INPUTS
- WAIT -

When the calibration has been completed, the unit will display

CONNECT REFERENCE INPUTS
- DONE -

f. Press **EXIT**. The unit will display

RETURN CAL MOD DIP SW
PRESS ANY KEY TO RESTART

g. Turn off the test voltage and current, and the system power.

h. Pull the unit from its case.

i. Set DIP switch 2 to ON (down), and verify that the other switches are in the correct positions for your application.

j. Put the unit back in its case and make sure that the connections are seated properly.

k. Apply system power and the test voltage and current.

l. After the power-on self-test has finished, verify the following readings using the monitor status mode:

Voltage: Phase A = Phase B = Phase C = 120 V ac Neutral = 120 V ac

Peak Phase Voltage (PU): A = 1.00 B = 1.00 C = 1.00

Positive Sequence Voltage: 0.0 V ac

Negative Sequence Voltage: 0.0

Zero Sequence Voltage: 120.0 V ac

Power: Real Power = 1.0 pu Reactive Power = 1.0 pu Power Factor = 1.0

Current: Phase A = Phase B = Phase C = Neutral = 5 A Negative Sequence = 0.0 A

m. Disconnect power from the unit.

n. Remove test input wiring and measurement leads.

-END-

M-0420 DESIGN CHANGES

Beckwith Electric maintains a system whereby customers can obtain information concerning all design changes to our units. Full documentation on each unit is kept on file by model number, serial number, and software version (if applicable).

Each unit has a model number consisting of a letter and four numbers. Significant enhancements are marked with a suffix letter. The rule is that it must be possible to use any later version as a replacement for an earlier version. The opposite may not be true because of features added. If later units are not fully interchangeable for older units, a change in the model number is made.

Changes are recorded by software version number.

D-0020V04.01-32



HOST PROCESSOR SOFTWARE VERSIONS

D-0020V00.68

Added VT and CT ratios settable through the communications interface only. Communications terminal type no longer supported.

D-0020V00.69

Line-to-line suffix (AB, BC, CA) added to target and status display screens when line-to-line option switch is set. VT and CT ratios made settable through the user interface.

D-0020V00.70-07

VT and CT scale factors changed to support fractional values.

M-0420 DESIGN CHANGES

D-0020V01.03-10 ECO 698

Self-test alarm relay changed to normally closed. The following were added:

- Internal VT fuse-loss detection
- VT Fuse Loss Alarm Output
- External VT Fuse-Loss Input (60 FL)
- Auxiliary Trip Output Relay
- Voltage Restraint (51 VR)
- Delta-Y Transform (51 VC/51VR)
- DSP Version Compatibility Check
- Continuous Power Supply Check

D-0020V02.00-21 ECO 755

Capability to include the following options was added:

- Directional Phase Overcurrent (67)
- Directional Control of 51V

D-0020V03.00-32 ECO 814

Internal fuse-loss algorithm enabling/disabling added.

Selectable fuse-loss blocking for 27, 51V, 67, and 32R functions added.

Auto-rearming option for fault recorder added.

D-0020V04.01-32

Power factor now displayed as an absolute value (no sign shown).

TARGET LEDs cannot be reset until all out-of-bound conditions are OK.

Review setpoints screens now scroll only forward.

RELAY OK LED can be programmed to flash or remain on continuously.

Date and time stamp of last power-up added.

Fault recorder programmable post trigger delay added.

Communications access code added.

Range of VT and CT ratios increased.

Modem communications improved.

Fault recorder triggering for multiple faults improved.

APPENDIX A

THEORY OF OPERATION

One early presumption in the design of the M-0420 was that the approach to be pursued would necessarily involve very sophisticated analytical procedures in order to efficiently accommodate multiple functions in one package. In fact, it was realized that the design would require digital signal processing (DSP) techniques in order to make the extremely rapid computations necessary to accommodate all functions in real time. At the same time, the inherent limits on accuracy for many analog components would not be a factor in the new relay.

The approach followed in this project replaces the entire analog signal-processing hardware with a Digital Signal Processor (DSP). If the relay were designed with an analog "front end," it would require analog circuitry for each channel to calculate the magnitude and phase angle, and other analog circuits for the calculation of negative sequence current, real and reactive power, and other functions.

While DSPs are highly effective for signal-processing applications, they are not very efficient for general purpose applications and have limited memory space. Therefore, the multifunction relay uses a dual-processor architecture: the DSP executes all the signal-processing algorithms, while a general-purpose processor (denoted as the host processor) is used mainly for input/output (I/O) processing, including the relay logic.

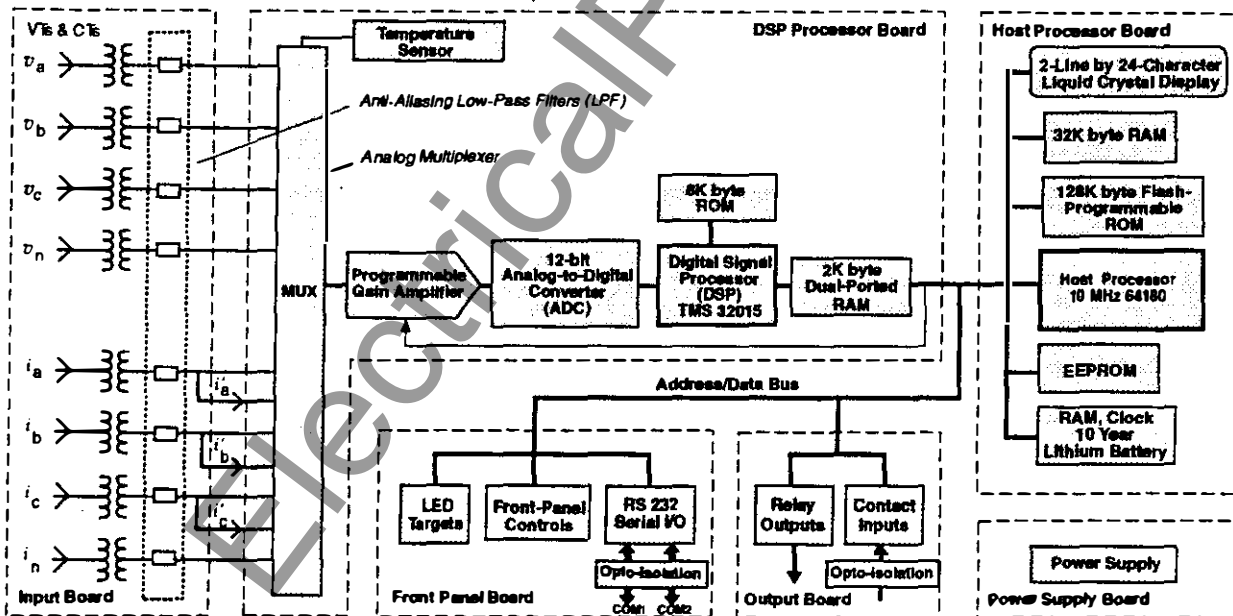


FIGURE A-1 System Block Diagram

SYSTEM BLOCK DIAGRAM

As shown in Figure A-1, the inputs to the M-0420, filtered to remove higher order harmonics, are multiplexed (MUX) and then passed through an analog-to-digital converter (ADC) to the digital signal processor, which performs a discrete fourier transform (DFT) 16 times per cycle for each of the eleven inputs. The host processor manages I/O functions (including the front panel controls, the LCD display, and the two RS-232C ports), updates the memories for setpoint values, records trip information, and ultimately analyzes the data from the DSP to determine the need for a trip command.

The voltage and current signals are scaled and isolated using voltage transformers (VT) and current transformers (CT). These isolated analog signals must be filtered to remove unwanted harmonic content above 480 Hz to accommodate a 960 Hz sampling rate, according to the Nyquist criterion, to avoid aliasing or the incorrect interpretation of frequency components by the system. Anti-aliasing low-pass filters (LPF) are applied individually to the eight inputs for this purpose.

