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1.1 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:

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.

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.

Compact Size – The relay occupies a panel space less than 8 inches wide and 21 inches high, yet can operate fourteen protective functions.

Operation – All settings can be established or changed using the front panel controls and alphanumeric display.

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.

Functions – The functions respond in the same manner as do electromechanical relays, including time delays, and the nomenclature is the same.

This Instruction Book provides details of the installation and operation of the relay. 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 (727) 544-2326.

1.2 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 relay.
- Read Chapter 2, **Application**, for information on using the relay 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 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 BECOPLOT® User's Guide for information on configuring and interrogating the relay via a personal computer running the optional BECOCOM communications software package, and for information on plotting downloaded fault data via the optional BECOPLOT software package.

The M-0420 Multifunction Relay Instruction Book has been organized to address the needs of different parts of your organization. If you are responsible for verifying that the relay 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 relay 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 relay, please refer to Chapter 6, **Installation.**

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

Please don't hesitate to call your local sales representative or Beckwith's application engineers (727-544-2326) for assistance in resolving any problems.

1.3 Configuration As Shipped

You can become familiar with the basic operation of the relay 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 relay 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 below; setting is also 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.

1.4 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. Internal relay functions 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, 3-phase
27N	RMS Undervoltage, Neutral Circuit or Zero Sequence
32	Directional Power Relay, 3-phase, Forward (32F) and Reverse (32R)
46	Negative Sequence Overcurrent Relay, 3-phase
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
81O	Overfrequency
81U	Underfrequency
60FL	V.T. Fuse Loss Detection
*Optional	

Table 1-1 M-0420 Device Functions

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 nonvolatile memory where it is unaffected by a loss of power or other system disturbance.

The M-0420 Multifunction Relay 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 C37.90 and C37.90.1. 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.

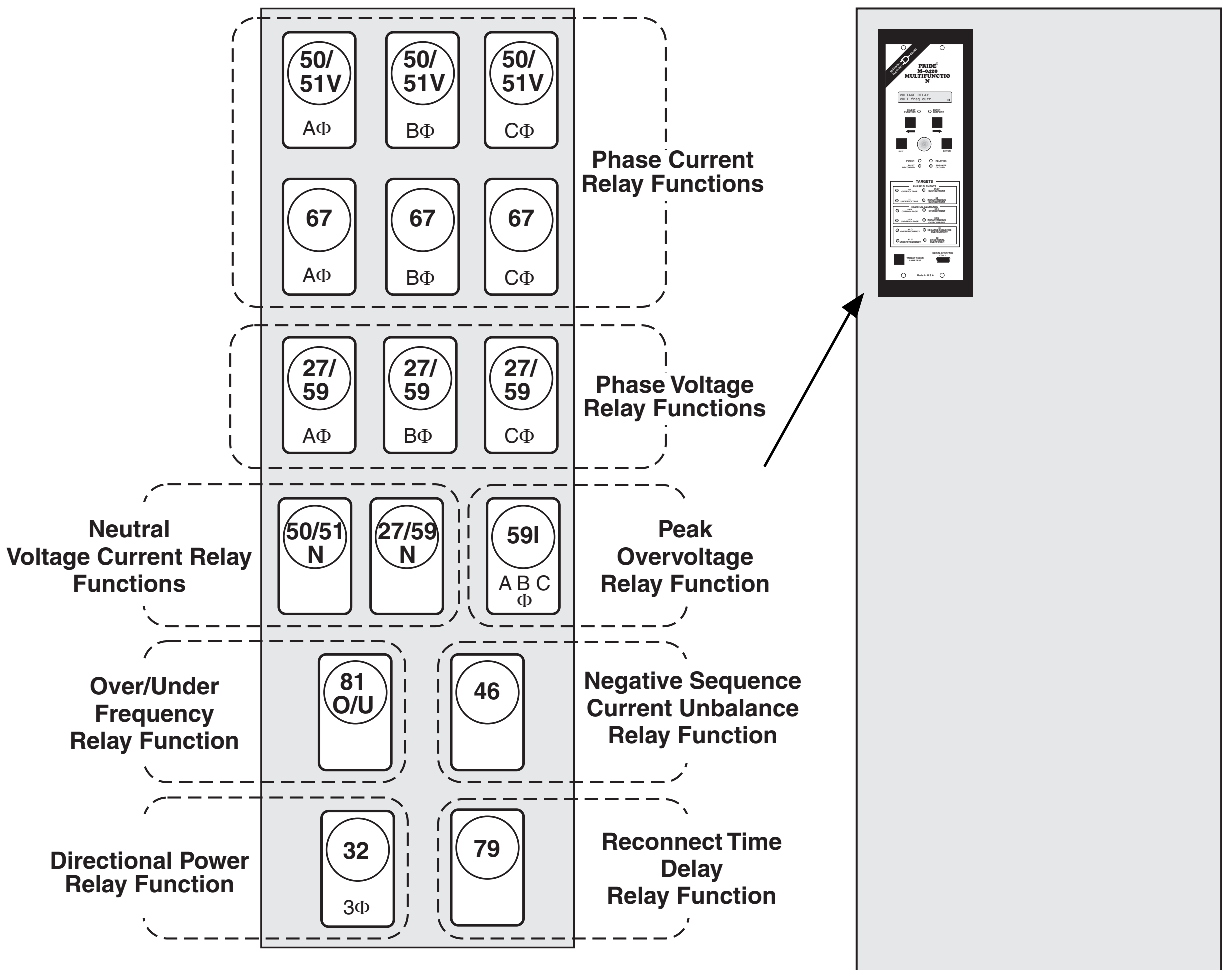

Figure 1-1 Traditional Relaying vs the M-0420 Multifunction Relay

1.5 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 relay 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 relay. As shown in these diagrams, the inputs to the relay, 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 relay 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 relay 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 relay 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.

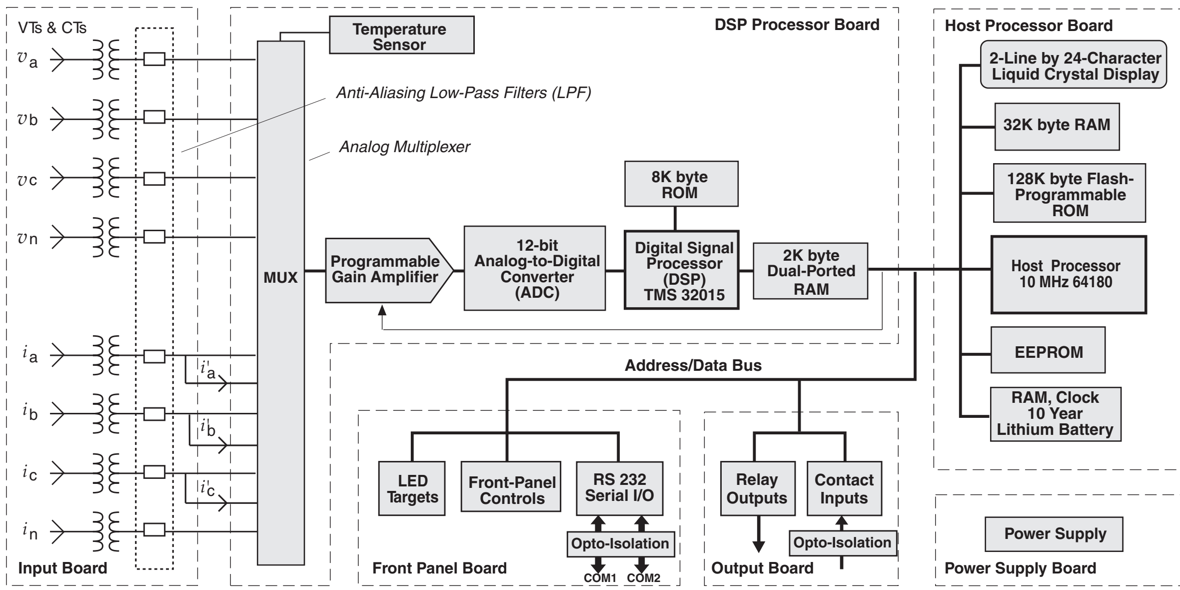

Figure 1-2 M-0420 Block Diagram

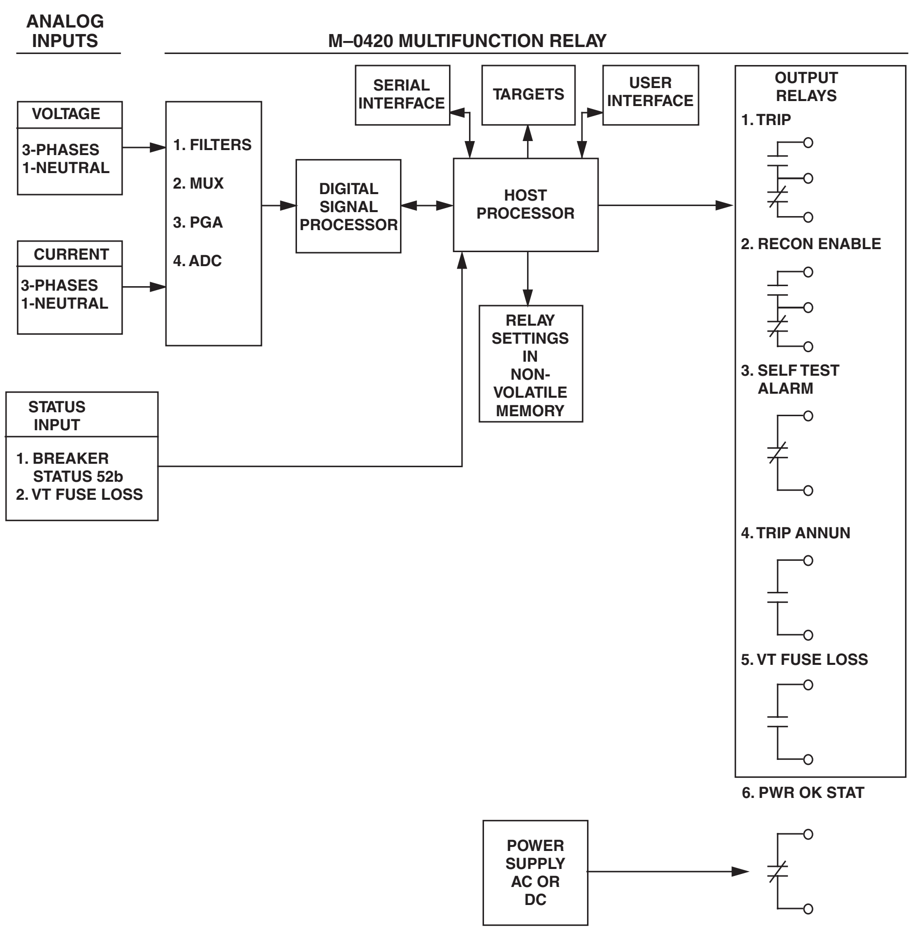

Figure 1-3 M-0420 Functional Diagram

1.6 User Considerations

In the design of the M-0420 Multifunction Relay, careful consideration was given to making its use as similar as possible to that 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 electromechanical 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 buttons and the rotary knob.

Communication Capabilities

One of the important features of the relay 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 computer.

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 mis-operation. Likewise, if system power fails, an output contact closes.

Internal Calibration Correction

One of the most important and novel advantages of the relay 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 relay 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.

1.7 Options

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

67 Phase Directional Overcurrent

The relay 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 51V function, thereby realizing a directional inverse time overcurrent function.

Neutral Current Input

The relay 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 relay 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.

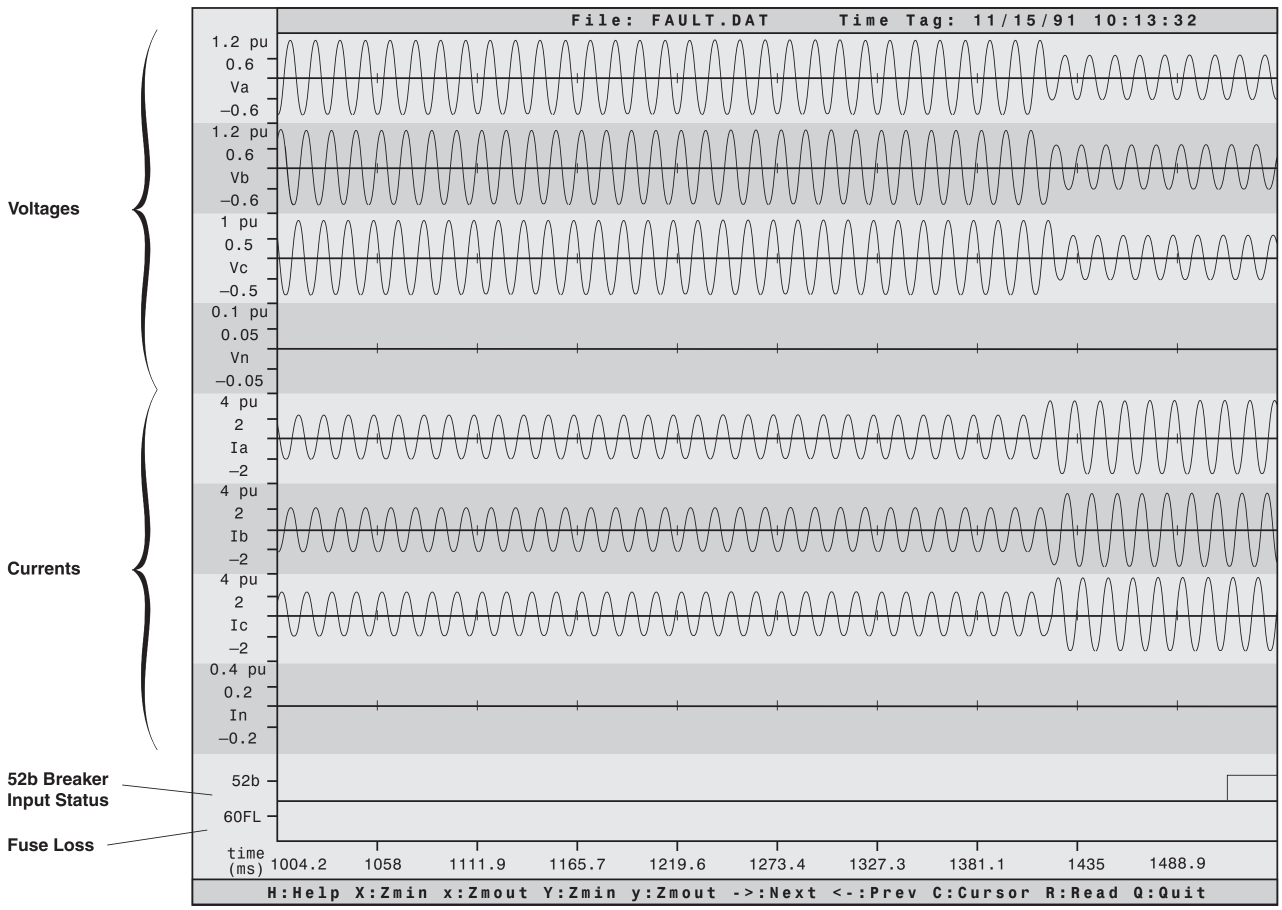

Figure 1-4 M-0428A BECOPLOT® Fault Data Analysis Software Output

1.8 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 regulator can be used to allow an M-0420 Multifunction Relay 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 relay 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 relay 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 relay's rear-panel (COM2) port and a modem. This cable has DB25 (25-pin) connectors at each end.

The M-0423 cable is a 10 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.

1.9 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 relay applications, and are available upon request from Beckwith Electric Co., Inc.

[1] *Grid Interconnection Performance Requirements and Current Practice*. Gas Research Institute, Topical Report 87-0117, 1986.

[2] *IEEE Guide for Interfacing Dispersed Storage and Generation Facilities with Electric Utility Systems*. ANSI/IEEE Std. 1001-1988.

[3] *Intertie Protection of Consumer-Owned Sources of Generation*, 3 MVA or Less. IEEE Publication 88TH0224-6-PWR.

[4] ANSI/IEEE C37.102-1987 "*IEEE Guide for AC Generator Protection*."

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[6] W.E. Feero, W.B. Gish, and C.L. Wagner, "*Overvoltages on Distribution System Generation Separated from the Power Systems*," Final Report ERM-8701-07, April 1987, Electric Research and Management, Inc., State College, PA, 16804.

[7] A.G. Phadke, J.S. Thorp, and M.G. Adamiak, "*A New Measurement Technique for Tracking Voltage Phasors, Local System Frequency, and Rate-of-Change of Frequency*." IEEE Transactions on PAS, vol. PAS-102, No. 5, May 1983, pp. 1025-1038.

[8] David M. Denison, "*Application of Digital Fault Recorders on the Tampa Electric Company System*," 44th Annual Protective Relaying Conference, Georgia Institute of Technology, Atlanta, Georgia, May 2-4, 1990.

[9] *Electric Utility Systems and Practices*, 4th Edition, Homer M. Rustebakke, John Wiley & Sons, 1983.

[10] *Protective Relaying, Principles and Applications*, J. Lewis Blackburn, Marcel Dekker, Inc., 1987.

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

[12] Murty V. V. S. Yalla, Donald L. Hornak, "*A Digital Multifunction Relay for Intertie and Generator Protection*," Canadian Electrical Association 1992 Spring Meeting, Vancouver, B.C., March 1992.

[13] Murty V. V. S. Yalla, "*A Digital Multifunction Protective Relay*," IEEE Transactions on Power Delivery, Vol. 7, No. 1, January 1992, pp. 193-201.

2 Application

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2.1 Protective Applications

The sections that follow discuss briefly the principal applications of the M-0420 Multifunction Relay in intertie or generator protection. Section 2.6, Functions, 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 relay provides both under frequency (81U) and over frequency (81O) functions. The relay 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 from 1 to 8160 cycles, and magnitude range settings 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 non-sinusoidal wave can be dangerously high. Since the peak overvoltage (59I) function of the relay 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 relay 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.

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 downstream 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 relay.