To this point, the circuit is duplicated in hardware for each voltage or current input, but it now becomes efficient to multiplex or time-share those values for the digital portion of the design. The MUX performs a very high-speed electronic switch function, sequentially accepting scaled voltage signals from the filters and routing those signals to the programmable gain amplifier (PGA).

Because of the wide dynamic range of possible input current values, it is difficult to maintain accuracy for both low and high pickup values. Additionally, the gain of the voltage channels should be independent of the phase current pickup setting, and the gain of the neutral current channel may differ from that of the phase current channels. While electromechanical and static relay designs address this problem by providing coil taps on the input current transformer to adjust the pickup current, the multifunction relay uses the PGA. Noting that the relay needs to measure only up to 20 times the pickup value, the gain of the PGA can be adjusted accordingly for each input.

The output of the PGA, representing in time sequence the eleven measured parameters, is scaled to make it compatible with the ADC. Each of the inputs occupies the ADC 16 times per cycle, meaning that 12-bit resolution of eleven independent quantities must be determined every 1.042 ms.

Since available chips designed for efficient digital signal processing are not well suited to the overhead tasks of the relay, these functions are assigned to a second, or "host," microprocessor which is much better suited to the purpose. The host processor performs all overhead functions, e.g., monitors the keyboard for operator requests, updates memories for setpoint values, facilitates operator interaction via a 2-line-by-24-character liquid crystal display, establishes two-way communication using the RS-232C serial ports, and ultimately analyzes the data from the DSP to determine the need for a trip command.

DISCRETE FOURIER TRANSFORM

The digital signal processor makes possible the many calculations in the very limited time available. Fundamental to the relay are the rms value, frequency, and phase angle of the fundamental frequency phasors. A DFT is executed in order to estimate these parameters while filtering the dc offset and harmonics from the fundamental.

The use of an algorithm based on the DFT to compute the frequency and to determine the phase-angle for real/reactive power measurements has several advantages over the approach used in other commercially available digital frequency relays. Relays that calculate these values by measuring the time duration between the two successive zero crossings of the system voltage can be adversely affected by harmonic distortion and noise, which can shift the zero crossings or create multiple zero crossings. The algorithm used in the M-0420 uses voltage phasor estimates obtained from the DFT to compute the frequency. This algorithm not only provides very reliable frequency estimates, but since the DFT rejects dc and harmonic components in the signal, the frequency estimates are not affected by these components. Additionally, deriving the positive sequence voltage phasor from the DFT means that the frequency function will continue to operate should any single- or two-phase fault occur.

To describe the DFT, assume the analog inputs are sinusoidal signals corrupted by noise. The following mathematical notation will be used:

- $z(t)$ = The instantaneous value of a voltage or a current signal
- z_k = The sampled value of signal $z(t)$ at k -th instant
- ω_0 = The fundamental power system frequency in radians per second
- T = The interval between two samples, i.e., $z_k = z(kT)$
- N = The number of samples in one cycle of fundamental frequency

The computation of real (Z_{r_k}) and imaginary (Z_{i_k}) components of the complex phasor (\bar{Z}) are as follows:

$$Z_{r_k} = \frac{2}{N} \sum_{r=0}^{N-1} Z_{k-r} \cos \frac{2\pi r}{N}$$

$$Z_{i_k} = \frac{2}{N} \sum_{r=0}^{N-1} Z_{k-r} \sin \frac{2\pi r}{N}$$
(1)

where $z_{-1}, z_{-2}, \dots, z_{-(N-1)}$ are set to zero.

A major obstacle to the direct computation of (Z_{r_k}) and (Z_{i_k}) is that $2N$ multiplications are required at each sample. The above equations can be rewritten in recursive form to ease the computation:

$$Z_{r_k} = Z_{r_{k-1}} + \frac{2}{N} (Z_k - Z_{k-N}) \cos \frac{2\pi k}{N}$$

$$Z_{i_k} = Z_{i_{k-1}} + \frac{2}{N} (Z_k - Z_{k-N}) \sin \frac{2\pi k}{N}$$
(2)

where z_{-1}, z_2, \dots, z_N and Z_{r-1}, Z_{i-1} are set to zero, and only two multiplications are required per sample. Also, the use of (2) results in a stationary phasor in contrast to the use of (8) which would result in a rotating phasor.

The magnitude $|Z|$ and phase angle (θ) of the phasor can be obtained as follows:

$$|Z| = \sqrt{Z_r^2 + Z_i^2} \quad \text{and} \quad \theta = \tan^{-1}(Z_i / Z_r) \quad (3)$$

The peak Z_{1p} and rms value Z_{1rms} of the fundamental frequency component are given by:

$$\begin{aligned} Z_{1p} &= |Z| \quad \text{and} \\ Z_{1rms} &= |Z| / \sqrt{2} \end{aligned} \quad (4)$$

The filtering characteristics of the DFT algorithm can be better understood by looking at its frequency response. The frequency response for the real and imaginary computation of the DFT algorithm is obtained (for $N=16$) using the Z -transform technique and is given in Figure A-2. It can be seen from this figure that the DFT rejects dc and up to the 14th harmonic of the fundamental.

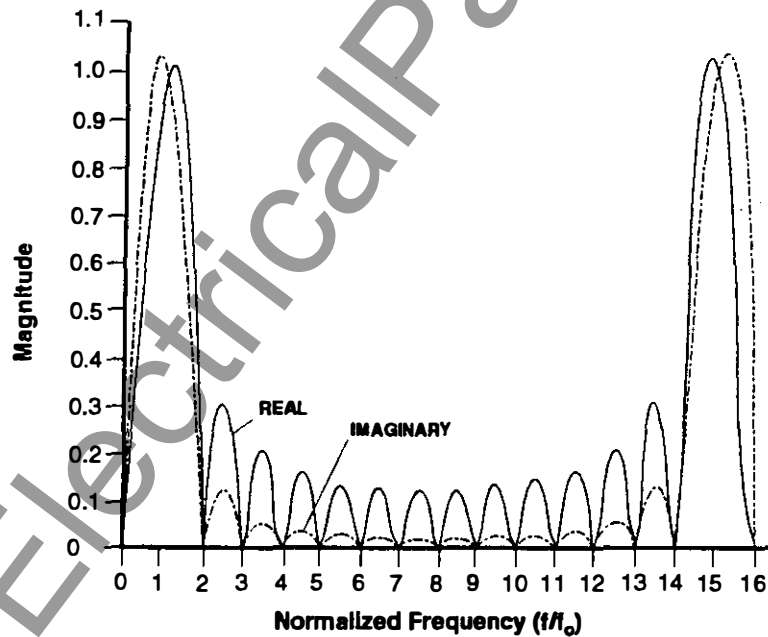


FIGURE A-2 Frequency Response of the DFT Algorithm

Phasor rotation is a basic operation which is useful in many applications when the signals are represented in phasor form. This operation can be used to correct sampling delays in a multi-channel data acquisition system when the sequential sampling technique is used with a single sample-and-hold circuit.

When n signals are sampled sequentially with a delay of ΔT seconds between successive channels, the phasor estimated at the n th channel should be rotated by an angle $-(n-1)\Delta\theta = -(n-1)\omega_0\Delta T$, to correct the phase delay introduced by the sequential sampling. The rotated phasor can be obtained as follows:

$$\begin{bmatrix} z'_{r_n} \\ z'_{i_n} \end{bmatrix} = \begin{bmatrix} \cos(-(n-1)\Delta\theta) & \sin(-(n-1)\Delta\theta) \\ -\sin(-(n-1)\Delta\theta) & \cos(-(n-1)\Delta\theta) \end{bmatrix} \begin{bmatrix} z_{r_n} \\ z_{i_n} \end{bmatrix}, n = 2, 3, \dots, 9 \quad (5)$$

where $z_{r_n} + j z_{i_n}$ is the original phasor and $z'_{r_n} + j z'_{i_n}$ is the corrected phasor.