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 this relay. 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)

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 relay power calculation 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-Motoring 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 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 overvoltage 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 relay 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 relay 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 relay implements the inverse time negative sequence overcurrent function ($I_2^2t=K$) 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). 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 relay 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 (60FL)

If the internal blown-fuse detection is enabled, or the external fuse-loss input is connected, the relay provides 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.

2.2 Trip Configuration vs. Applications

Figures 2-1 through 2-6 illustrate the protection capabilities and trip logic for both intertie and generator protection modes. To optimize the relay 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 functions are available at all times (individual functions can be disabled via the **CONFIGURE RELAYS** menu).

When **GENERATOR** is selected, the relay 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 relay 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**.)

2.3 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 relay. Figure 2-3 illustrates the trip logic used when the relay is configured for intertie protection.

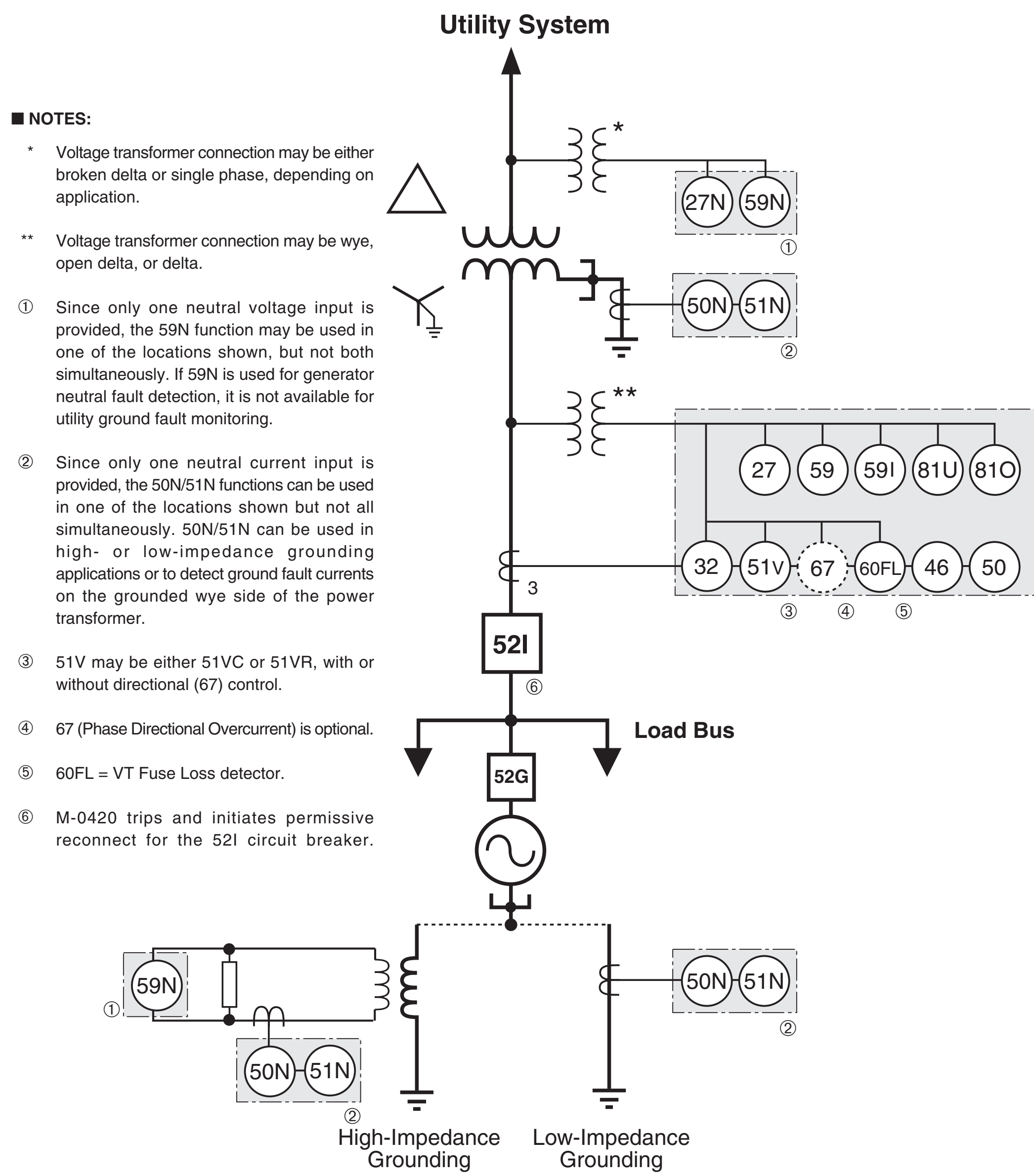
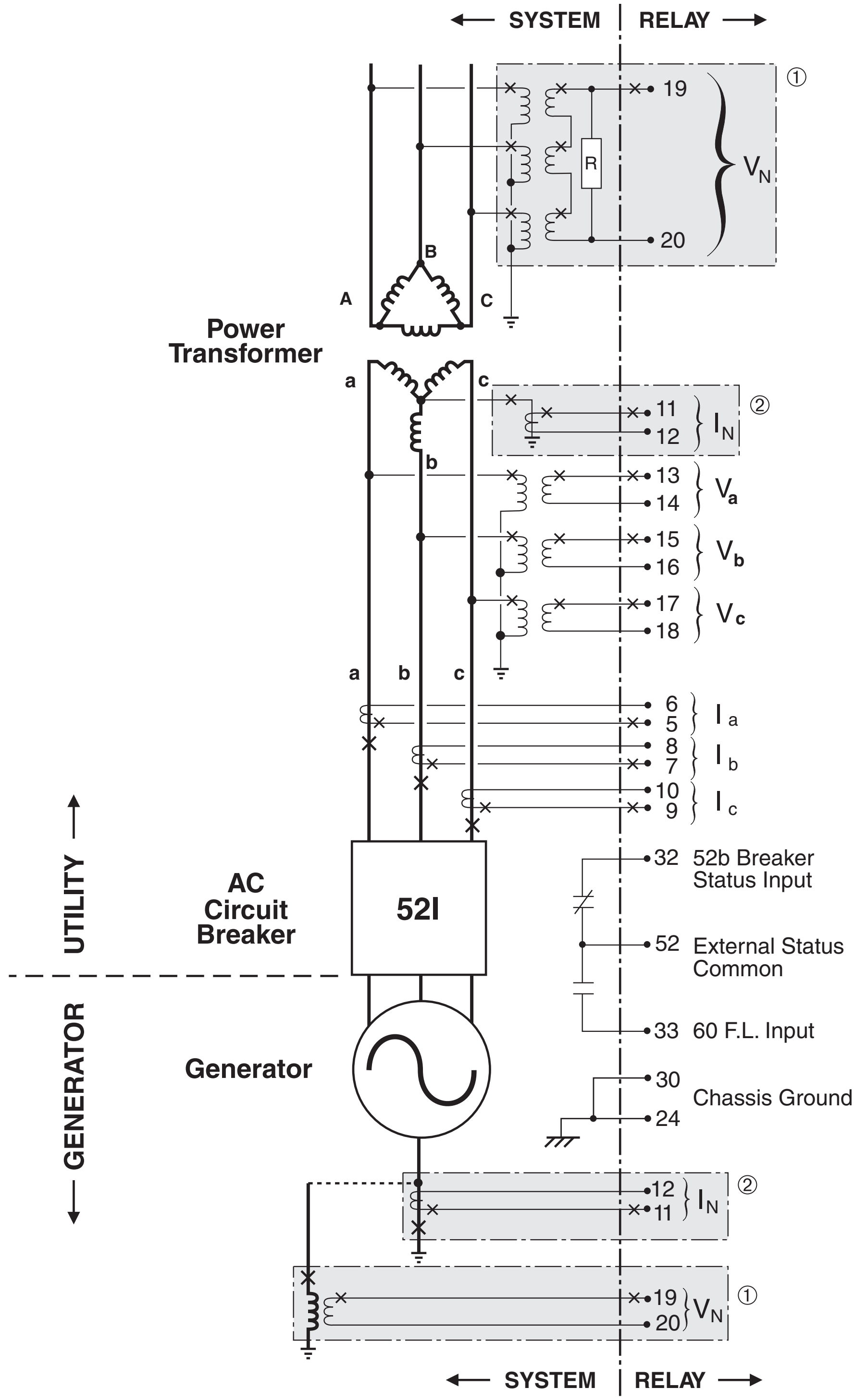


Figure 2-1 Intertie Protection –Typical One-Line Diagram



■ **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

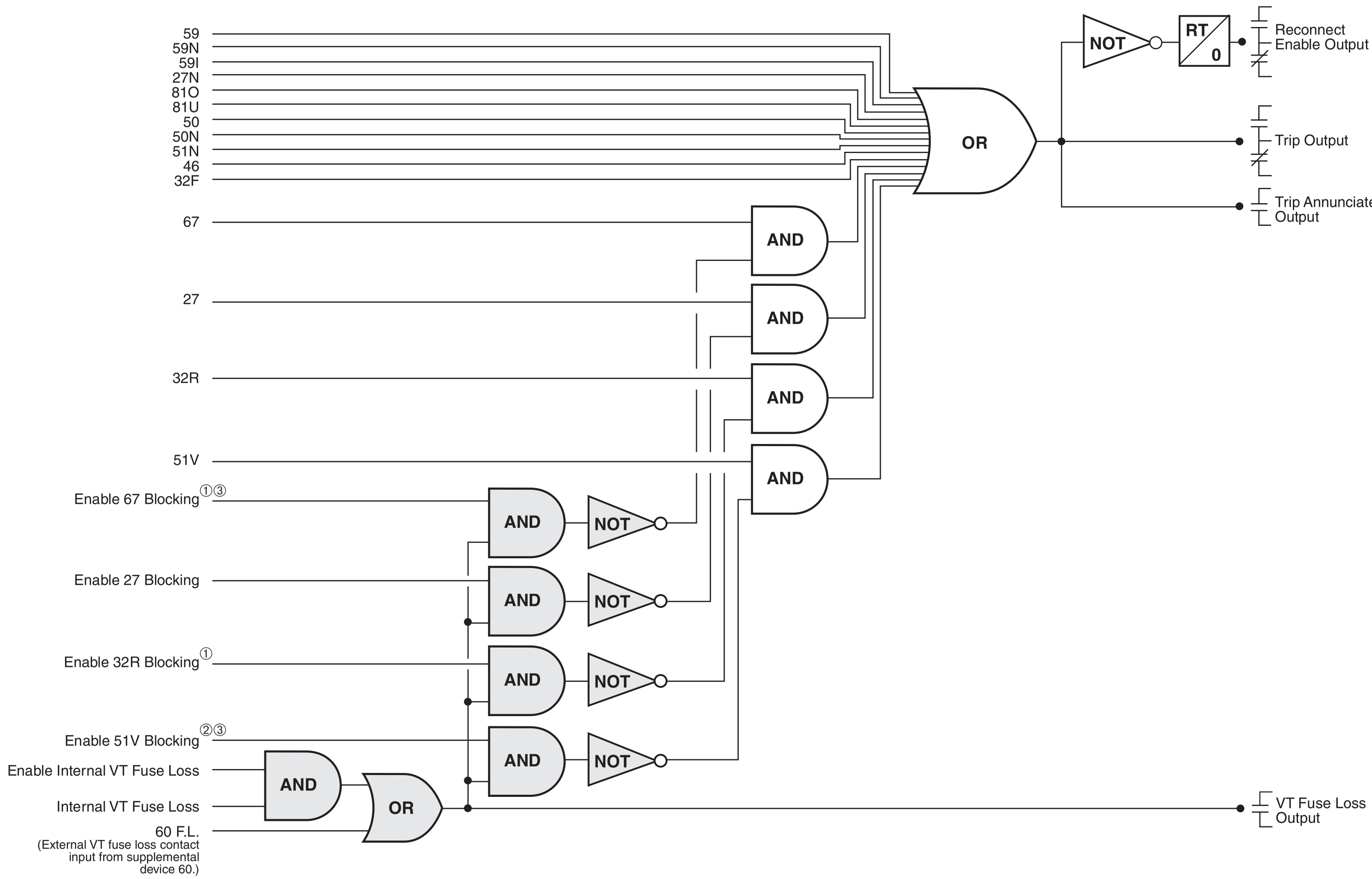


Figure 2-3 Intertie Protection–Trip Logic

■ **NOTES**: a When the high-speed setting has been selected for the 32R or 67 functions, the respective blocking function should not be enabled. b 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). c If 51V is controlled by the directional element of 67, 51V will be blocked when 67 is blocked.

2.4 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 Multifunction Protection Relay. Figure 2-6 illustrates the trip logic used when the relay 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**: These are guidelines only, and may not apply to all situations.