Estimation of RMS Value of the Signal

The rms value of a periodic signal, $z(t)$ with a period 2π radians is defined as:

$$Z_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} z^2(t) dt} \quad (6)$$

In discrete form, the rms value of a sampled signal, z_k , can be obtained as:

$$Z_{rms_k} = \sqrt{\frac{1}{N} \sum_{r=0}^{N-1} z_{k-r}^2} \quad (7)$$

where $z_{-1}, z_{-2}, \dots, z_{-(N-1)} = 0$.

The quantity Z_{rms_k} represents the rms value of the entire signal considering dc, fundamental and up to the n th harmonic where n is equal to $(\frac{N}{2} - 1)$.

Equation (14) can be rewritten in a recursive form to reduce the computations, as follows:

$$Z'_{rms_k} = Z'_{rms_{k-1}} + z_k^2 - z_{k-N}^2 \quad (8)$$

where: $Z'_{rms_{-1}} = 0$ and $z_{-1}, z_{-2}, \dots, z_{-N} = 0$

Now the rms value is given by:

$$Z_{\text{rms } k} = \sqrt{\frac{Z'_{\text{rms } k}}{N}} \quad (9)$$

Instantaneous Peak Voltage

Instantaneous peak value (Z_p) of a sampled signal z_k can be calculated as follows:

$$Z_p = \text{Max. of } \left[Z_{k-r} \right]_{r=0}^{N-1} \quad (10)$$

where $z_1, z_2, \dots, z_{(N-1)} = 0$.

The value Z_p should be distinguished from the value Z_{1p} . The value Z_p is the instantaneous peak value of the unfiltered signal whereas Z_{1p} is the estimated peak value of the fundamental frequency component.

Estimation of the Fundamental Frequency

Commercially available digitally-based frequency relays commonly measure the time duration between the two successive zero crossings of the system voltage to compute the frequency. The performance of these relays is adversely affected by the presence of harmonic distortion and noise which shifts the zero crossing or creates multiple zero crossings. Recently digital frequency relay algorithms have been proposed in the relaying literature [4]. The algorithm based on the DFT [5] is very attractive for implementation, and it provides very reliable frequency estimates. This algorithm uses voltage phasor estimates obtained from the DFT to compute the frequency. Since the DFT rejects dc and harmonic components in the signal, the frequency estimates are not affected by these components.

It was noted earlier that if recursive computations are used for the DFT, the resulting phasor estimates are stationary. Now, assume the input signal frequency is allowed to change slightly from its nominal value ($f_0 = \omega_0 / 2\pi$) an amount of Δf , while the sampling frequency remains constant. It can be shown that when the input signal frequency changes from f_0 to $(f_0 + \Delta f)$, the phasor undergoes magnitude and phase modifications. For small deviations in frequency, the magnitude factor is small compared to the phase factor, and the phase change can be used as a measure of the frequency deviation.

Let θ_k be the phase of the voltage phasor at the k-th instant, then the following phase recursive relation can be obtained:

$$\theta_k \approx \theta_{k-1} + \frac{\Delta f 2\pi}{f_0 N} \quad (11)$$

and

$$\Delta f \approx \frac{d\theta}{2\pi dt} \approx \frac{1}{2\pi} (\theta_k - \theta_{k-1}) f_0 N \quad (12)$$

Hence, the rate of change of the phase angle of the complex phasor is directly related to the deviation of the input signal frequency from the nominal frequency. The phasor diagram of the rotating phasor is shown in Figure A-3.

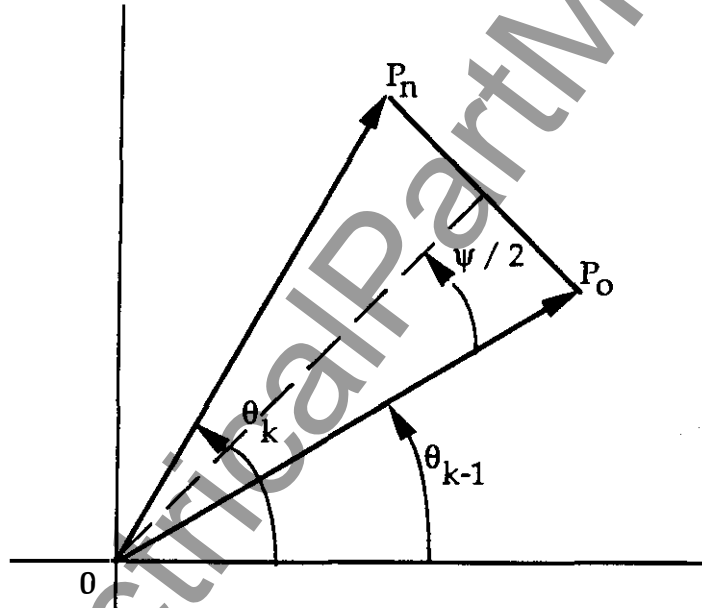


FIGURE A-3 Phasor Diagram

The angle $\psi = \theta_k - \theta_{k-1}$ is calculated every cycle as:

$$\psi = \tan^{-1} \left| \frac{\frac{1}{2}(\overline{OP}_n - \overline{OP}_0)}{\frac{1}{2}(\overline{OP}_n + \overline{OP}_0)} \right| \quad (13)$$

From the calculated value of ψ , the frequency can be obtained as:

$$f \approx f_0 + \frac{\psi}{2} \left(\frac{f_0 N}{\pi} \right) \quad (14)$$

It has been shown in [6] that the error in the estimated frequency can be reduced for larger values of Δf , if the positive sequence voltage phasor is used to compute the frequency instead of a voltage phasor from one phase. This is because there will be a cyclic variation in the estimated frequency as derived from one phase which is automatically filtered when positive sequence quantities are used. Further, the use of the positive sequence quantity eliminates any concern about loss of the sampled phase due to a single phase fault.

Calculation of Sequence Components

In protective relaying, it is often required to monitor the sequence components of voltage and current signals of a three-phase system. For example, in the multifunction relay, the positive sequence voltage phasor is used to compute the frequency and the negative sequence current is used to detect unbalances and open phases.

Let \bar{V}_a , \bar{V}_b and \bar{V}_c be the estimated phasors of the three phase voltages. Then, the positive \bar{V}_1 , negative \bar{V}_2 and zero sequence \bar{V}_0 components of the three phase voltages are given by:

$$\begin{bmatrix} \bar{V}_0 \\ \bar{V}_1 \\ \bar{V}_2 \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} \bar{V}_a \\ \bar{V}_b \\ \bar{V}_c \end{bmatrix} \quad (15)$$

where phasor $\bar{V} = (V_r + jV_i)$ and $\alpha = -0.5 + j0.866$ or $1 \angle 120^\circ$.

Calculation of Power/Power Factor

Computation of complex power can be easily achieved when the voltage and current signals are represented in phasor form. Let \bar{V} and \bar{I} represent complex phasors of voltage and current signals measured across a load. Then the complex power (\bar{S}) delivered to the load is given by:

$$\begin{aligned} \bar{S} &= \bar{V} \bar{I}^* = P + jQ \\ &= VI \cos\theta + j VI \sin\theta \end{aligned} \quad (16)$$

where real power is given by the real part of $\bar{V} \bar{I}^*$ and the reactive power is given by the imaginary part of $\bar{V} \bar{I}^*$, where * denotes a complex conjugate of a phasor.

For a three phase system, the total power is the sum of the individual power in each phase.

$$P_T + jQ_T = \sum_{l=a, b, c} \bar{V}_l \bar{I}_l^* \quad (17)$$

The power factor is computed to make possible its display as:

$$pf = \frac{P_T}{|S|} = \frac{P_T}{\sqrt{P_T^2 + Q_T^2}} \quad (18)$$

In this way the power factor is calculated using the defining equation with no simplifying assumptions on zero cross phase angles, a commonly used procedure which is correct only when dealing with pure sinusoids.