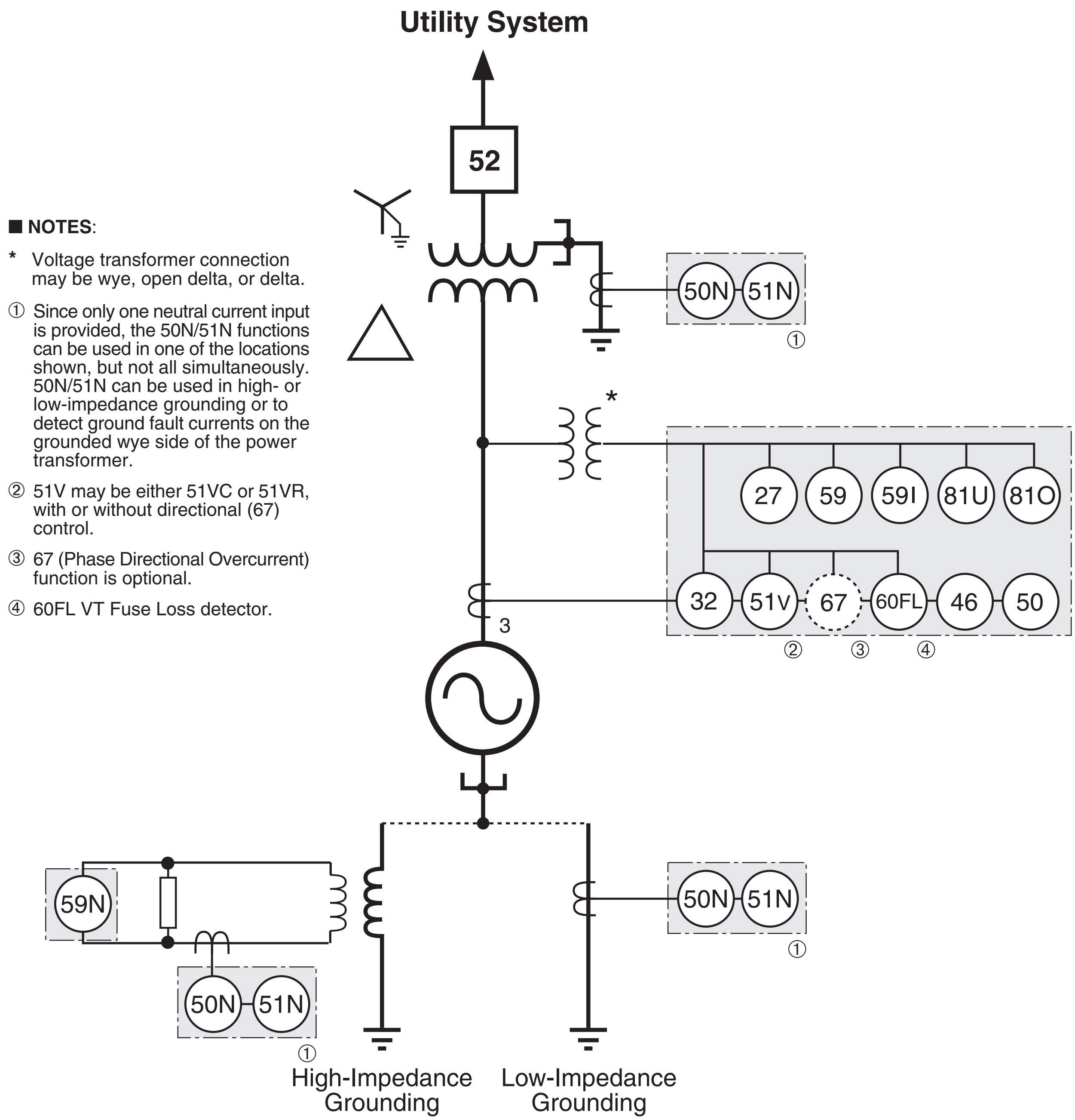
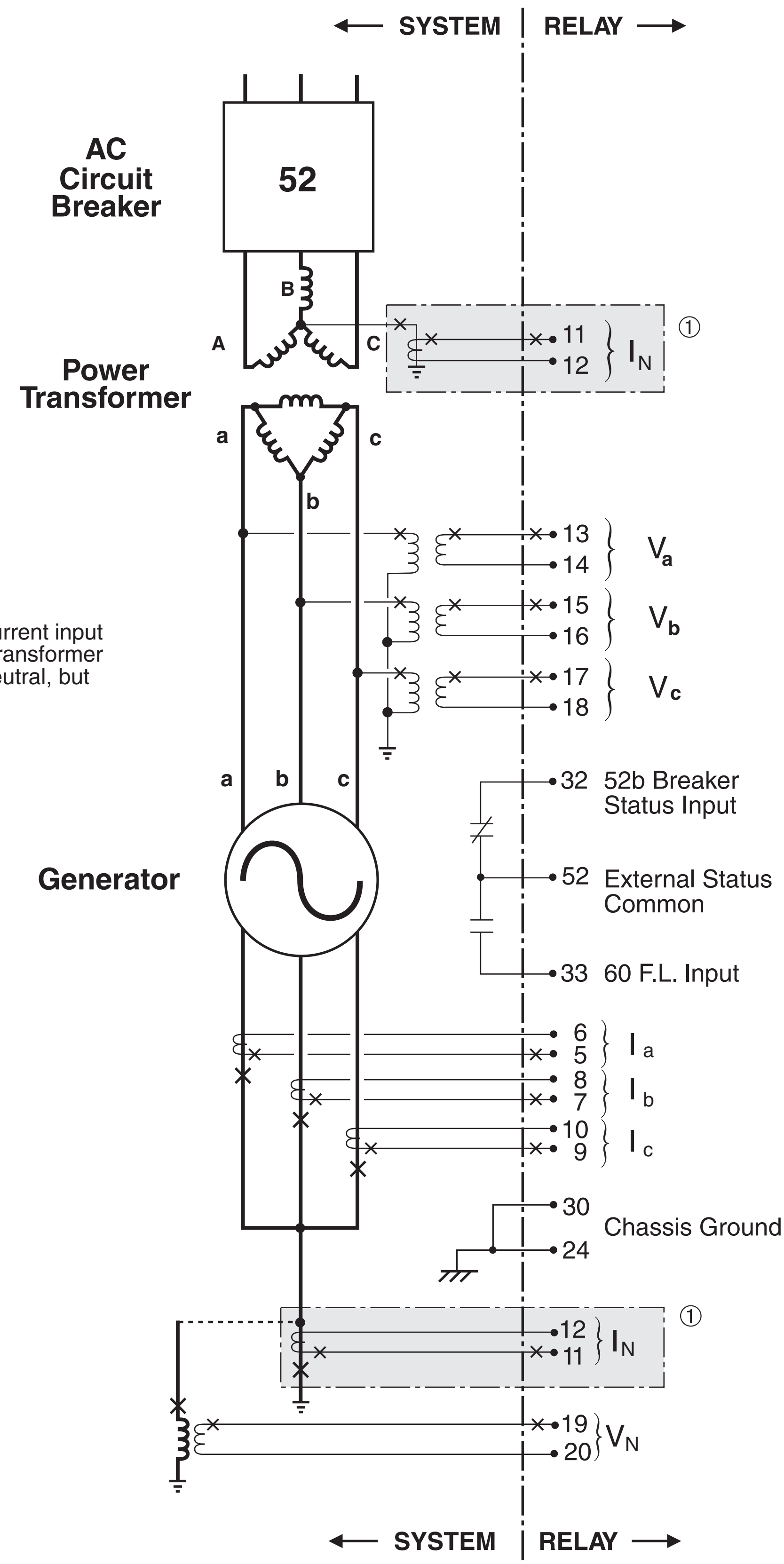
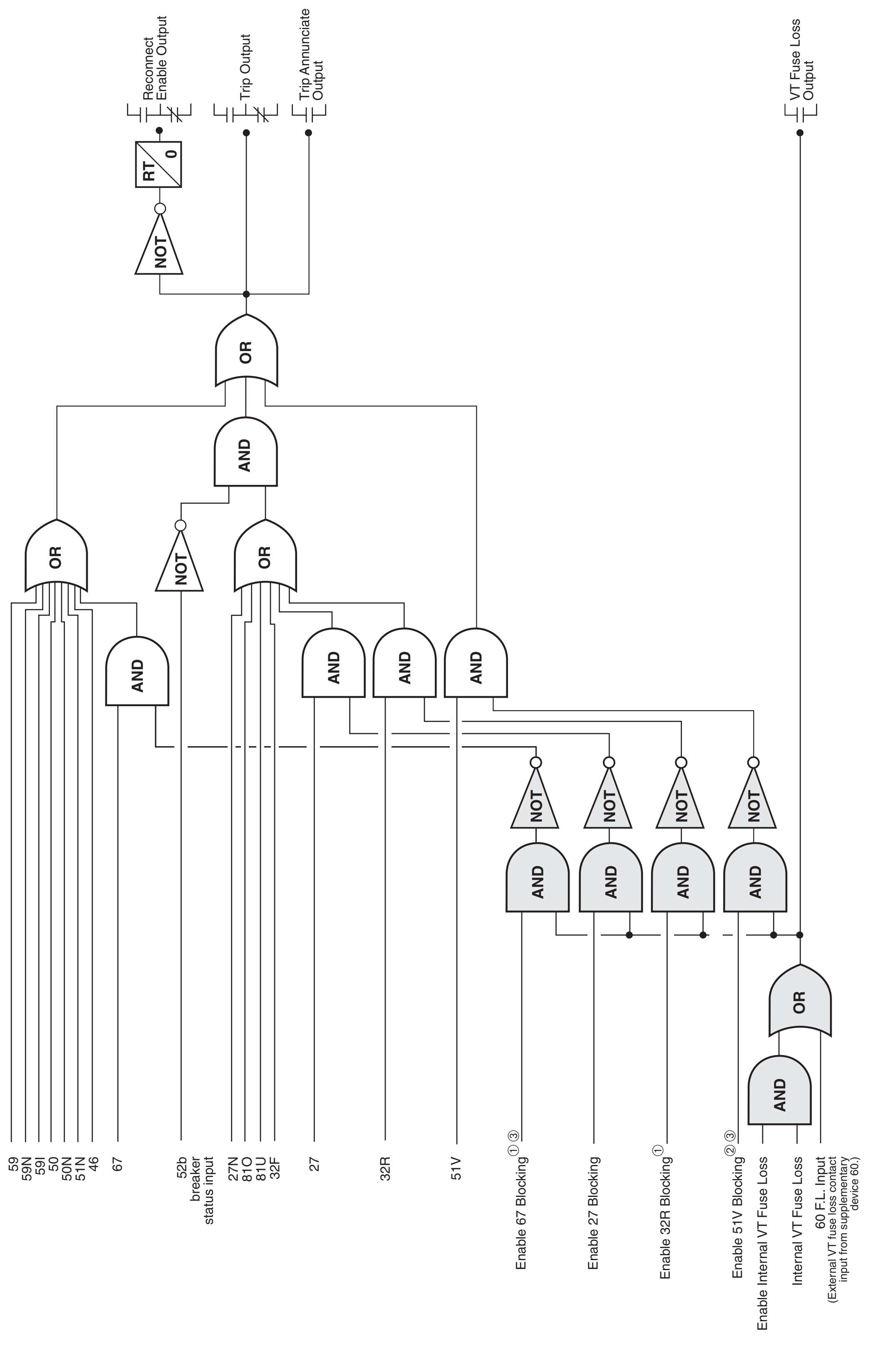


Figure 2-4 Generator Protection–Typical One-Line Diagram



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

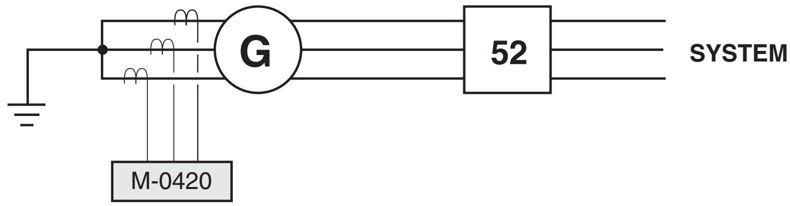
Figure 2-5 Generator Protection—Typical Three-Line Diagram



■ **NOTES**: a When the high-speed setting has been selected for the 32R or 67 functions, the respective blocking function should not be enabled. b 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). c If 51V is controlled by the directional element of 67, 51V will be blocked when 67 is blocked.

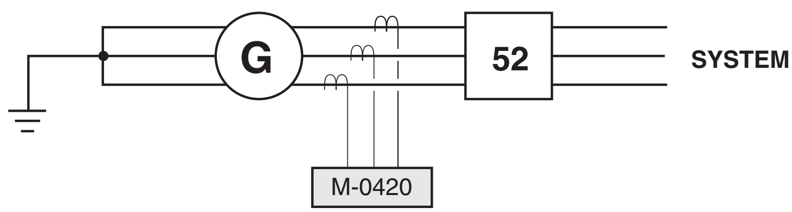
Figure 2-6 Generator Protection–Trip Logic

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 energizing is applicable to both CT positions.

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

2.5 Setpoints

The M-0420 Multifunction Relay 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 with two setpoints are shipped with the second one disabled. 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.

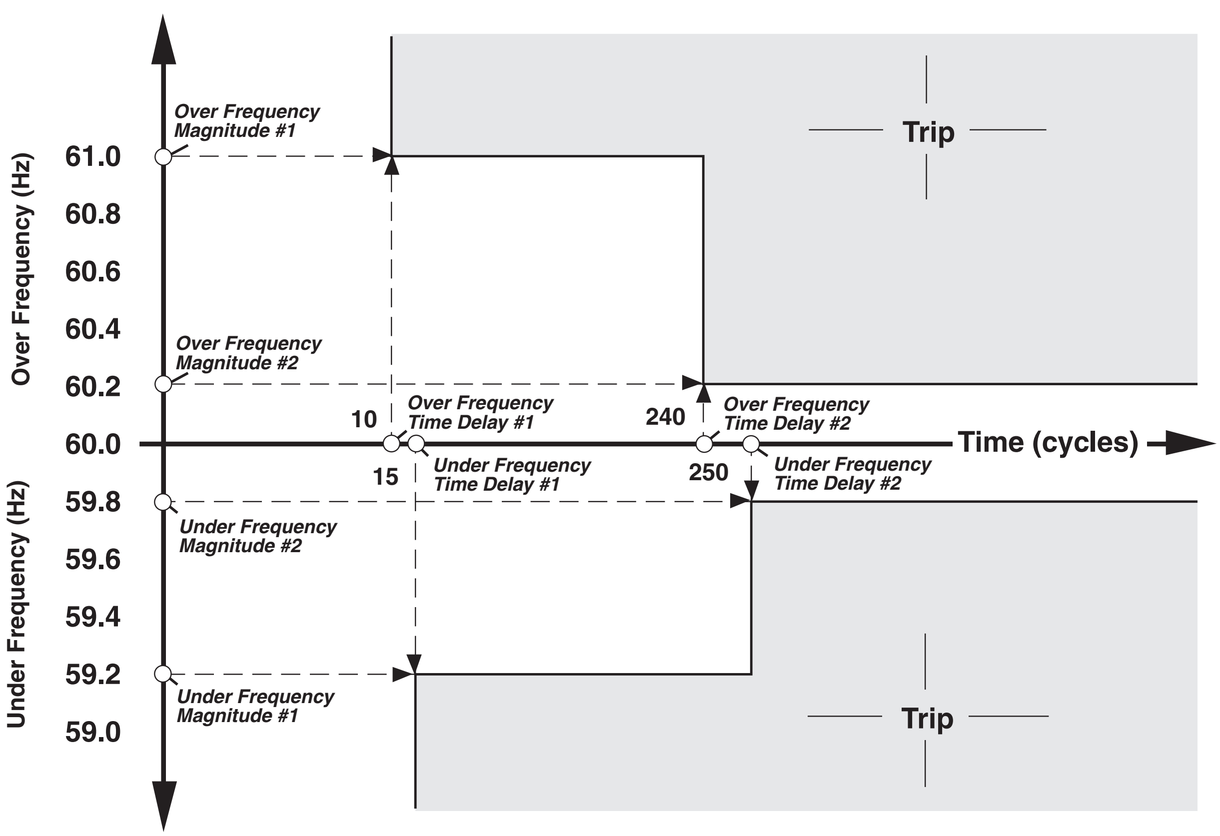


Figure 2-7 Example of Trip Characteristics: Over and Under Frequency

2.6 Functions

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 underfrequency characteristic at 57.5 to 58.0 Hz with a very short time delay, but allowing a higher frequency, say 59.0 Hz, to be maintained for several seconds.

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING†
Overfrequency (81O)			
Magnitude #1, #2	60.05 to 63.00 Hz (50.05 to 53.00 Hz)	0.05 Hz	60.50 Hz
Time Delay #1, #2	2 to 8160 cycles	1.0 cycle	30 cycles
Underfrequency (81U)			
Magnitude #1, #2	53.00 to 59.95 Hz (43.00 to 49.95 Hz)	0.05 Hz	59.50 Hz
Time Delay #1, #2	2 to 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 when shipped from 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 to 200 V	1.0 V	132 V
Time Delay #1, #2	1 to 8160 cycles	1.0 cycle	30 cycles
RMS Undervoltage, 3-Phase (27)			
Magnitude #1, #2	10 to 200 V	1.0 V	108 V
Time Delay #1, #2	1 to 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 when shipped from 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 nonlinear, being variable as the transformer core cycles in and out of magnetic saturation. At this time, the voltage waveform will be expected to be very rich in harmonics, to the extent that it is possible that the peak voltage of the non-sinusoidal 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 x $\sqrt{2}$ = 170 V, a 1.2 per unit setting would initiate tripping action at 1.2 x 170 = 204 V, as instantaneously detected. Note that, because of the non-sinusoidal voltage waveform expected, the rms value of this voltage cannot be so simply calculated as 204 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 x $\sqrt{2}$ = 98 V.

FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING†
Peak Overvoltage (59I)*			
Magnitude #1, #2	1.05 to 1.50 pu	0.01 pu	1.10 pu
Time Delay #1, #2	1 to 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 when shipped from 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 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 to 200 V	1.0 V	150 V
Time Delay #1, #2	1 to 8160 cycles	1.0 cycle	30 cycles
RMS Undervoltage, Neutral Circuit or Zero Sequence (27N)			
Magnitude #1, #2	10 to 200 V	1.0 V	60 V
Time Delay #1, #2	1 to 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 when shipped from 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*.)

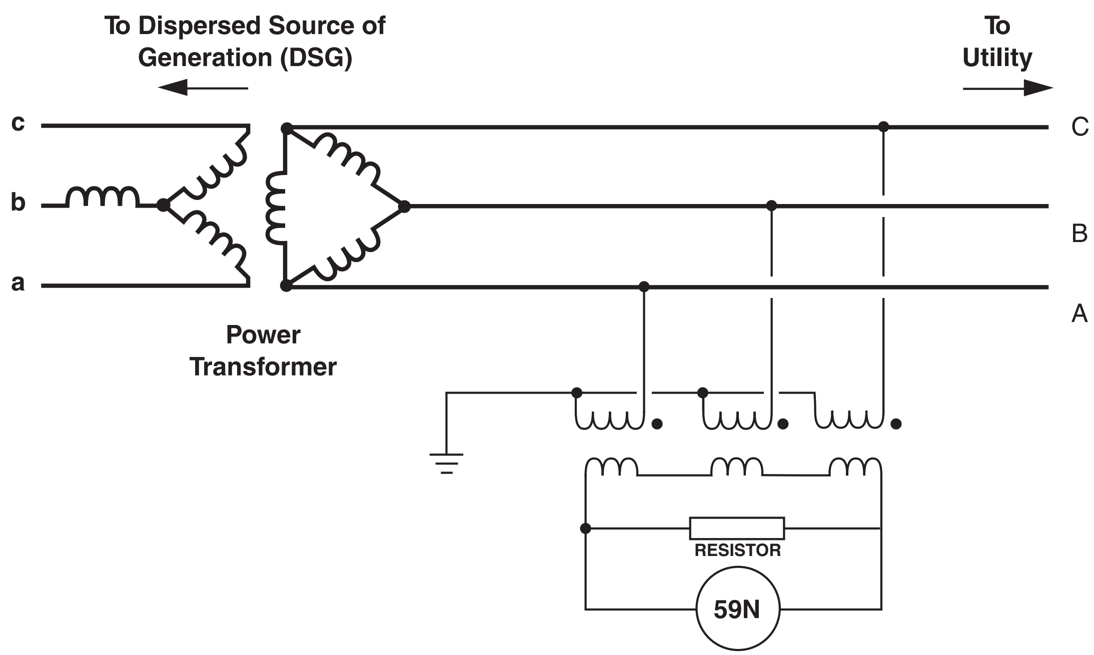


Figure 2-8 Ground Fault Detection Using 59N and Broken-Delta VTs

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:

1. A fault on the phase that includes the VT will pull that phase voltage low and initiate operation of the 27N device.
2. 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.

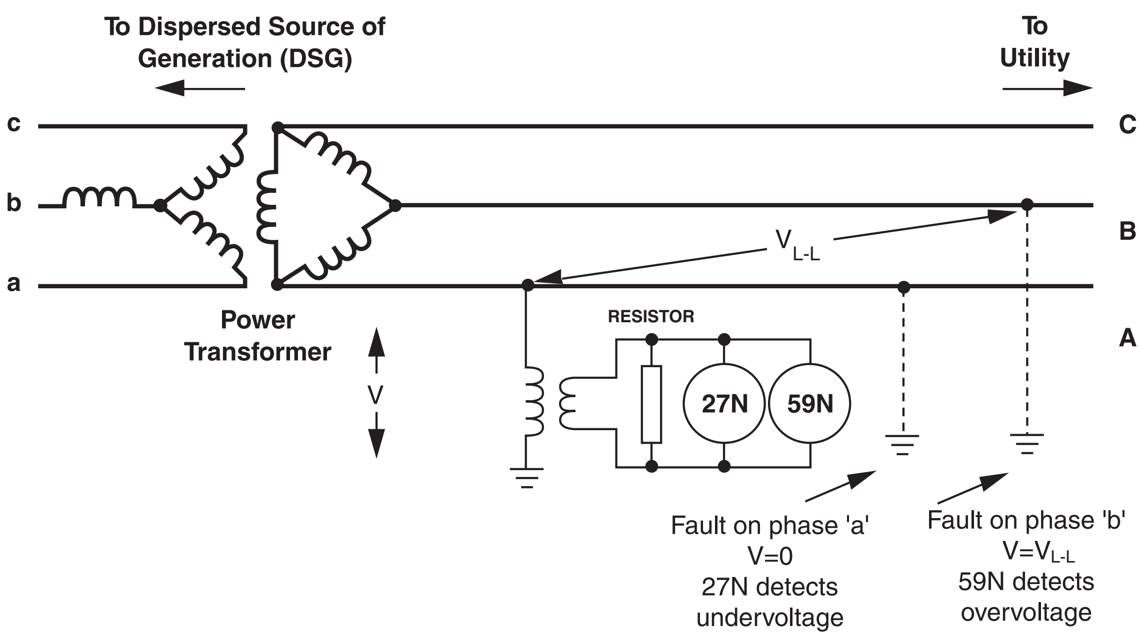


Figure 2-9 Ground Fault Detection Using 27N and 59N with One VT

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 downstream 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 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 menu, just as one would through 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 inclusion or exclusion of 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/wye transformer, proper voltages (equivalent to the high-side of the transformer) should be used for the 51VR or 51VC element. The relay can internally determine the equivalent high-side voltages of the delta/wye unit transformer, saving auxiliary instrument transformers. The voltage-current pairs used are shown in Table 2-6.