Implementation of Inverse Time Overcurrent Relay Curves

The time current characteristic of an induction type overcurrent relay can be modeled as:

$$\int_{t_0}^t f(I) dt \geq K \quad (19)$$

Where I is the current in multiples of tap setting, K is the time-dial setting and function f determines the shape of the curve. In the above equation the integration process begins when the current exceeds the tap setting and the relay operates when the integral exceeds K .

The digital implementation of (19) is used in this relay. Let I_k be the current magnitude in multiples of the tap setting and consider the following integration with an initial sum (U_0) set to zero:

$$U_k = U_{k-1} + f(I_k) \quad (20)$$

and if we say the relay is operated when the running sum reaches a threshold value K_{iv} , then the relay operating time (T_0) for a constant magnitude of current is given by:

$$T_0 = \frac{K_{iv} T}{f(I_k)} \quad (21)$$

where $T = 4.17$ ms is the time interval used for the integration.

Four independent integrators – three for phase elements and one for neutral element – are used. The integration function allows the overcurrent relay to coordinate with existing electromechanical relays. The integration function provides correct relay operation for dynamic fault currents. The relay actuating quantity can be selected as the rms current or the fundamental frequency rms current.

The function $f(I_k)$ in (20) is approximated as a piece-wise quadratic polynomial as follows [7,9]:

$$f'(I^2) = A_0 + A_1(I^2) + A_2(I^2)^2 \quad (22)$$

where f' is a weighted least-squares approximation of f , and A_0 , A_1 , and A_2 are the polynomial coefficients. The variable in the approximating function is selected as I^2 instead of I to avoid the square root computation.

ACKNOWLEDGEMENTS

Beckwith Electric Company is pleased to acknowledge the financial support of the Gas Research Institute, Consolidated Edison Company of New York and Rochester Gas and Electric Company in the development of this product.

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- [4] *Microprocessor Relays and Protection Systems*. IEEE Tutorial Course Text, 88EH0269-1-PWR.
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APPENDIX B

SELF-TEST ERROR CODES

Error Code	Description
1	Host to DSP sync fail (int1)
2	DSP aux register fail
3	DSP RAM fail
4	DSP Program fail
5	DSP ALU fail
6	DSP status register fail
7	DSP shifter fail
8	DSP multiplier fail
9	DSP miscellaneous fail
10	(reserved for DSP)
11	(reserved for DSP)
12	high-speed interrupt fail (int2)
13	dual-ported RAM fail, DSP side
14	A/D timing fail
15	Incompatible DSP Software Version
16	Uncalibratable inputs
17	(reserved for DSP)
18	(reserved for DSP)
19	(reserved for DSP)
20	uninitialized EEPROM 0
21	uninitialized EEPROM 1
22	uninitialized EEPROM 2 (not used at present)
23	checksum error EEPROM 0
24	checksum error EEPROM 1
25	checksum error EEPROM 2 (not used at present)

TABLE B-1 Self-Test Error Codes

Error Code	Description
26	read/write error EEPROM 0
27	read/write error EEPROM 1
28	read/write error EEPROM 2 (not used at present)
29	DPRAM calibration values checksum error
30	fault recorder buffer fail
31	watchdog for values update failure
32	values update out-of-sequence failure
33	unimplemented host interrupt (NMI)
34	unrecognized DSP interrupt code failure
35	unimplemented host interrupt
36	unimplemented host restart
37	unimplemented host opcode trap
38	main routing return error
39	math error (square root or divide by zero)
40	WARNING: low clock battery
41	read/write clock RAM fail
42	dual-ported RAM fail, host side
43	dual-ported RAM fail-to-read-clear, host side
44	WARNING: uninitialized clock RAM
45	(unused)
46	EEPROM write verify error
47	Communication Buffer Error
48	unrecognized failure code
49	failure of DSP to enter run mode
50	failure of DSP to enter self-test mode

TABLE B-1 Self-Test Error Codes (continued)

Error Code	Description
51	phase ground reference gain 1 fail
52	neutral ground reference gain 1 fail
53	phase ground reference gain 8 fail
54	neutral ground reference gain 8 fail
55	positive supply reference fail
56	negative supply reference gain 1 fail
57	negative supply reference gain 2 fail
58	negative supply reference gain 4 fail
59	negative supply reference gain 8 fail

TABLE B-1 Self-Test Error Codes (continued)

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APPENDIX C

COMMUNICATIONS

The M-0420 incorporates two serial ports for intelligent, digital communication with external devices. Equipment such as RTU's, data concentrators, modems, 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 M-0420 is accessible remotely through the communication software interface and the data exchange protocol.

- **NOTE:** For detailed information on communications, refer to the M-0429A BECOCOM™/M-0428A BECO PLOT™ User's Guide.

THE BECOCOM™ PROTOCOL

The M-0420 and the M-0429 communications software use the BECOCOM protocol. The protocol implements full-duplex, serial, byte-oriented, asynchronous communication and can be used to fulfill the following communication functions:

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

COMMUNICATION PORTS

The M-0420 has both front- and rear-panel RS-232 ports. The front-panel connector is a 9-pin (DB9S) connector configured as DTE (Data Terminal Equipment) per the RS-232C standard. The rear-panel connector is a 25-pin (DB25S) connector also configured as DTE. Signals are defined as shown in Table C-1.

- **NOTE:** The RS-232C standard specifies a combined cable length between the modem, relays and communication-line splitter not to exceed 50 feet. Successful operation cannot be guaranteed for cable exceeding this recommendation. Every effort should be made to keep cabling as short as possible. Low capacitance cable is recommended for long runs.

All control signals are electrically compatible with RS-232 levels and are actively driven, with the exception of the front panel DTR signal which is permanently wired TRUE. All RS-232 signals are optically isolated to withstand 1414 V dc and incorporate MOV protection. Each communication port can be configured for any of the standard baud rates (300, 600, 1200, 2400, 4800, and 9600).

- **NOTE:** The RS-232 communication ports are excluded by Beckwith Electric from passing ANSI/IEEE C37.90.1-1989. We suggest the use of fiber optic communication lines to avoid any question of surge-withstand capability.

	Signal	COM1	COM2
RX	Receive Data	Pin 2	Pin 3
TX	Transmit Data	Pin 3	Pin 2
RTS	Request-to-Send	Pin 7	Pin 4
CTS	Clear-to-Send	Pin 8	Pin 5
DTR	Data Terminal Ready	Pin 4	—
SGND	Signal Ground	Pin 5	Pin 7
CGND	Chassis Ground	—	Pin 1

TABLE C-1 Communication Port Signals

DIRECT TERMINAL COMMUNICATIONS VIA COM1

The M-0420 provides a limited communications ability via the front panel COM1 port: a subset of the status parameters and control functions can be executed via a standard “dumb” terminal. This function can be used in testing or while the unit is on-line.

- **NOTE:** The M-0420 must not be in local mode.

Any terminal which supports ANSI emulation (sometimes called an ANSI BBS terminal) can be used. Additionally, a compatible PC running any standard terminal emulator software (such as Procomm or Smarterm) set to the ANSI terminal type can be used.

Because most terminals and PCs are also configured as DTE (Data Terminal Equipment) some form of null modem cable is usually required. Pin-outs for these cables are provided in Figures C-1 and C-2. These cables are available from Beckwith Electric, or can be fabricated or purchased from most computer supply houses.

The baud rate and parity of the terminal must match the settings of the M-0420. The M-0420 always communicates with 8 data bits, 1 stop bit, and either even or no parity.

The commands available in this mode are listed in Table C-2. They can be issued by pressing the appropriate key.

■ **NOTE:** Do not use other keys. They are reserved for factory uses and may result in unpredictable operation.

Procedure: M-0420 Terminal Communications via COM1

1. Set the baud rate and parity on the **CONFIGURE COM1** menu on the M-0420.
2. Exit local mode.
3. Connect properly wired cable between the front-panel **COM1** port and the terminal or PC.
4. Set the terminal baud rate, number of bits, number of stop bits, etc.
5. Press any of the key codes defined in Table C-2.

Key*	Function
M	Metering and Status
A	Arm Fault Recorder
D	Disarm Fault Recorder
F	Trigger Fault Recorder
R	Reset Local LED Targets
Z	Clear Trip History Records

**Note: Letters must be upper case.*

TABLE C-2 Terminal Commands

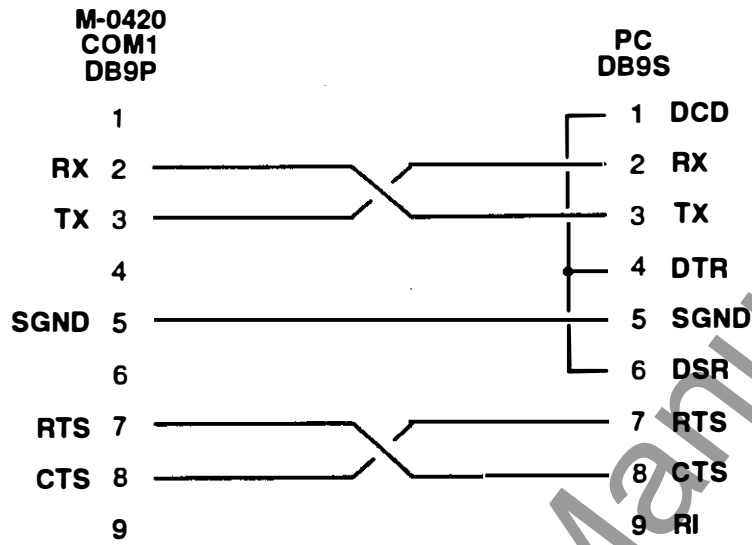


FIGURE C-1 Null Modem Cable: M-0420 COM1 to PC (9-pin)

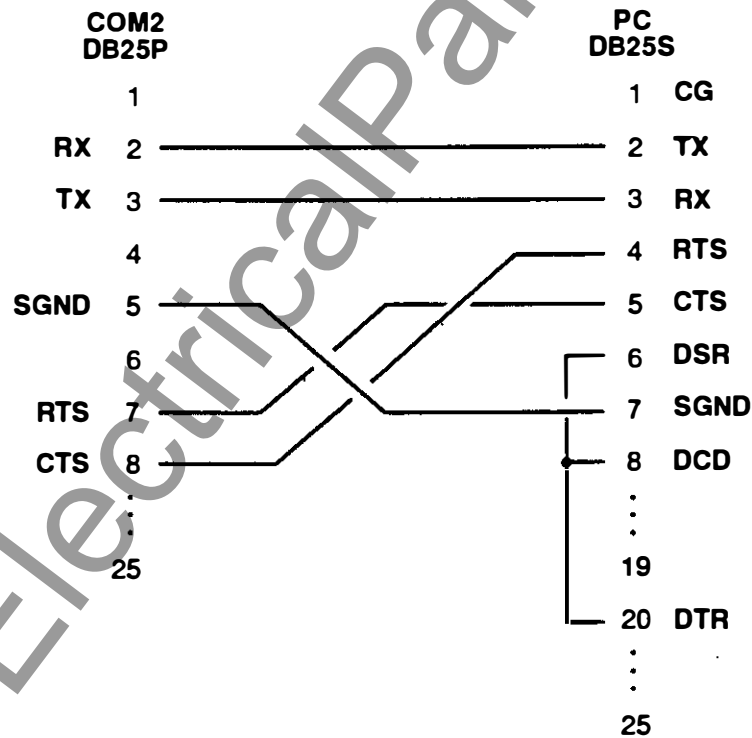


FIGURE C-2 Null Modem Cable: M-0420 COM2 to PC (25-pin)

APPENDIX D

PRINTED CIRCUIT BOARD INTERCONNECTIONS

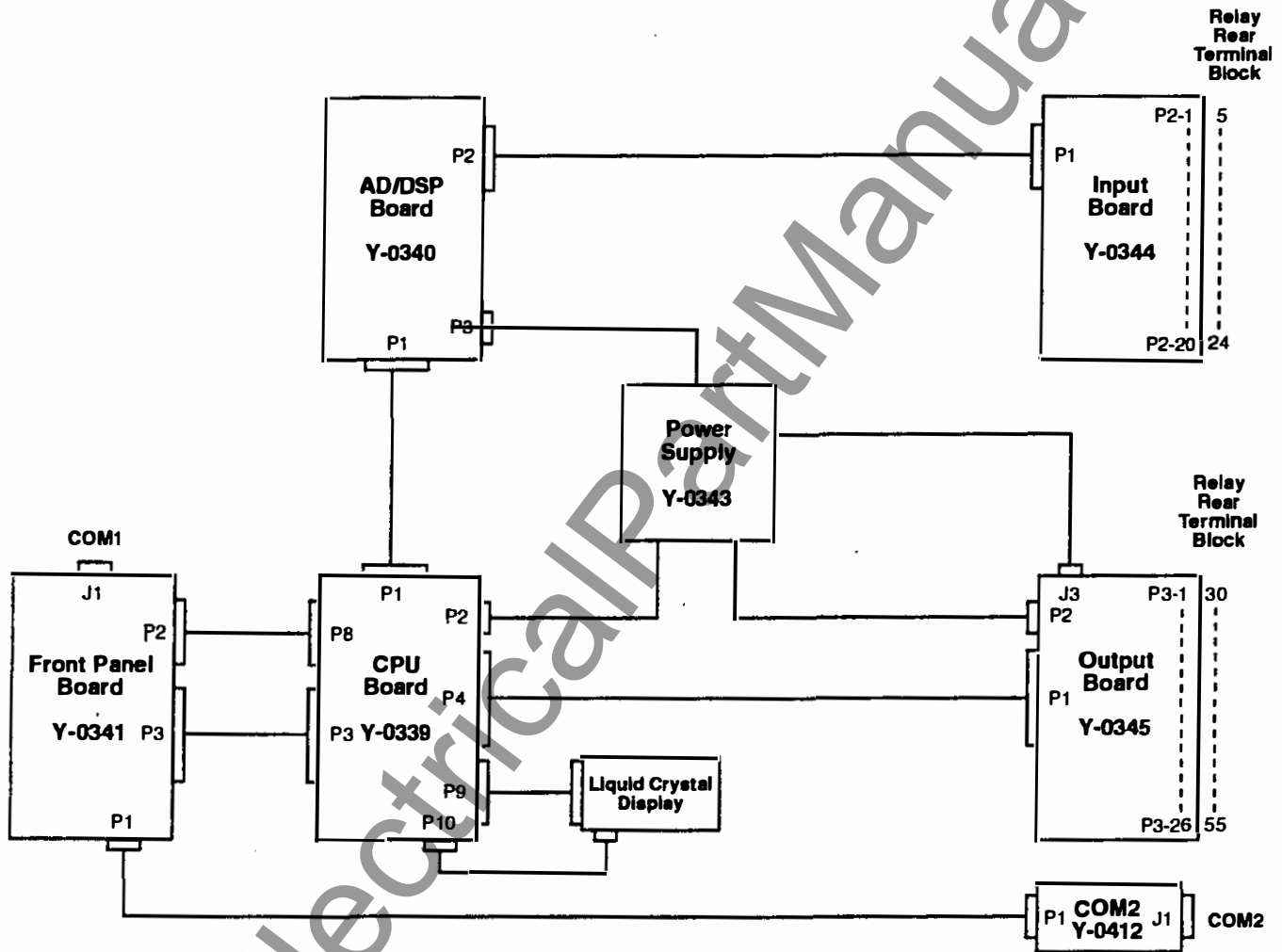


FIGURE D-1 M-0420 Board Interconnections

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APPENDIX E CONFIGURATION RECORD FORMS

This appendix contains forms that you can photocopy for recording and keeping on file the configuration of your M-0420(s).