▲ **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).

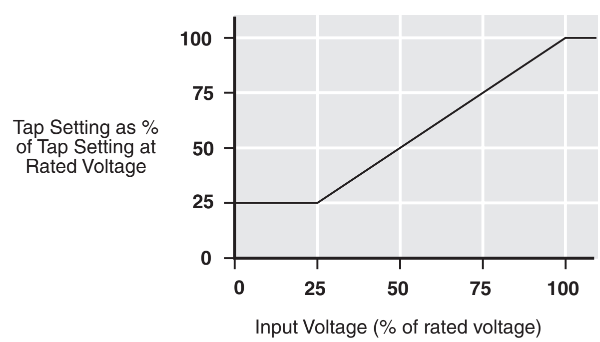


Figure 2-10 Voltage Restraint (51VR) Characteristic

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	$(V_{CA}-V_{BC})/\sqrt{3}$

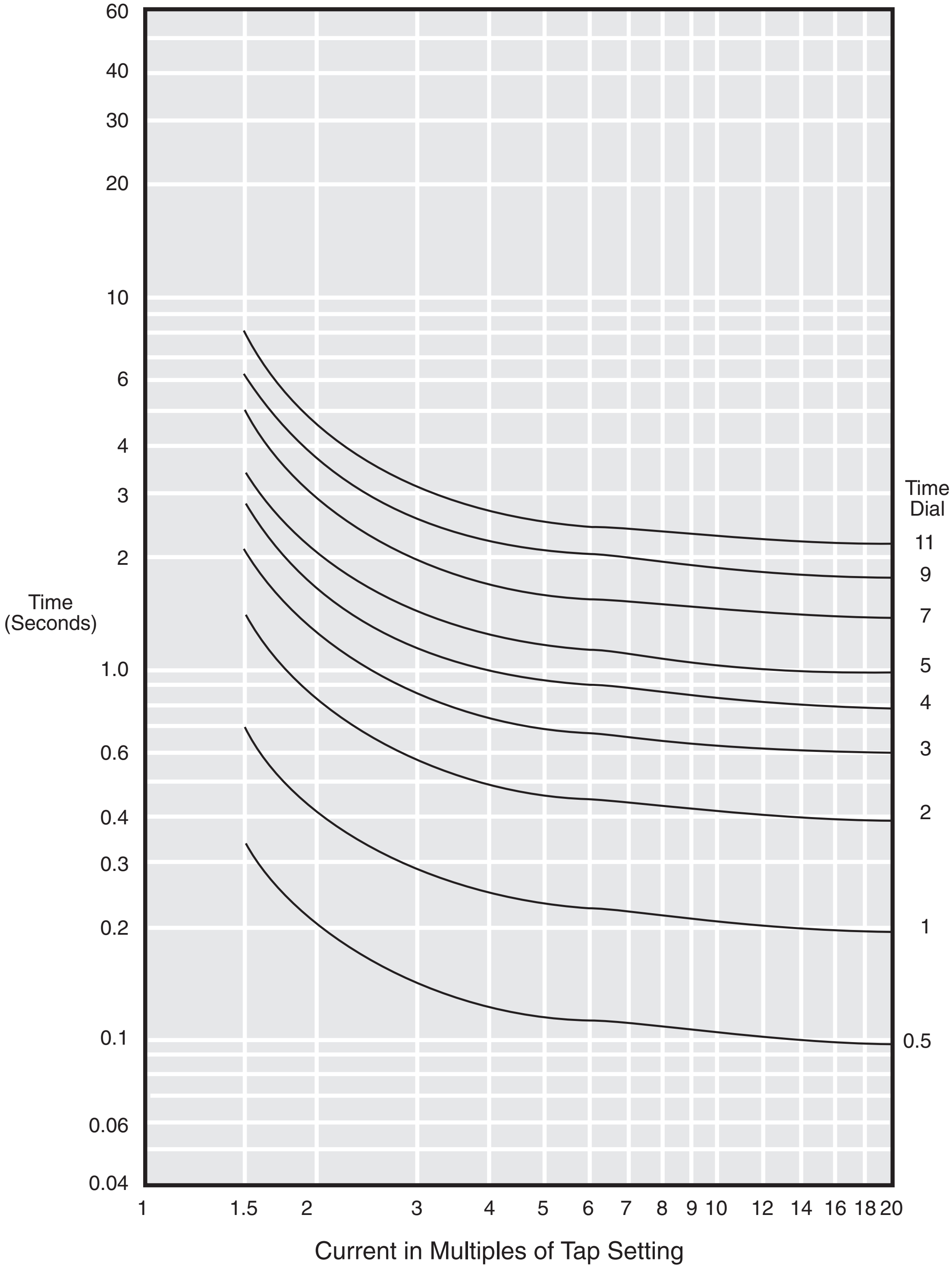
Table 2-6 Delta/Wye Transformer Voltage-Current Pairs

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 relay 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.

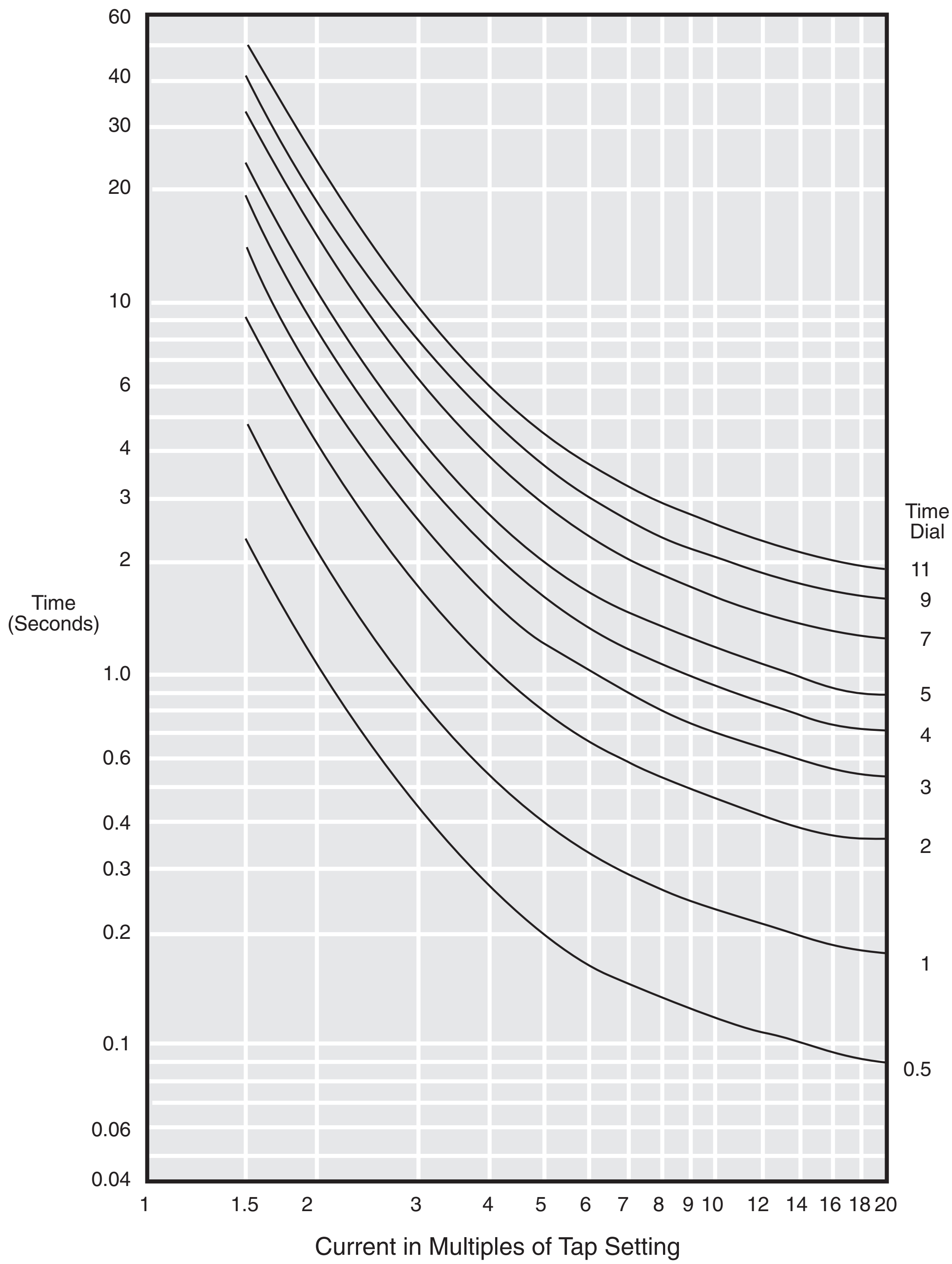
FUNCTION	SETPOINT RANGE	INCREMENT	INITIAL SETTING†
Inverse Time Overcurrent, 3-Phase with Voltage Control and Voltage Restraint (51V)			
Characteristic Curves	Definite, Inverse, Very Inverse, Extremely Inverse		Very Inverse
Tap Setting	0.50 to 1.45 A 1.50 to 2.90 A 3.00 to 5.80 A 6.00 to 12.00 A	0.05 A 0.10 A 0.20 A 0.50 A	6.0 A
Time Dial Setting	0.5 to 11.0	0.1	5.0
Voltage Control (VC) or Voltage Restraint (VR)	10 to 200 V (0.08 to 1.67 pu) Linear Restraint	1 V	132 V (1.1 pu)
Voltage Control and Restraint are disabled when shipped from factory. *†Initial Setting: The value is in setpoint memory until reprogrammed by the operator.*			

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



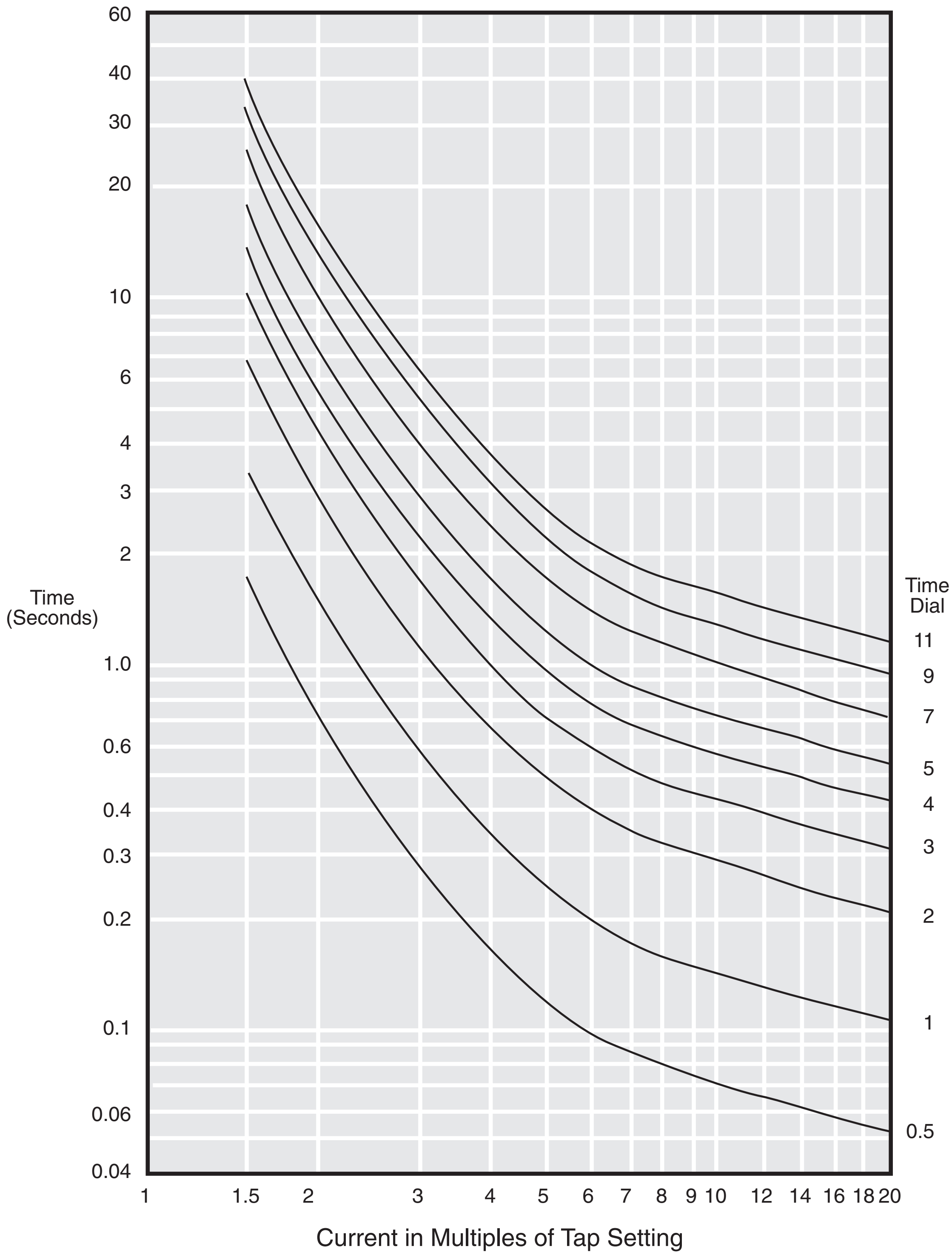
■ **NOTE**: An additional one-cycle time delay should be added to these curves in order to obtain the relay operating time.

Figure 2-11 Definite Time Overcurrent Curve



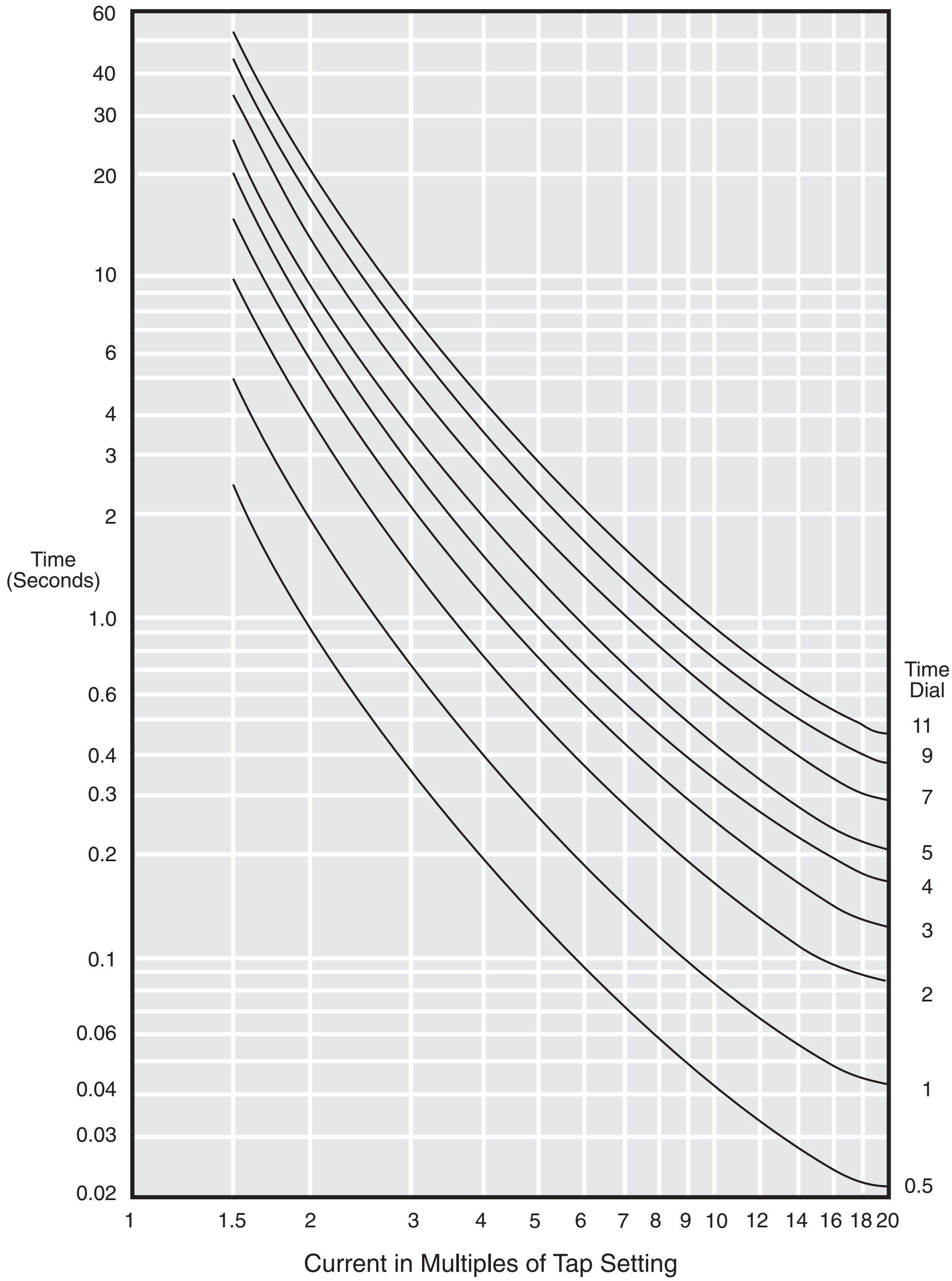
■ **NOTE**: An additional one-cycle time delay should be added to these curves in order to obtain the relay operating time.

Figure 2-12 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 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 2-14 Extremely Inverse Time Overcurrent Curve

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	Definite, Inverse, Very Inverse, Extremely Inverse		Very Inverse
Tap Setting	0.50 to 1.45 A 1.50 to 2.90 A 3.00 to 5.80 A 6.00 to 12.00 A	0.05 A 0.10 A 0.20 A 0.50 A	6.0 A
Time Dial Setting	0.5 to 11.0	0.1	5.0
†Initial Setting: The value is in setpoint memory until reprogrammed by the operator.			