The first form is the Functional Configuration Record. This form reproduces the **CONFIGURE RELAYS** series of menus accessible from the M-0420 front panel. For each function or setpoint, circle whether it is enabled or disabled.

The following Setpoint Configuration Record forms allow you to record the specific values entered for each enabled setpoint or function. (The provided check boxes allow you to mark the enabled setpoints and functions.)

Examples of the suggested use of these forms are provided below.

Finally, an Internal DIP Switch Configuration Record form is provided for noting the settings of the internal configuration DIP switches.

59

PHASE OVERVOLTAGE #1
disable ENABLE

PHASE OVERVOLTAGE #2
DISABLE enable

Functional Configuration

59

<input checked="" type="checkbox"/> PHASE OVERVOLTAGE #1
122.5 Volts (1.02 PU)

DELAY PHASE OVERVOLT #1
300 Cycles

<input type="checkbox"/> PHASE OVERVOLTAGE #2
___ Volts (___ PU)

DELAY PHASE OVERVOLT #2
___ Cycles

Setpoint Configuration

CONFIGURE RELAYS
← setup stat CONFIG →

CONFIGURE RELAY
VOLTAGE_RELAY →

59 PHASE OVERVOLTAGE #1
disable ENABLE

PHASE OVERVOLTAGE #2
DISABLE enable

59I PEAK OVERVOLTAGE #1
disable ENABLE

PEAK OVERVOLTAGE #2
DISABLE enable

27 PHASE UNDERVOLTAGE #1
disable ENABLE

PHASE UNDERVOLTAGE #2
DISABLE enable

59N NEUTRAL OVERVOLTAGE #1
disable ENABLE

NEUTRAL OVERVOLTAGE #2
DISABLE enable

27N NEUTRAL UNDERVOLTAGE #1
disable ENABLE

NEUTRAL UNDERVOLTAGE #2
DISABLE enable

CONFIGURE RELAY
← FREQUENCY_RELAY →

81O OVERFREQUENCY #1
disable ENABLE

OVERFREQUENCY #2
DISABLE enable

81U UNDERFREQUENCY #1
disable ENABLE

UNDERFREQUENCY #2
DISABLE enable

* This menu will not appear if Phase Time Overcurrent is disabled.
** This menu will not appear if Voltage Control/Voltage Restraint are not enabled.
*** Optional.

CONFIGURE RELAY
← CURRENT_RELAY →

51V PHASE TIME OVERCURRENT
disable NONDIRECTIONAL/directional

* VOLTAGE CONTROL OVERCURREN
DISABLE v_cntrl v_restrnt

** VC DELTA-Y TRANSFORM
DISABLE enable

*** PHASE DIRECTIONAL OVRCCR
57 disable enable high_spd

50 PHASE INST OVERCURRENT
disable ENABLE

51N NEUTRAL TIME OVERCURRENT
disable ENABLE

50N NEUTRAL INST OVERCURRENT
disable ENABLE

46 NEG SEQ TIME OVERCURRENT
disable ENABLE

CONFIGURE RELAY
← POWER_RELAY →

32F FORWARD OVERPOWER
disable ENABLE

32R REVERSE OVERPOWER
disable ENABLE high_spd

CONFIGURE TRIP CIRCUIT
← TRIP fuse

TRIP CIRCUIT
INTERTIE generator

60FL **CONFIGURE V-T FUSE LOSS**
← trip FUSE

INTERNAL FUSE LOSS LOGIC
disable ENABLE

BLOCK PHASE UNDERVOLTAGE
disable ENABLE

BLOCK REVERSE POWER
DISABLE enable

BLOCK TIME OVERCURRENT
disable ENABLE

BLOCK DIR OVERCURRENT
DISABLE enable

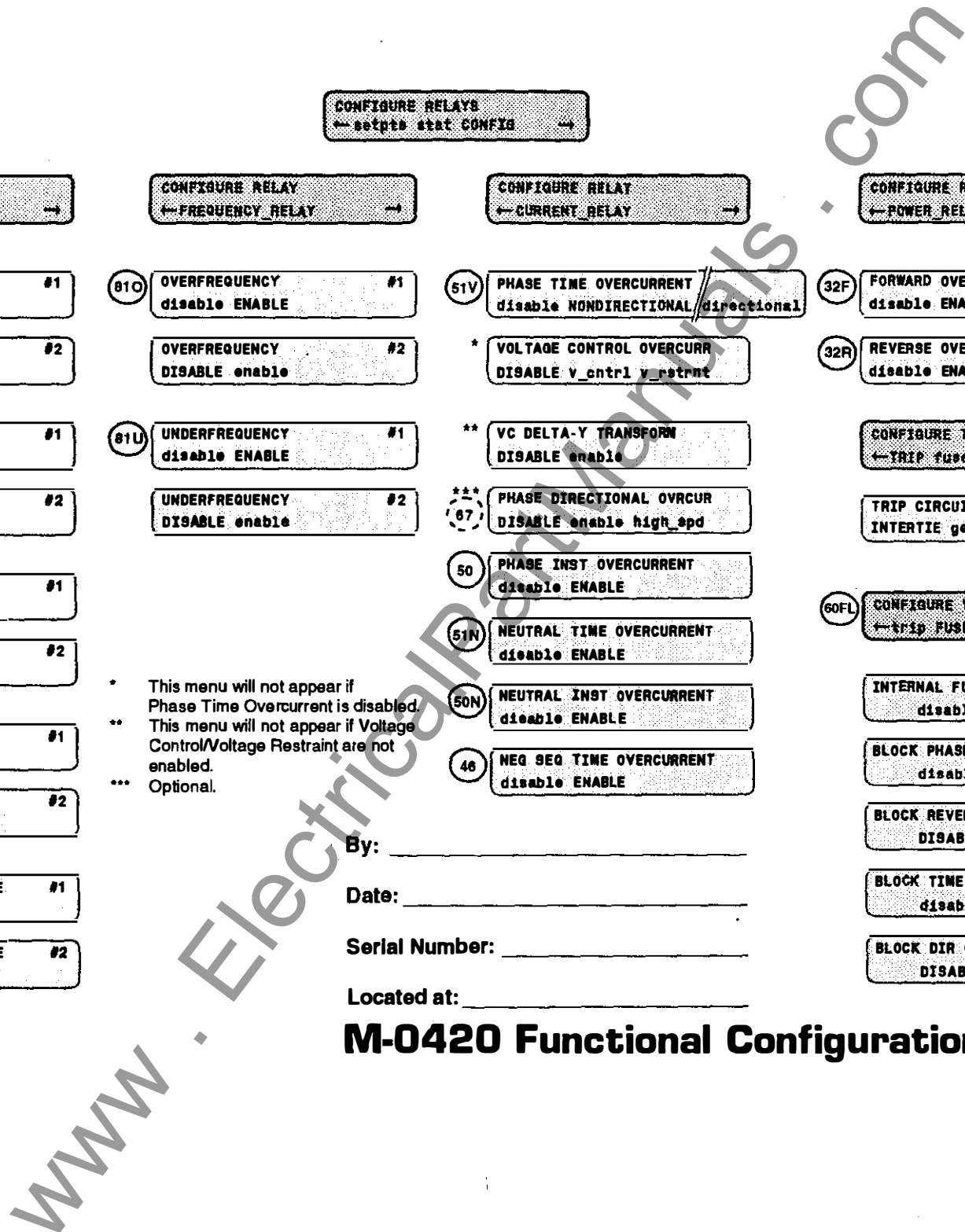
By: _____

Date: _____

Serial Number: _____

Located at: _____

M-0420 Functional Configuration Record



VOLTAGE RELAY
VOLT freq curr powr →

OVERVOLTAGE SETPOINTS
PHASE_OVER phase_under →

59

PHASE OVERVOLTAGE #1
_____ Volts (_____ PU)