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 to 240.0 A *	0.1 A	10.0 A
Trip Time Response	2 cycles maximum		
* Not to exceed 20 times the maximum phase overcurrent tap setting for the range chosen for 51V.			
Instantaneous Overcurrent, Neutral (50N)			
Magnitude	1.0 to 240.0 A*	0.1 A	10.0 A
Trip Time Response	2 cycles maximum		
*Not to exceed 20 times the maximum phase overcurrent tap setting for the range chosen by 51N.			
Initial Setting: The value is in setpoint memory until reprogrammed by the operator; functions with two setpoints have only setpoint #1 enabled when shipped from factory.			

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

46 Negative Sequence Overcurrent

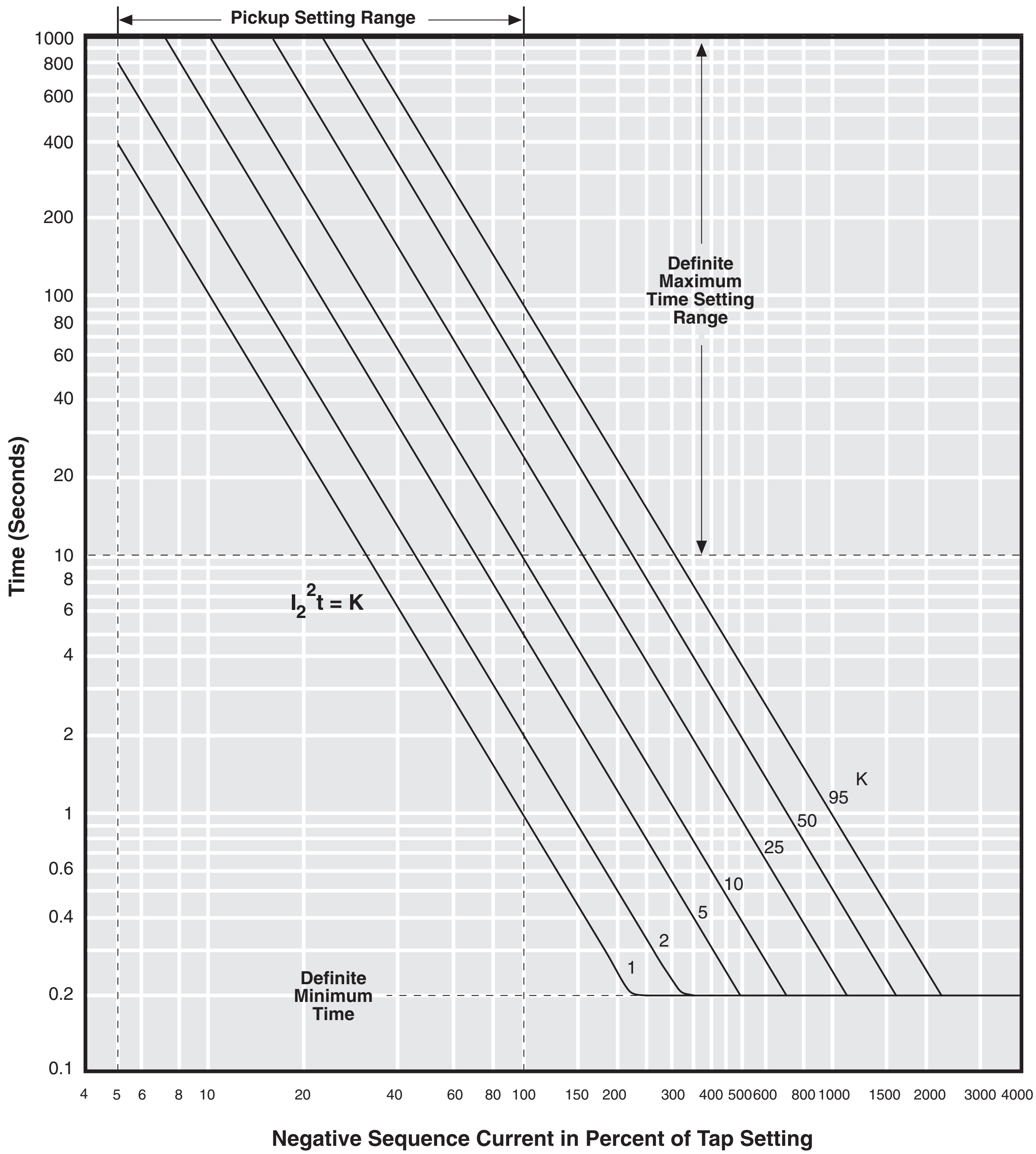
Unbalanced faults and other system conditions can cause unbalanced three-phase currents in the generator. The negative sequence components of these currents cause double-frequency currents in the rotor that can lead to severe overheating and damage. The negative sequence overcurrent function is set to operate before the specified limit for the machine is reached. As established by the ANSI standards, limits are expressed as $I_2^2t=K$, 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.

The negative sequence overcurrent function has a tap setting variable from 1 A to 5 A and a pick-up 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 to 5.0 A	0.1 A	5.0 A
Pickup as % of Tap Setting	5 to 100%	1%	50%
Time Dial Setting	1 to 95	1.0	25.0
Definite Maximum Time to Trip	600 to 60,000 cycles	5 cycles	10,000 cycles
†*Initial Setting: The value is in setpoint memory until reprogrammed by the operator; functions with two setpoints have only setpoint #1 enabled when shipped from factory.*			

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 any one 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. 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-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 VA	=600 VA

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:

Line-to-Neutral Voltage Input Option		
	120 V secondary VTs	**69.3 V secondary VTs**
Base volt-amperes (1 pu)	$=3 \times V_{PHASE} \times I_{PHASE}$	$=3 \times V_{PHASE} \times I_{PHASE}$
	$=3 \times 120 \times 5$	$=3 \times 69.3 \times 5$
	=1800 VA	=1039 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:

Three-Phase Reverse Power	
120 V secondary VTs	**69.3 V secondary VTs**
=1800 VA	$=1800/\sqrt{3}=1039$ VA

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

Single-Phase Reverse Power	
120 V secondary VTs	**69.3 V secondary VTs**
=600 VA	$=600/\sqrt{3}=346$ VA

Function	Setpoint Range	Increment	Initial Setting
Directional Power, 3-Phase (32)			
Forward Power Flow Magnitude	0.02 to 3.0 pu	0.01 pu	3.0 pu
Time Delay #1, #2	1 to 8160 cycles	1.0 cycle	30 cycles
Reverse Power Flow Magnitude	0.02 to 3.0 pu	0.01 pu	3.0 pu
Time Delay*	1 to 8160 cycles	1.0 cycle	30 cycles
** Time Delay, high-speed setting has no intentional delay; response time=0.75 cycle ±0.5 cycle.*			

Table 2-11 Directional Power (32) Setpoint Ranges

67 Phase Directional Overcurrent Option

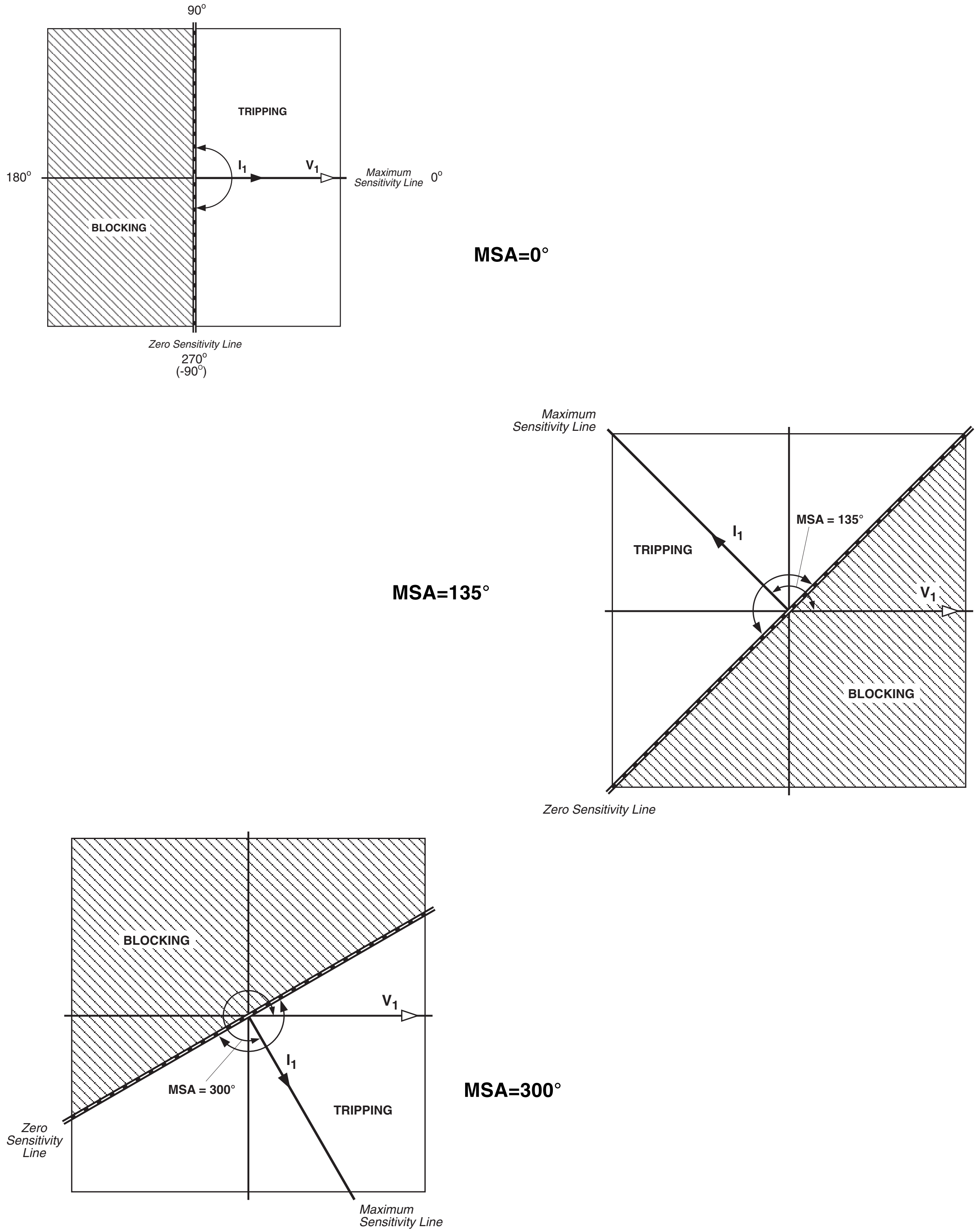
For intertie protection applications, the phase directional overcurrent relay allows greater selectivity for utility system faults, since the directional element can be set to look toward the utility system. As a generator protection relay, the 67 function, looking into the generator, can provide protection for accidental energizing 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 prefault 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 to 240* A	0.1 A	10.0 A
Time Delay **	1 to 8160 cycles	1.0 cycle	30 cycles
Directional Element			
Maximum Sensitivity (Torque) Angle (MSA)	0° to 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. †Initial Setting: The value is in setpoint memory until reprogrammed by the operator; functions with two setpoints have only setpoint #1 enabled when shipped from factory.*			

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 to 8160 cycles	1.0 cycle	60 cycles
†Initial Setting: The value is in setpoint memory until reprogrammed by the operator.			

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

60FL VT Fuse-Loss Detection

Since some relay functions may otherwise send an inadvertent trip signal when a voltage-transformer fuse is blown, the relay 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 V) *and* (V_2>0.33 V_1) *and* [(I_2 <0.167 I_1) *or* (I_1 < 0.33 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 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 $I_1 < 0.33$ 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 relay 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 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 51V function is enabled when the blown VT fuse condition is detected, the relay will disable 51VC (if VC is enabled) or disable VR of 51VR (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.

2.7 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 PC-compatible 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.*

3 Front Panel Controls

3.1 Introduction ... 3–1
3.2 Target/Status Indicators and Controls ... 3–3
3.3 Serial Interfaces (COM1 and COM2) ... 3–3

3.1 Introduction

The M-0420 Multifunction Relay has been designed to be quick and easy 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/right arrow buttons, the **EXIT** and **ENTER** buttons, 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 relay, the LCD displays menus that guide you to the desired 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/right arrow buttons 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/right arrow buttons and/or the rotary knob to increment or decrement the currently displayed value.

Left/Right Arrow Buttons

You use the left/right arrow buttons 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.

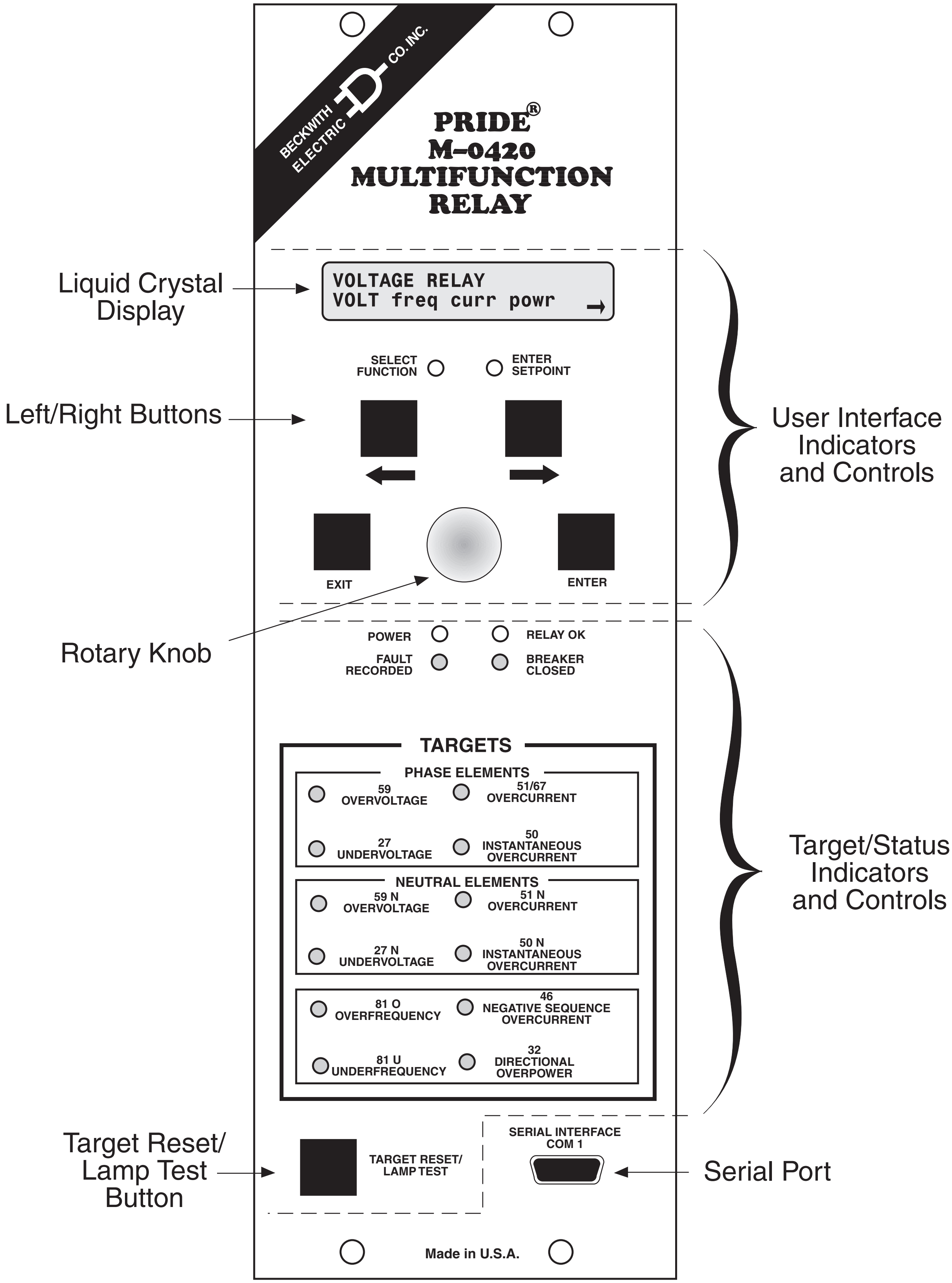


Figure 3-1 M-0420 Front Panel

EXIT Button

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

ENTER Button

The **ENTER** button is used to choose a highlighted menu selection, to replace a setpoint or other programmable value with the currently displayed value, or to select one of several displayed options, such as **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/right arrow buttons 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/right arrow buttons to choose among menu selections displayed on the LCD.

3.2 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** button.

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 relay's 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 button 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 Button

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** button 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** button will display the pick up status of the relay functions.

3.3 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 interrogation of the relay via a portable computer. An additional port, **COM 2**, is available at the rear of the relay. This 25-pin port will normally be used for remote setting and interrogation of the relay 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 BECOCOM®/M-0428A BECOPLOT® User's Guide.