DELAY PHASE OVERVOLT #1
_____ Cycles

PHASE OVERVOLTAGE #2
_____ Volts (_____ PU)

DELAY PHASE OVERVOLT #2
_____ Cycles

59I

PEAK OVERVOLTAGE #1
_____ PU

DELAY PEAK OVERVOLT #1
_____ Cycles

PEAK OVERVOLTAGE #2
_____ PU

DELAY PEAK OVERVOLT #2
_____ Cycles

UNDERVOLTAGE SETPOINTS
phase_over PHASE_UNDER →

27

PHASE UNDERVOLTAGE #1
_____ Volts (_____ PU)

DELAY PHASE UNDERVOLT #1
_____ Cycles

PHASE UNDERVOLTAGE #2
_____ Volts (_____ PU)

DELAY PHASE UNDERVOLT #2
_____ Cycles

OVERVOLTAGE SETPOINTS
← NUTRL_OVER nutr1_under

59N

NEUTRAL OVERVOLTAGE #1
_____ Volts (_____ PU)

DELAY NEUTRL OVERVOLT #1
_____ Cycles

NEUTRAL OVERVOLTAGE #2
_____ Volts (_____ PU)

DELAY NEUTRL OVERVOLT #2
_____ Cycles

UNDERVOLTAGE SETPOINTS
← nutr1_over NUTRL_UNDER

27N

NEUTRAL UNDERVOLTAGE #1
_____ Volts (_____ PU)

DELAY NEUTRL UNDERVOLT #1
_____ Cycles

NEUTRAL UNDERVOLTAGE #2
_____ Volts (_____ PU)

DELAY NEUTRL UNDERVOLT #2
_____ Cycles

■ NOTE: When 69.3 V is chosen for the VT secondary voltage, 69.3 V is internally converted to 120 V (1 pu) for all calculations and for setting and display purposes. For example, if a pickup of 73 V (1.1 pu) is desired when 69.3 V has been chosen for the VT secondary voltage, this will be displayed and entered as 126.4 V (1.1 pu on 120 V base).

By: _____

Date: _____

Serial Number: _____

Located at: _____

**Voltage Relay
Setpoint Configuration Record**

FREQUENCY RELAY
volt FREQ curr powr →

OVERFREQUENCY SETPOINTS
OVER under

UNDERFREQUENCY SETPOINTS
over UNDER

810

810

OVERFREQUENCY #1
_____ Hz

UNDERFREQUENCY #1
_____ Hz

DELAY OVERFREQUENCY #1
_____ Cycles

DELAY UNDERFREQUENCY #1
_____ Cycles

OVERFREQUENCY #2
_____ Hz

UNDERFREQUENCY #2
_____ Hz

DELAY OVERFREQUENCY #2
_____ Cycles

DELAY UNDERFREQUENCY #2
_____ Cycles

By: _____

Date: _____

Serial Number: _____

Located at: _____

**Frequency Relay
Setpoint Configuration Record**

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CURRENT RELAY
volt freq CURR powr →

OVERCURRENT SETPOINTS
PHASE_OVER nutr1_over →

OVERCURRENT SETPOINTS
phase_over NUTRL_OVER →

OVERCURRENT SETPOINTS
← NEG_SEQ_OVER

51V*

51N

46

TAP PHASE OVERCURRENT
_____ Amps

TAP NEUTRAL OVERCURRENT
_____ Amps

TAP NEG SEQ OVERCURRENT
_____ Amps

TIMING PHASE OVERCURRENT
def inv VINV einv

TIMING NUTRL OVERCURRENT
def inv VINV einv

PICKUP NEG SEQ OVERCURR
_____ %

TIME DIAL PHASE OVERCURR

TIME DIAL NUTRL OVERCURR

TIMING NEG SEQ OVERCURR
I_SQUARED_T

VOLTAGE CONTROL OVERCURR
_____ Volts (_____ PU)

or

Linear Restraint

TIME DIAL NEG SEQ OVRCUR

67**

ANGLE DIR ELEMENT
_____ DEG.

PICKUP PHASE DIR OVERCUR
_____ Amps

DELAY PHASE DIR OVERCUR
_____ Cycles

MAX TIME NEG SEQ OVERCUR
_____ Cycles

50

50N

PHASE INST OVERCURRENT
_____ Amps

NUTRL INST OVERCURRENT
_____ Amps

By: _____

Date: _____

Serial Number: _____

Located at: _____

Current Relay Setpoint Configuration Record

* See note concerning 69.3 V VT secondary ratio on Voltage Relay configuration record form.

** Optional.

POWER RELAY
volt freq curr POWR →

RECONNECT RELAY
← RECON →

FORWARD POWER SETPOINTS
FORWARD reverse

REVERSE POWER SETPOINTS
forward REVERSE

RECONNECT SETPOINTS
RECON

32F

32R

79

FORWARD OVERPOWER
_____ PU

REVERSE OVERPOWER
_____ PU

DELAY RECONNECT
_____ CYCLES

DELAY FORWARD POWER
_____ Cycles

DELAY REVERSE POWER
_____ Cycles

By: _____

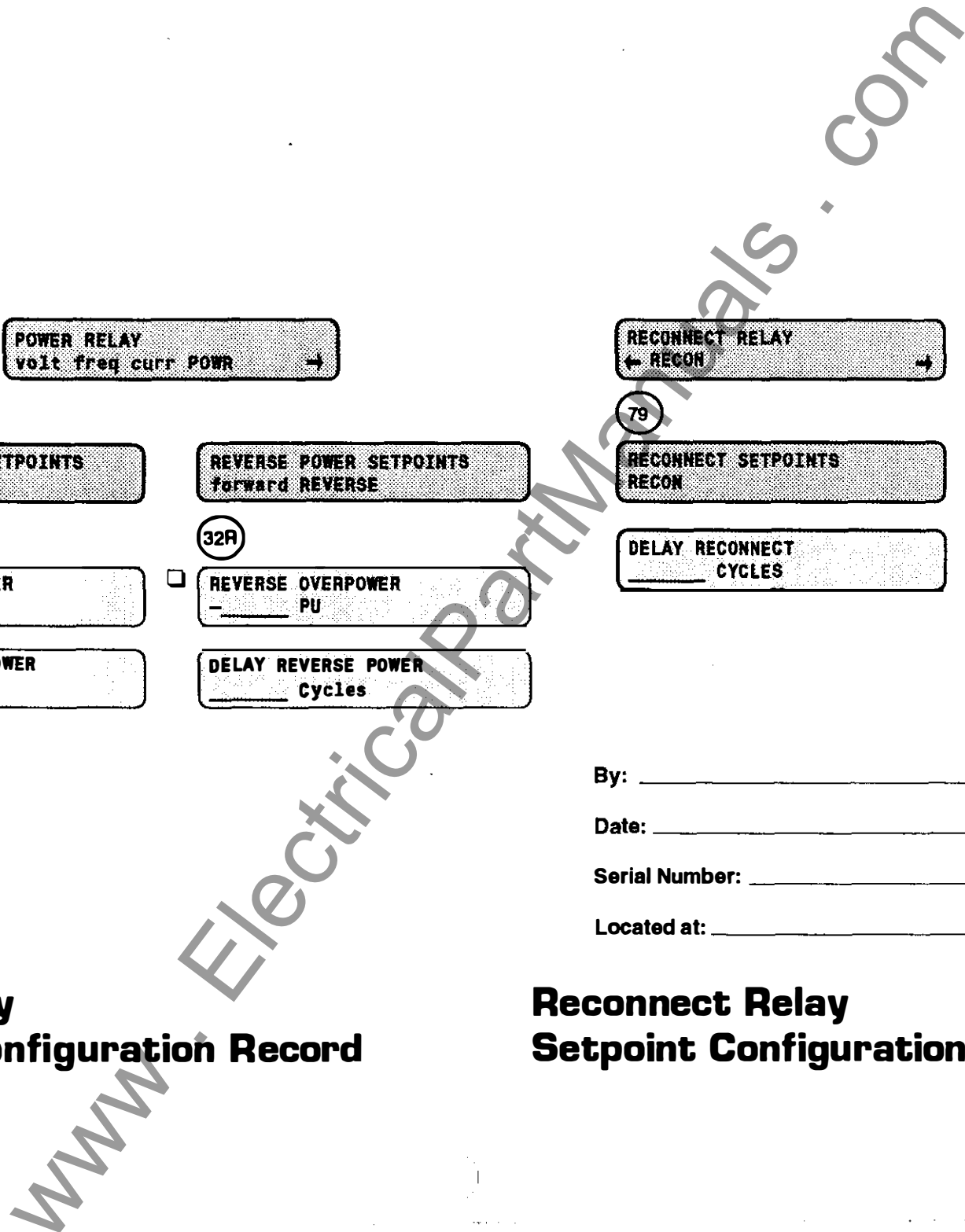
Date: _____

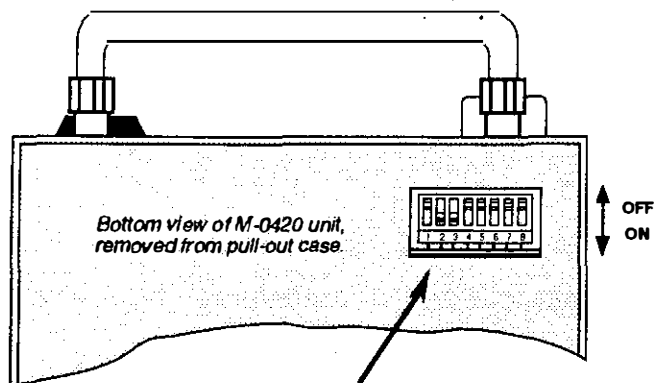
Serial Number: _____

Located at: _____

Power Relay Setpoint Configuration Record

Reconnect Relay Setpoint Configuration Record





OFF (UP)	
<input type="checkbox"/>	Reverse Power Initiation: PA + PB + PC < setpoint Directional Current: Ia, Ib, and Ic > setpoint
<input type="checkbox"/>	Diagnostic Mode
<input type="checkbox"/>	Calibrate Relay
<input checked="" type="checkbox"/>	Not for user selection. This switch must be set OFF.
<input type="checkbox"/>	5 VT inputs: line to ground
<input type="checkbox"/>	6 VT secondary voltage: 120 V ac
<input type="checkbox"/>	7 System Frequency: 60 Hz ††
<input type="checkbox"/>	8 RMS magnitude calculated by fundamental frequency component only *

<input type="checkbox"/>	Not for user selection. This switch must be set OFF.
<input type="checkbox"/>	Normal Operation
<input type="checkbox"/>	Normal Operation
<input type="checkbox"/>	Reverse Power Initiation: PA or PB or PC < setpoint Directional Current: Ia or Ib or Ic > setpoint
<input type="checkbox"/>	6 RMS magnitude calculated by total waveform (including harmonics) *
<input type="checkbox"/>	7 System Frequency: 50 Hz ††
<input type="checkbox"/>	8 VT secondary voltage: 69.3 V ac **
<input type="checkbox"/>	5 VT inputs: line to line †

ON (DOWN)

Check the box adjacent to the switch settings you have chosen.

For additional reference, shade in the corresponding DIP switch positions.

NOTES:

- * 59N and 27N functions respond to fundamental frequency component of input waveform only, regardless of the position of switch 8.
- ** When 69.3 V is chosen for the VT secondary voltage, 69.3 V is internally converted to 120 V (1 pu) for all calculations and for setting and display purposes.
- † If line-to-line is chosen for the basic VT inputs (DIP switch 5 is ON), reverse power sensing will respond to total three-phase power regardless of the setting of DIP switch 4.
- †† If the system frequency selection (DIP switch 7) is changed from the original factory calibration, the unit must be recalibrated (see the self-calibration procedure in Chapter 7, Test Procedures).

By: _____

Date: _____

Serial Number: _____

Located at: _____

Internal DIP Switch Configuration Record

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PATENT

The units described in this manual are protected by U.S. Patent 5,224,011 and other foreign patents applied for.

Buyer shall hold harmless and indemnify the Seller, its directors, officers, agents, and employees from any and all costs and expense, damage or loss, resulting from any alleged infringement of United States Letters Patent or rights accruing therefrom or trademarks whether federal, state, or common law, arising from the Seller's compliance with Buyer's designs, specifications, or instructions.

WARRANTY

Seller hereby warrants that the goods which are the subject matter of this contract will be manufactured in a good workmanlike manner and all materials used therein will be new and reasonably suitable for the equipment. Seller warrants that if, during a period of two years from date of shipment of the equipment, the equipment rendered shall be found by the Buyer to be faulty or shall fail to perform in accordance with Seller's specifications of the product, Seller shall at his expense correct the same, provided however that Buyer shall ship the equipment prepaid to Seller's facility. The Seller's responsibility hereunder shall be limited to the replacement value of the equipment furnished under this contract. The foregoing shall constitute the exclusive remedy of the Buyer and the sole liability of the seller and is in lieu of all other warranties, whether written, oral, implied or statutory, except as to the title of the Seller to the equipment furnished. No implied statutory warranty of merchantability or of fitness for a particular purpose shall apply. Seller does not warrant any product or services of others which Buyer has designated.

SELLER MAKES NO WARRANTIES EXPRESSED OR IMPLIED OTHER THAN THOSE SET OUT ABOVE. SELLER SPECIFICALLY EXCLUDES THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION CONTAINED HEREIN. IN NO EVENT SHALL SELLER BE LIABLE FOR CONSEQUENTIAL, EXEMPLARY, OR PUNITIVE DAMAGES OF WHATEVER NATURE.

Any equipment returned for repair must be sent with transportation charges prepaid. The equipment must remain the property of the Buyer. The aforementioned warranties are void if the value of the unit is invoiced to the Seller at the time of return.

INDEMNIFICATION

The Seller shall not be liable for any property damages whatsoever or claims of any kind whether based on contract, warranty, tort including negligence or otherwise, or for any loss or damage arising out of, connected with, or resulting from this contract, or from the performance or breach thereof, or from all services covered by or furnished under this contract.

In no event shall the Seller be liable for special, incidental, exemplary or consequential damages including, but not limited to loss of profits or revenue, loss of use of the equipment or any associated equipment, cost of capital, cost of purchased power, cost of substitute equipment, facilities or services, downtime costs, or claims or damages of customers or employees of the Buyer for such damages, regardless of whether said claim or damages is based on contract, warranty, tort including negligence or otherwise.

Under no circumstances shall the Seller be liable for any personal injury whatsoever.

It is agreed that when the equipment furnished hereunder or any services furnished hereunder are to be used or performed in connection with any nuclear installation, facility, or activity, Seller shall have no liability for any nuclear damage, personal injury, property damage, or nuclear contamination to any property located at or near the site of the nuclear facility. Buyer agrees to indemnify and hold harmless the Seller against any and all liability associated therewith whatsoever whether based on contract, tort, or otherwise. Nuclear installation or facility means any nuclear reactor and includes the site on which any of the foregoing is located, all operations conducted on such site and all premises used for such operations. It is the intention of the parties that this is a complete indemnification and hold harmless agreement in regard to all claims arising from nuclear operations of Buyer.