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4 Operation

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4.1 Introduction

While the M-0420 Multifunction Relay 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.**

4.2 Software Flow

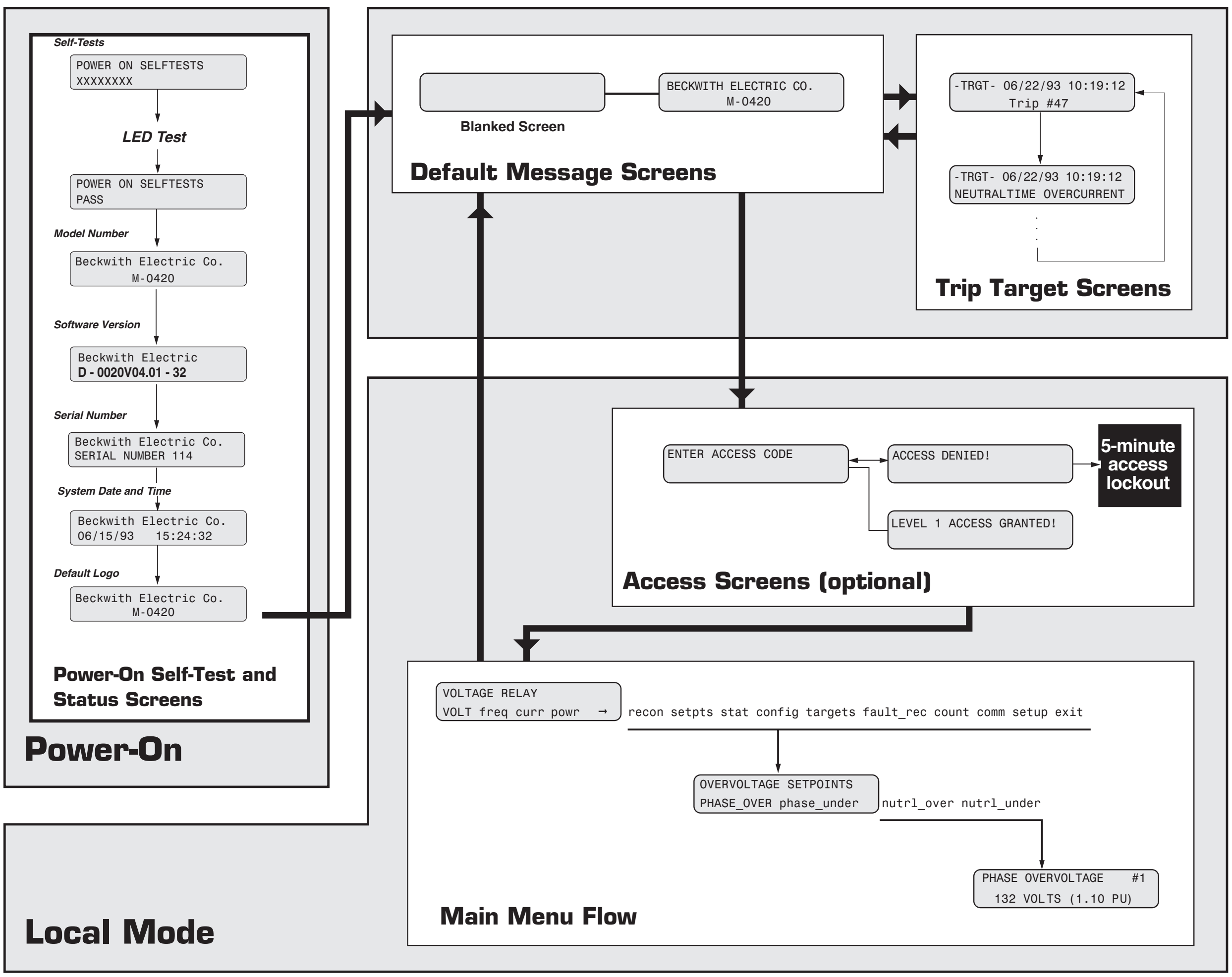
Power-On Self-Test and Status Screens

Each time it is powered up, the relay performs a number of self-tests to ensure its correct operation. During the self-tests, the display presents a lowercase “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 relay is powered and unattended, the display is blanked to increase its life-span. 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:** Communications through the front/rear-panel communications ports is suspended while the M-0420 is in local mode.

Figure 4-1 Software Flow

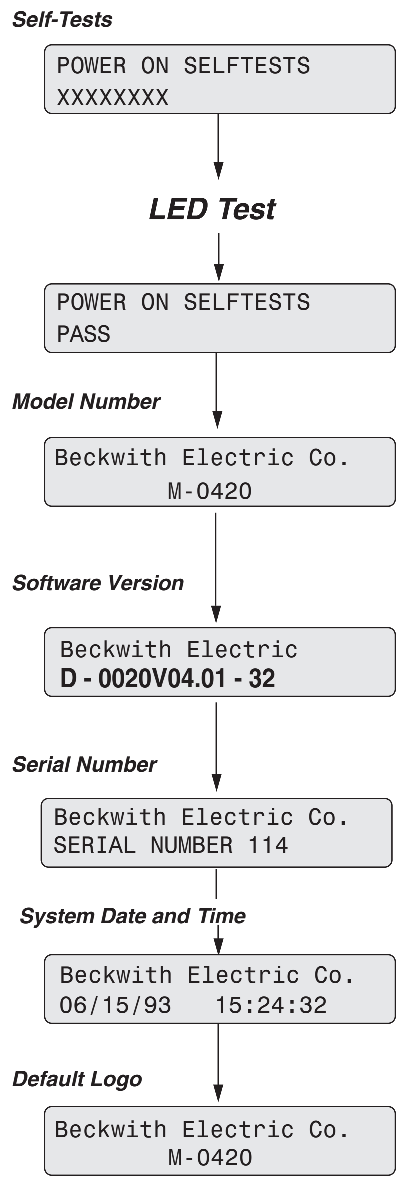


Figure 4-2 Power-On Self-Test and Status Screens

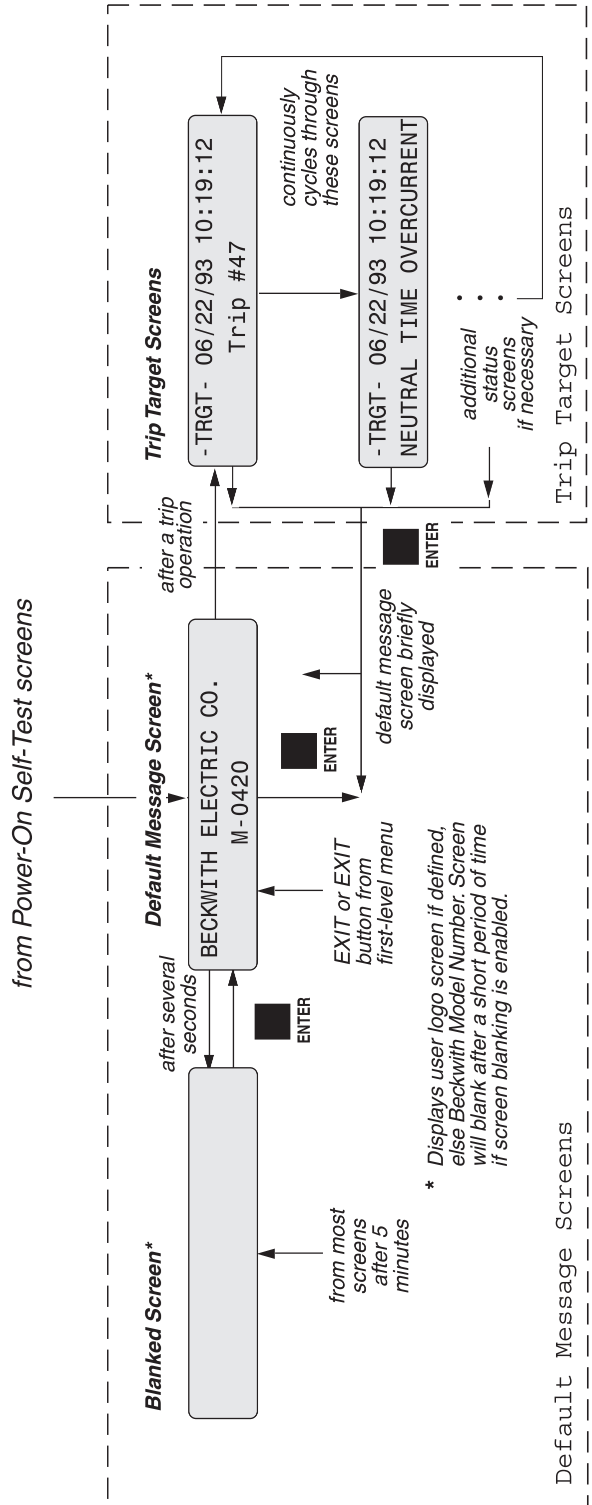


Figure 4-3 Default Message Screens

■ **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 relay from the front panel.

Access Screens

To prevent unauthorized access to relay 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, Access Screens, will be displayed after **ENTER** is pressed from the default message screen (see above). The relay 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 protective functions. Figure 4-5, Front Panel Operation, 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.

4.3 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 buttons 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** button. 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.)

4.4 Entering Values

Numeric values must be entered for the 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.

■ **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/right arrow buttons 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** button 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 relay will not allow you to enter a digit outside 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.

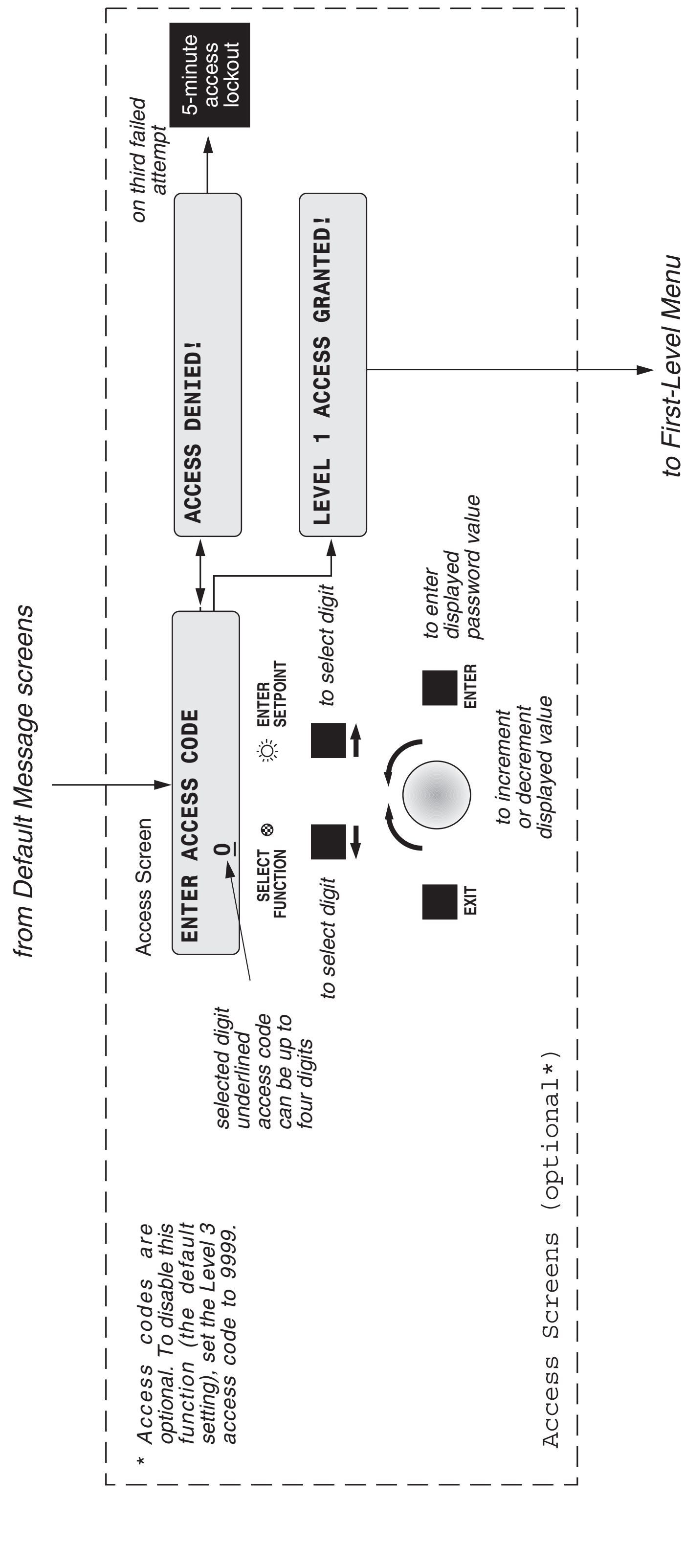


Figure 4-4 Access Screens

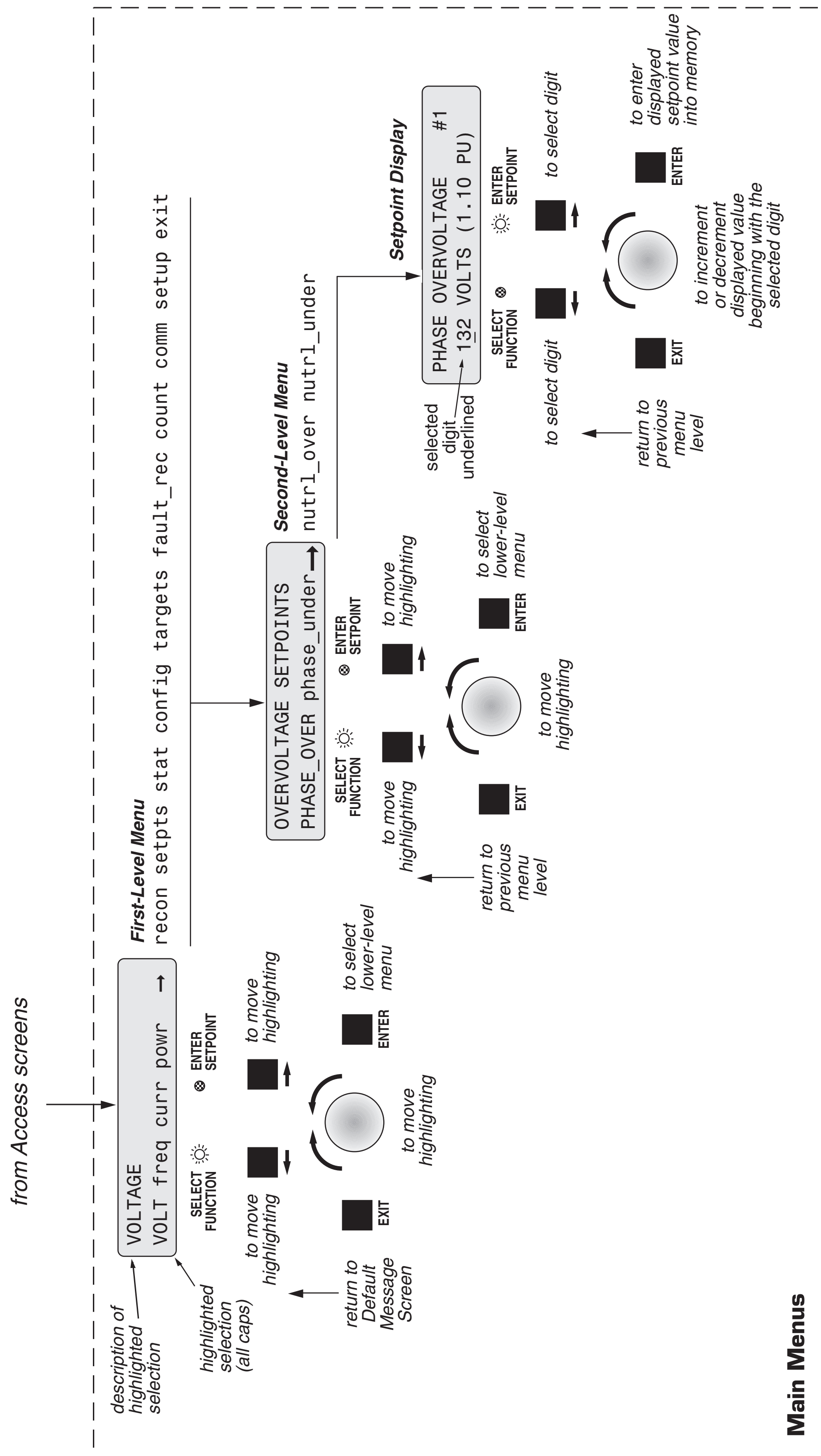


Figure 4-5 Front Panel Operation

4.5 Access Codes

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

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 buttons, 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.

4.6 Enabling and Disabling Relay Functions

Each relay function 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.

5 Menu Reference

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5.2 Relay Functions 5–1
5.3 Review Setpoints 5–2
5.4 Monitor Status 5–2
5.5 Configure Relays 5–3
5.6 View Target History 5–4
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5.1 Introduction

This chapter provides a short description for each main menu selection available in the M-0420 Multifunction Relay Version 4.01 software. Flowcharts are provided for the relay configuration menus. (Figure 5-1, M-0420 Menu Flow, summarizes the 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 relay settings are enabled or disabled as shipped from the factory (see Figure 7-1).

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

5.2 Relay Functions

Voltage Relay

```
VOLTAGE RELAY
VOLT freq curr powr →
```

The **VOLTAGE RELAY** menu selection provides access to the voltage functions of the relay. 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.

Frequency Relay

```
FREQUENCY RELAY
volt FREQ curr powr →
```

The **FREQUENCY RELAY** menu selection provides access to the frequency functions. 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.

Current Relay

```
CURRENT RELAY
volt freq CURR powr →
```

The **CURRENT RELAY** menu selection provides access to the current functions. 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.

■ **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.

Power Relay

```
POWER RELAY
volt freq curr POWR →
```

The **POWER RELAY** menu selection provides access to the power functions. 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.

Reconnect Relay

```
RECONNECT RELAY
← RECON →
```

The **RECONNECT RELAY** menu selection provides access to the reconnect function. 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.

5.3 Review setpoints

```
REVIEW SETPOINT
← SETPTS stat config →
```

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.

5.4 Monitor status

```
MONITOR STATUS
← setpts STAT config →
```

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

■ **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**.

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: including the external VT fuses and the relay's internal fuses.

Temperature: the unit's internal temperature as reported by the on-board temperature sensor

Time of Last Power Up

5.5 Configure Relays

```
CONFIGURE RELAYS
← setpts stat CONFIG →
```

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

Functions are grouped under the following submenus: Voltage Relay, Frequency Relay, Current Relay, Power Relay, Trip Circuit Type (Intertie or Generator), and 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 DISABLED \SEE 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 Multifunction Relay 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 functions work as described in this Instruction Book.

When **GENERATOR** is selected, the relay 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 relay will not send an unwanted trip signal while the generator is off-line, 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.

5.6 View target History

```
VIEW TARGET HISTORY
← TARGETS fault_rec →
```

The **VIEW TARGET HISTORY** menu enables you to review the targets for the previous five trip conditions. As shown in Figure 5-18, Example of Target History Screens, 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 Target Information #0–4, 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 **CLEAR TARGET HISTORY** screen.

5.7 Fault Recorder

```
FAULT RECORDER
← targets FAULT_REC →
```

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 BECOCOM software. This software also permits the user to trigger the fault recorder manually.

■ **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.

5.8 Read Counter

```
READ COUNTER
← COUNT comm 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

5.9 Communication

```
COMMUNICATION
← count COMM setup exit
```

You can configure the relay 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 relay 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 Multifunction Relay or other compatible Beckwith products) to share a phone line or modem. Each relay can be given an individual address ranging from 1–200. All relays 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

```
COMMUNICATION ADDRESS
com1 com2 com_adr ACCSS→
```

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

Issue COM2 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 COM2 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 EØ QV &DØ SØ=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 **COM2** 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 (727) 544-2326 for further information.

5.10 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 disp→
```

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 disp→
```

The **ALTER ACCESS CODES** menu selection enables you to define and change access codes. The relay 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/right arrow buttons.

■ **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 disp→
```

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.

LCD Display Blanking

```
LCD DISPLAY BLANKING
←vers access time DISP→
```

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.

Input User Logo

```
USER LOGO LINE 1
←LOGO1 logo2 dipsw →
```

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.

DIP Switch settings

```
DIP SWITCH SETTINGS
←  logo1 logo2 DIPSW→
```

```
1X    8 OFF DIPSWITCH
XXXXXXX     on
```

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**.

VT and CT Ratios

```
VT & CT 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, the relay can be programmed with VT and CT ratios. During communications, these ratios are transmitted to the BECOCOM program. 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**: These ratios are used for BECOCOM display purposes only; they are not used in the relay for any calculations and need not be set if remote communication is not desired.

■ **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:

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

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.

5.11 EXIT LOCAL MODE

```
EXIT LOCAL MODE
← count comm setup EXIT
```

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

5.12 Menus

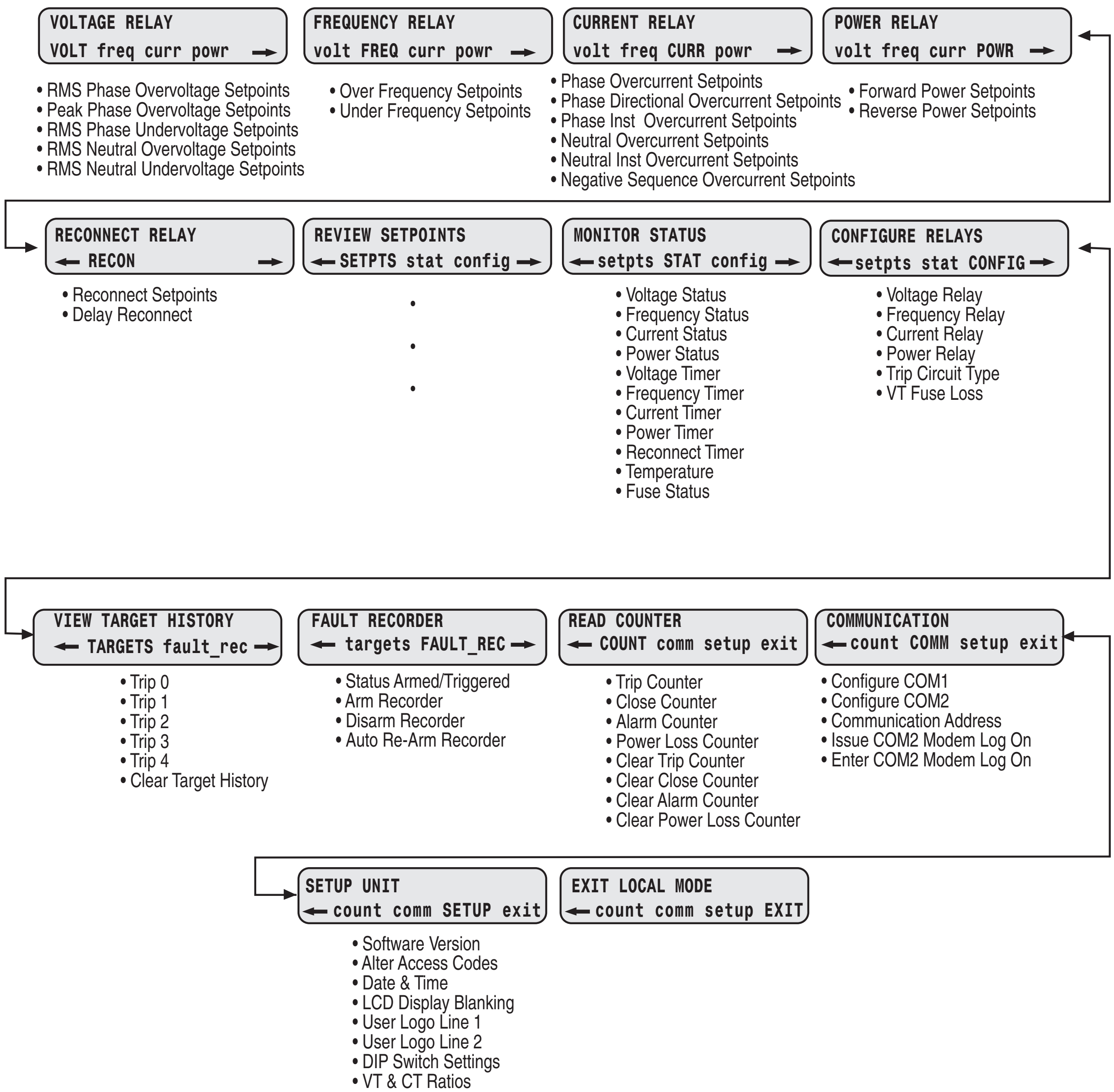
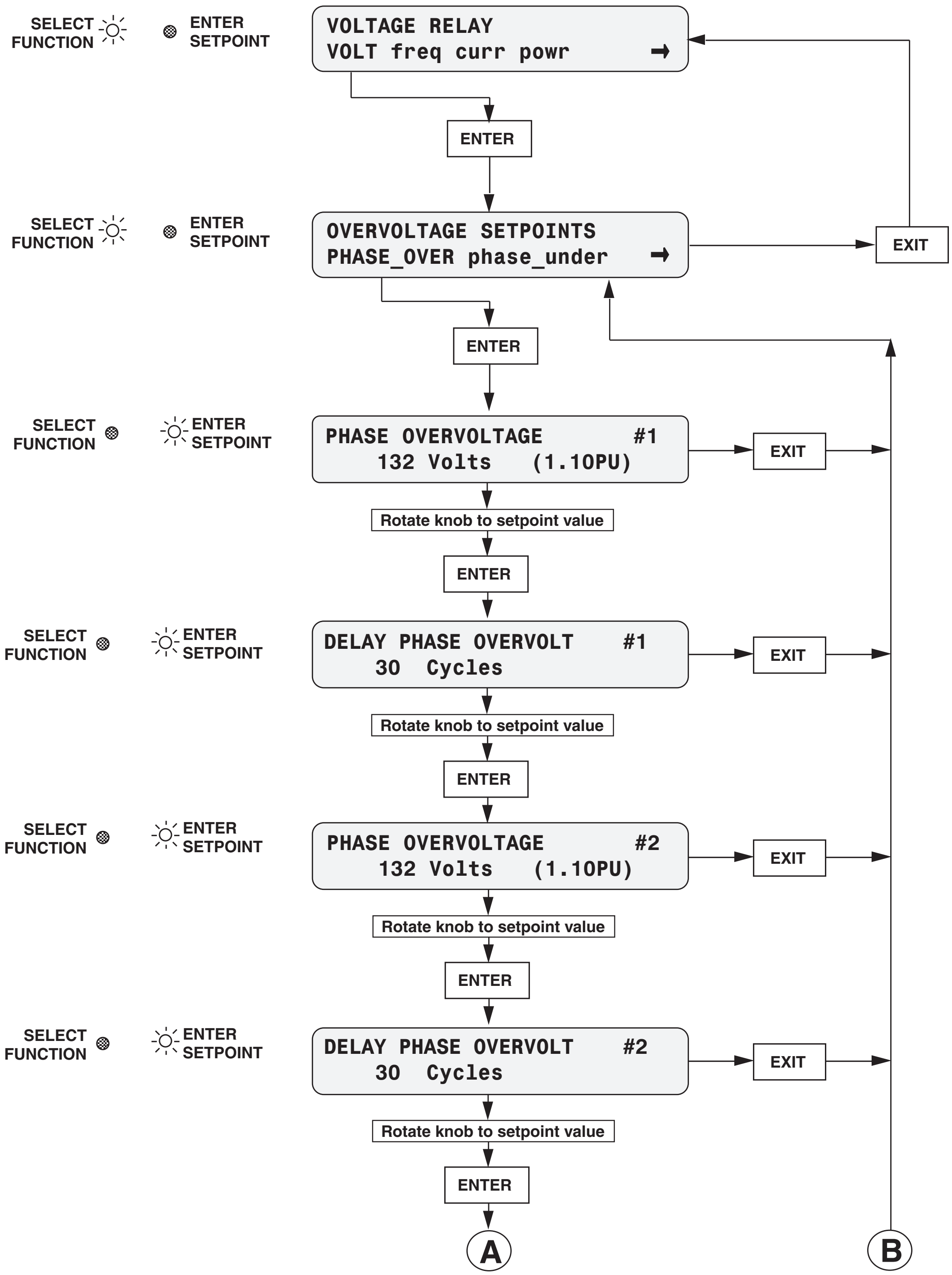
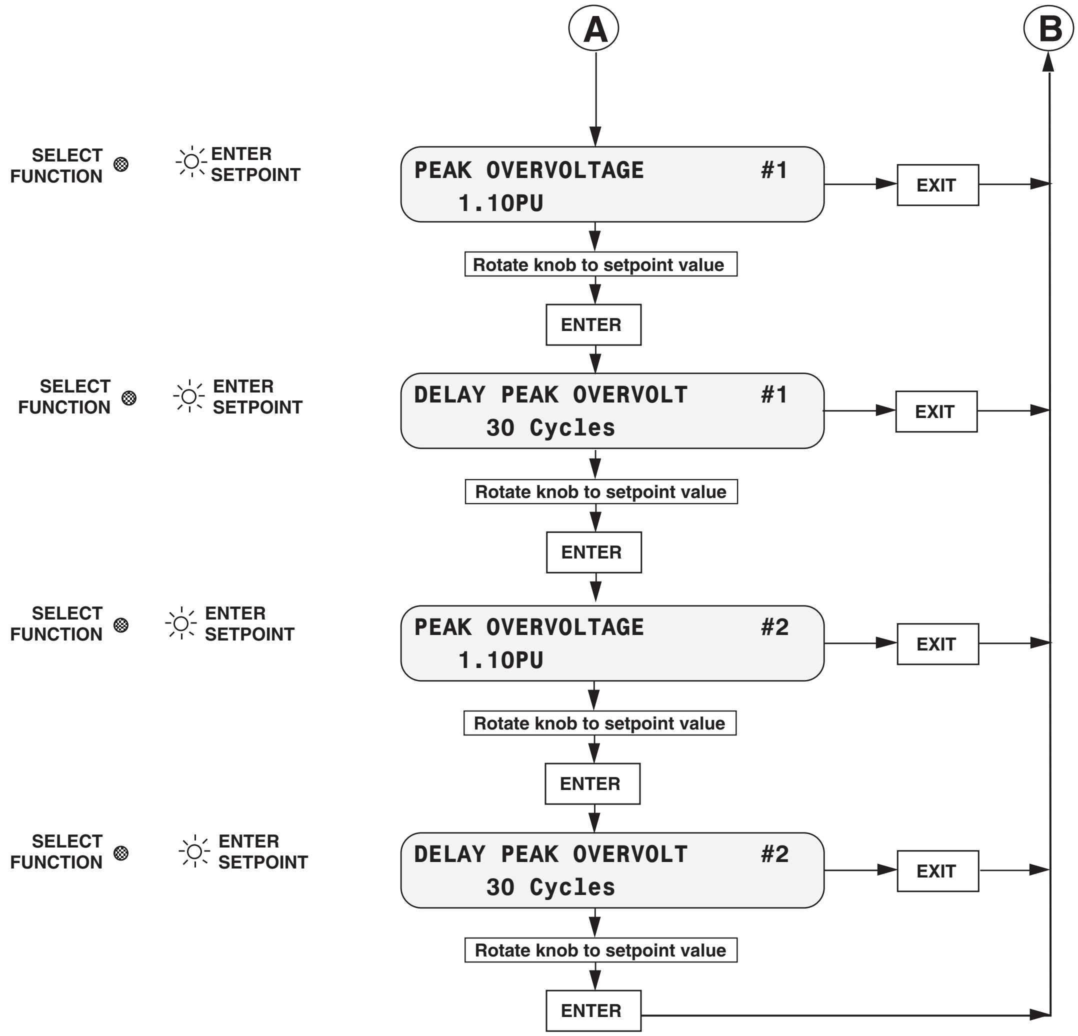


Figure 5-1 M-0420 Menu Flow, Version 4.01 Software



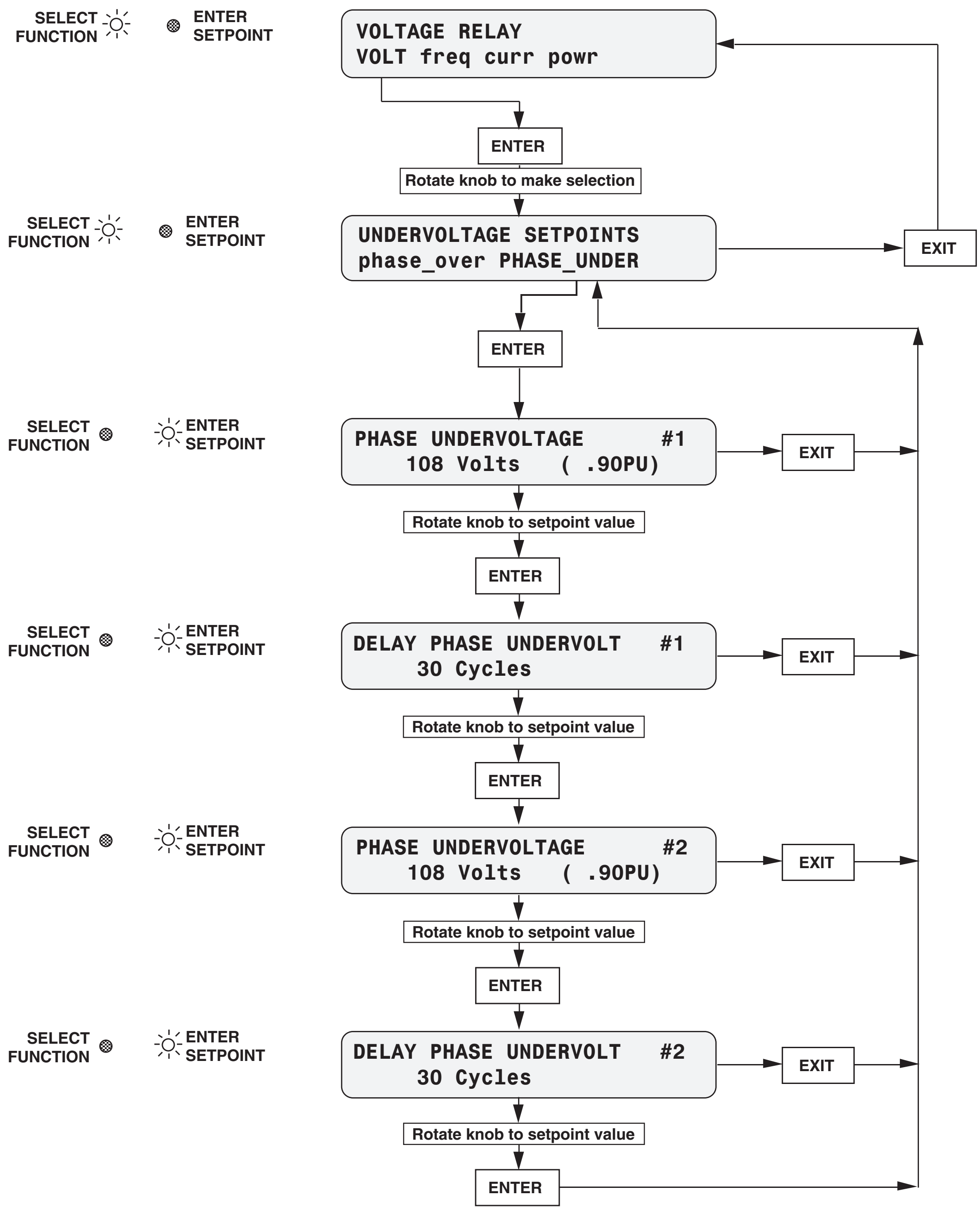
■ **NOTE:** Setpoints #2 are disabled as shipped, and do not appear on the menu. Use **CONFIGURE RELAYS** menu to enable them.

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



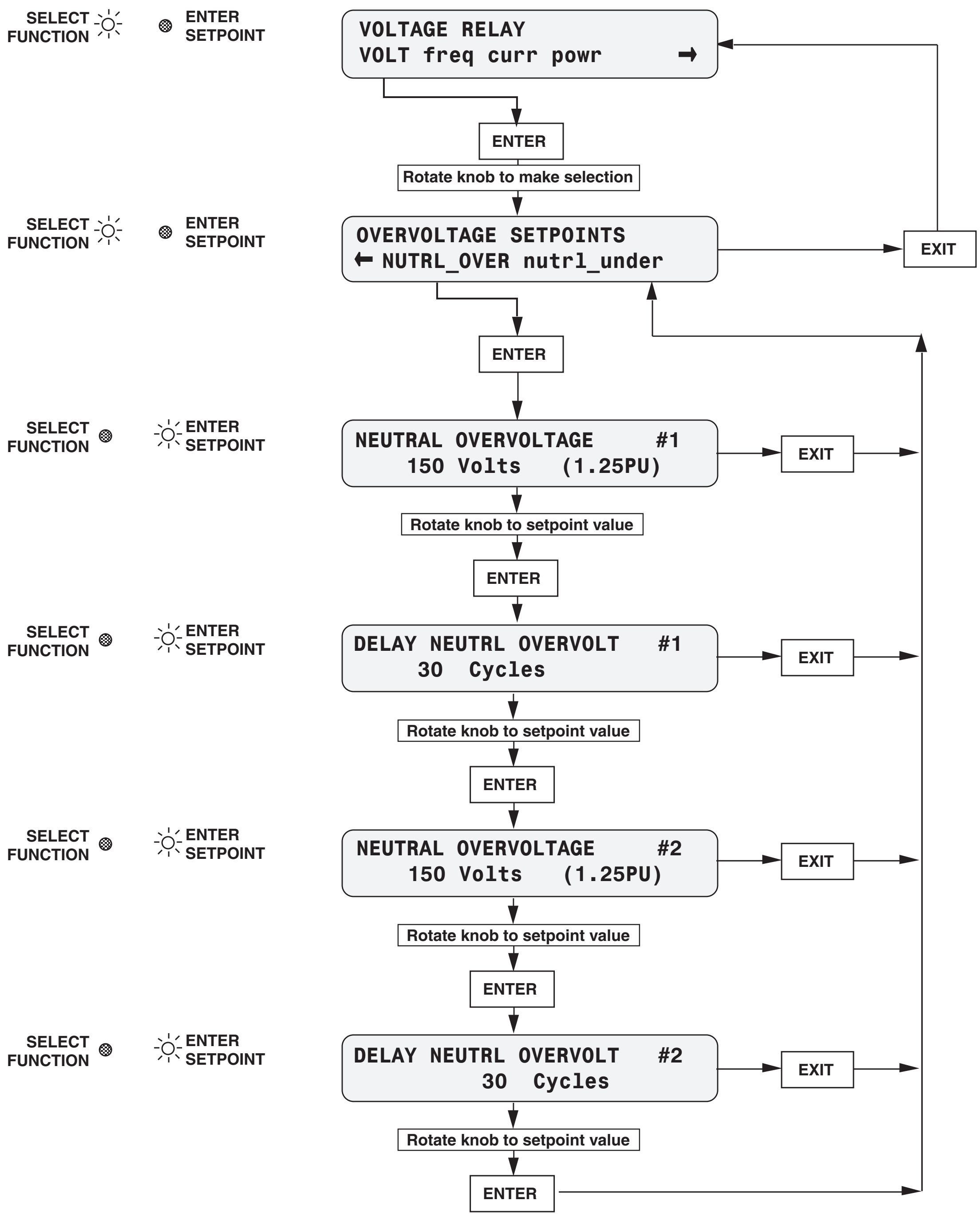
■ **NOTE:** Setpoints #2 are disabled as shipped, and do not appear on the menu. Use **CONFIGURE RELAYS** menu to enable them.

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



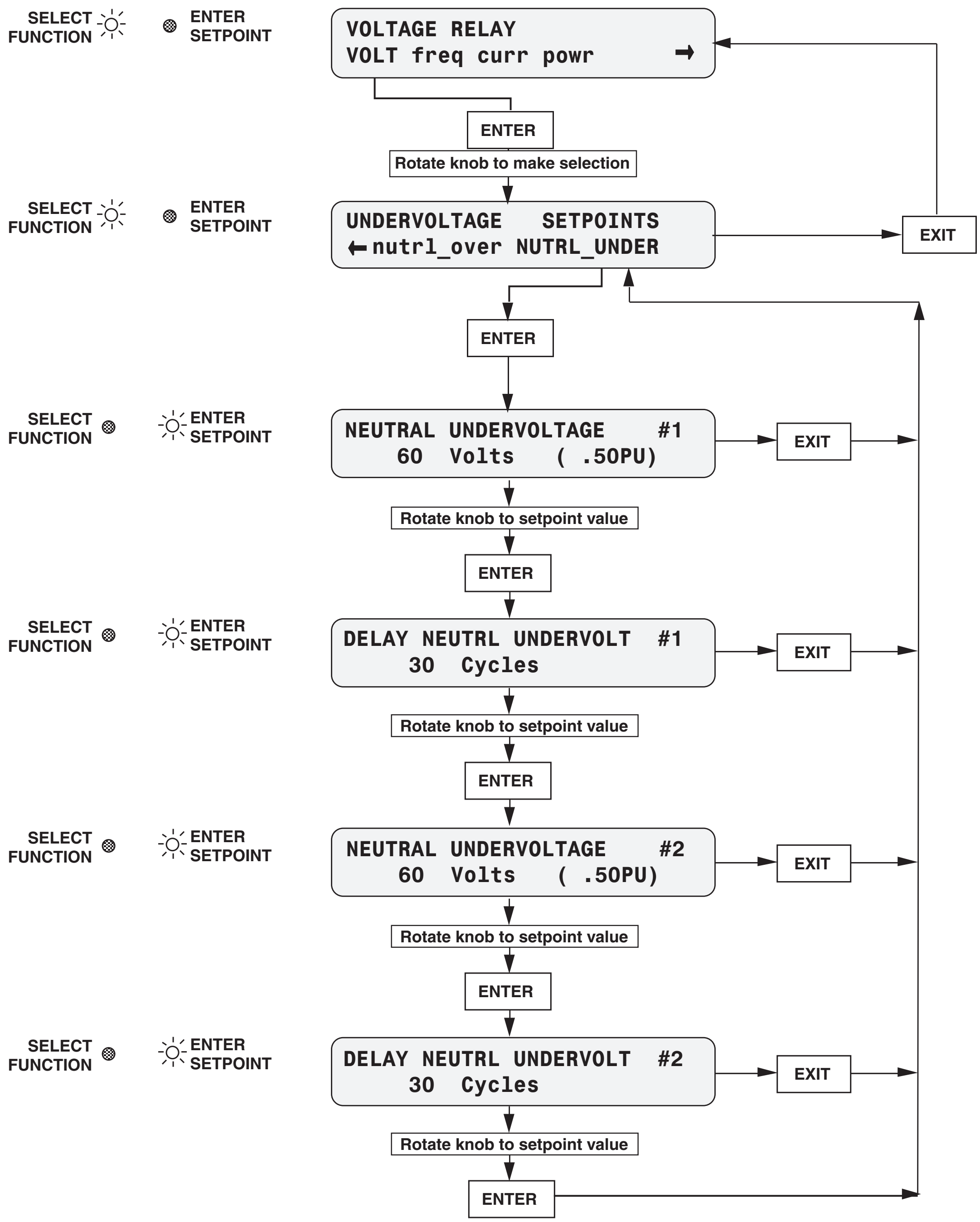
■ **NOTE:** Setpoints #2 are disabled as shipped, and do not appear on the menu. Use **CONFIGURE RELAYS** menu to enable them.

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



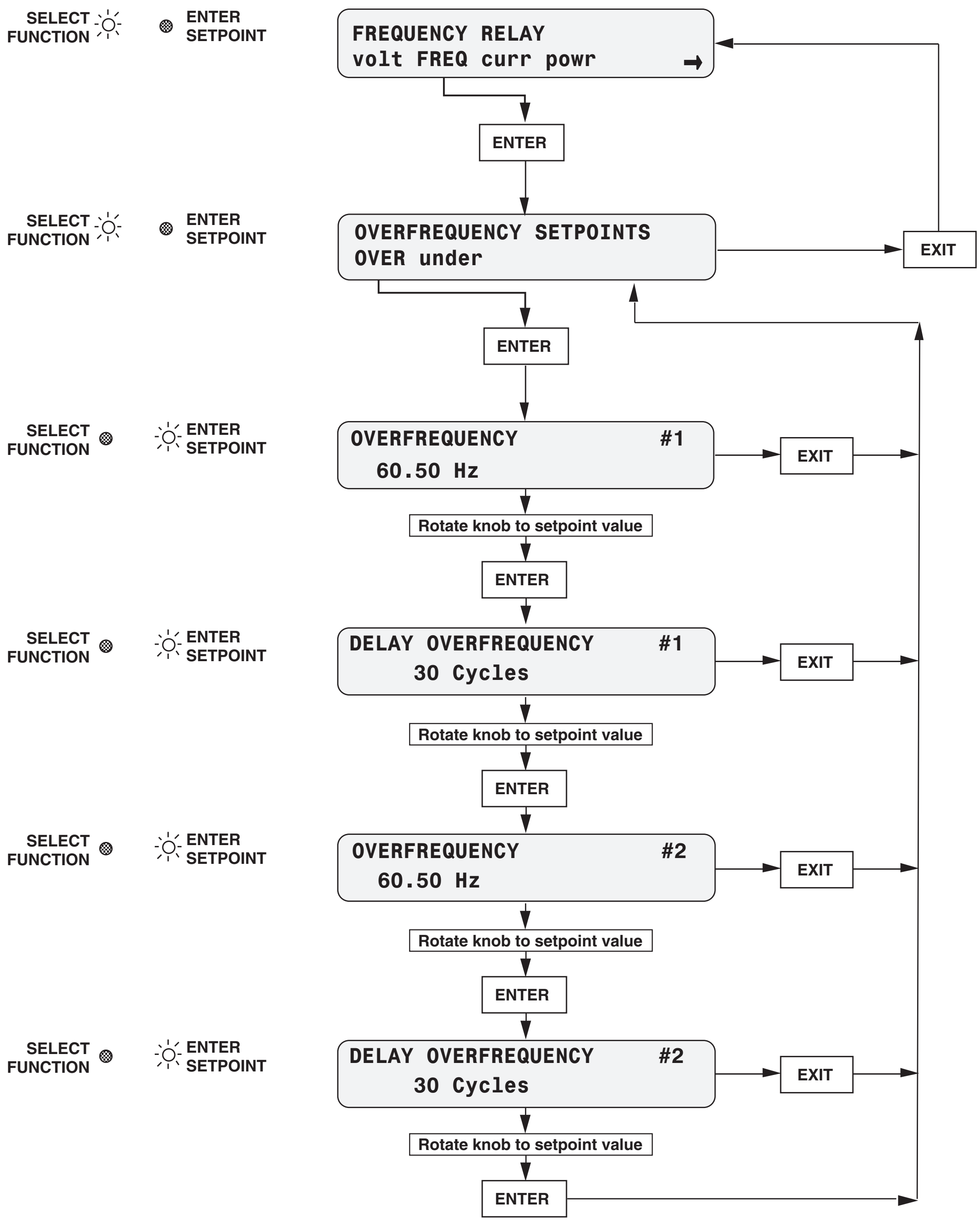
■ **NOTE:** Setpoints #2 are disabled as shipped, and do not appear on the menu. Use **CONFIGURE RELAYS** menu to enable them.

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



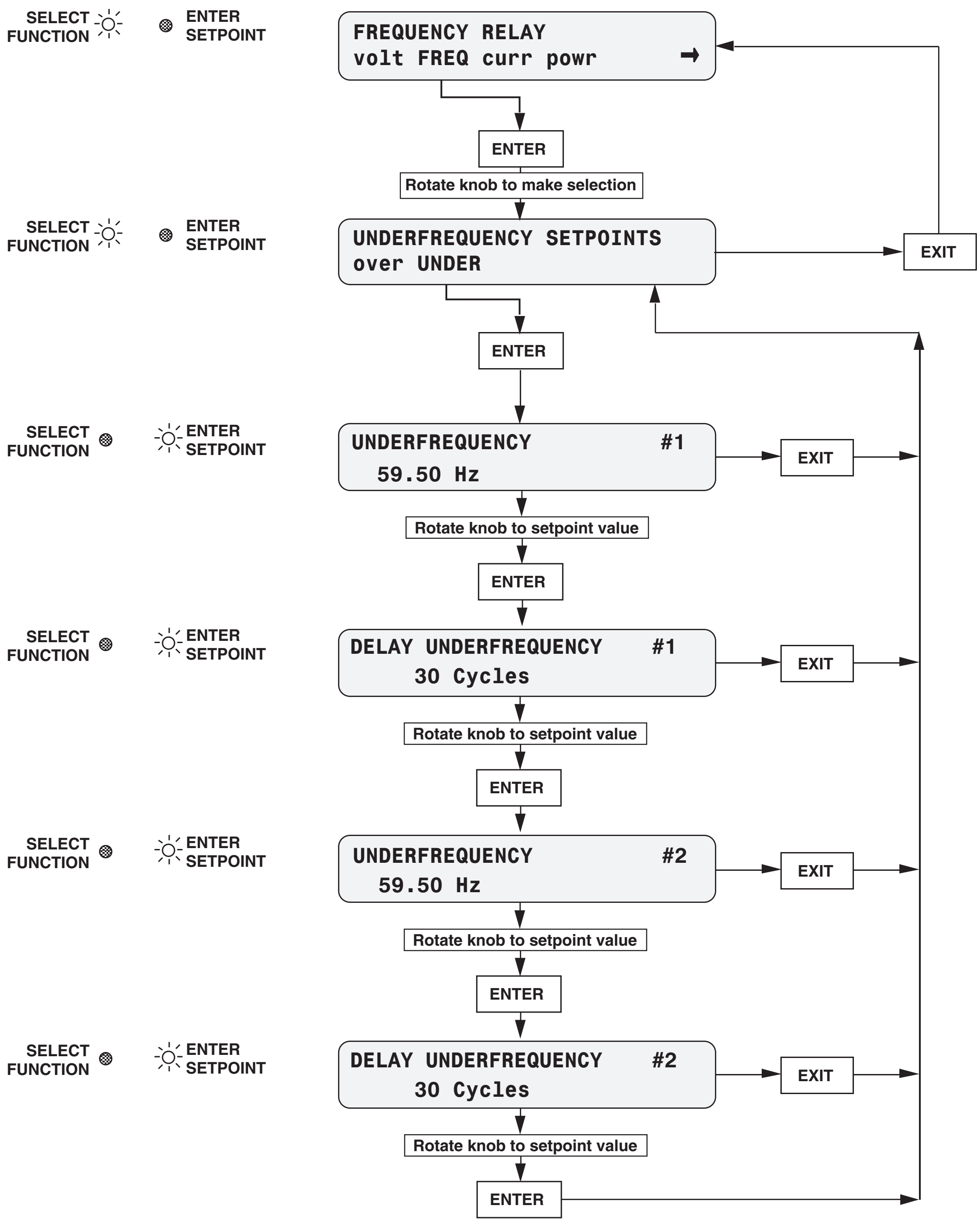
■ **NOTE:** Setpoints #2 are disabled as shipped, and do not appear on the menu. Use **CONFIGURE RELAYS** menu to enable them.

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



■ **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 (81O)



■ **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)

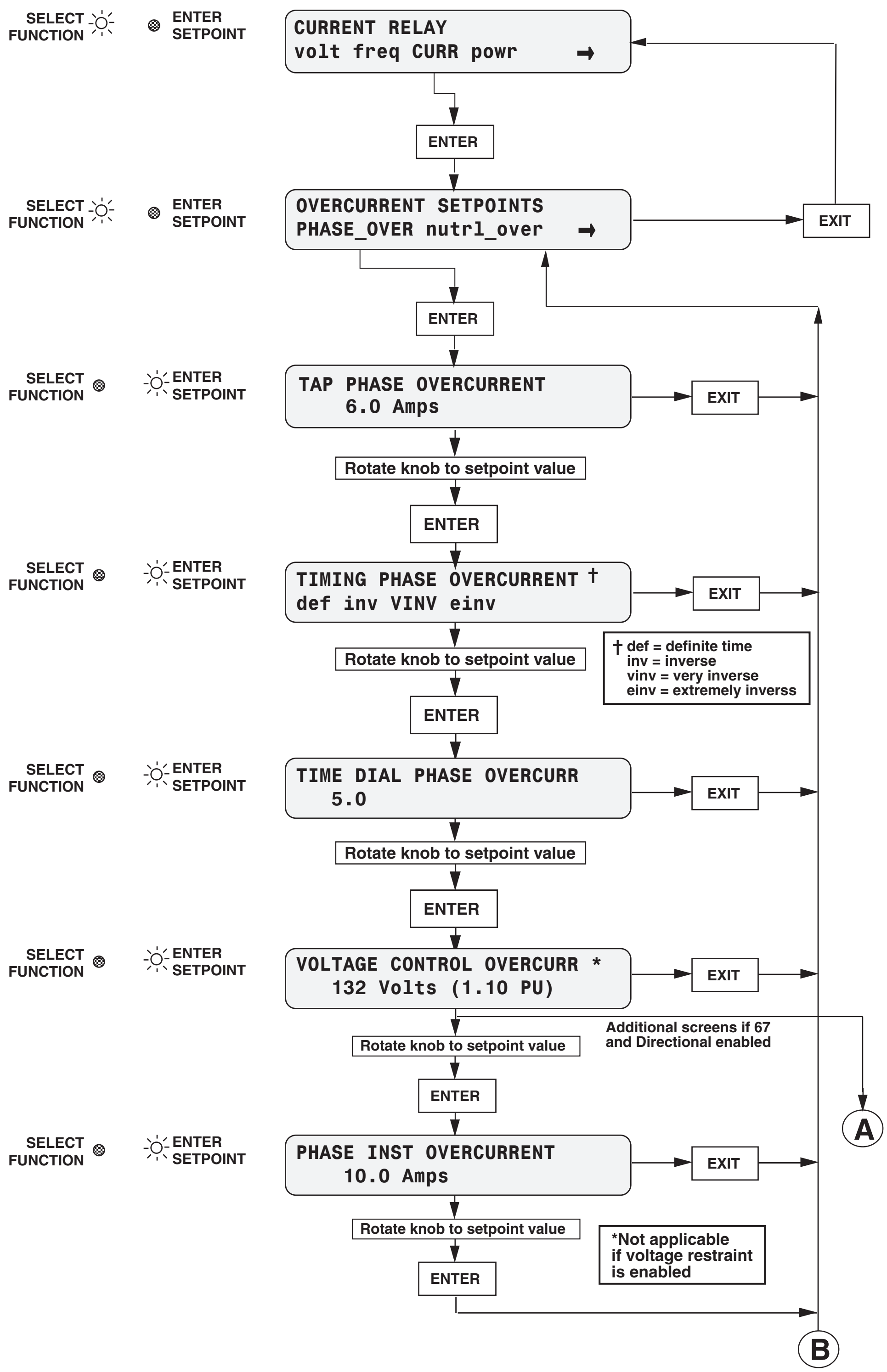
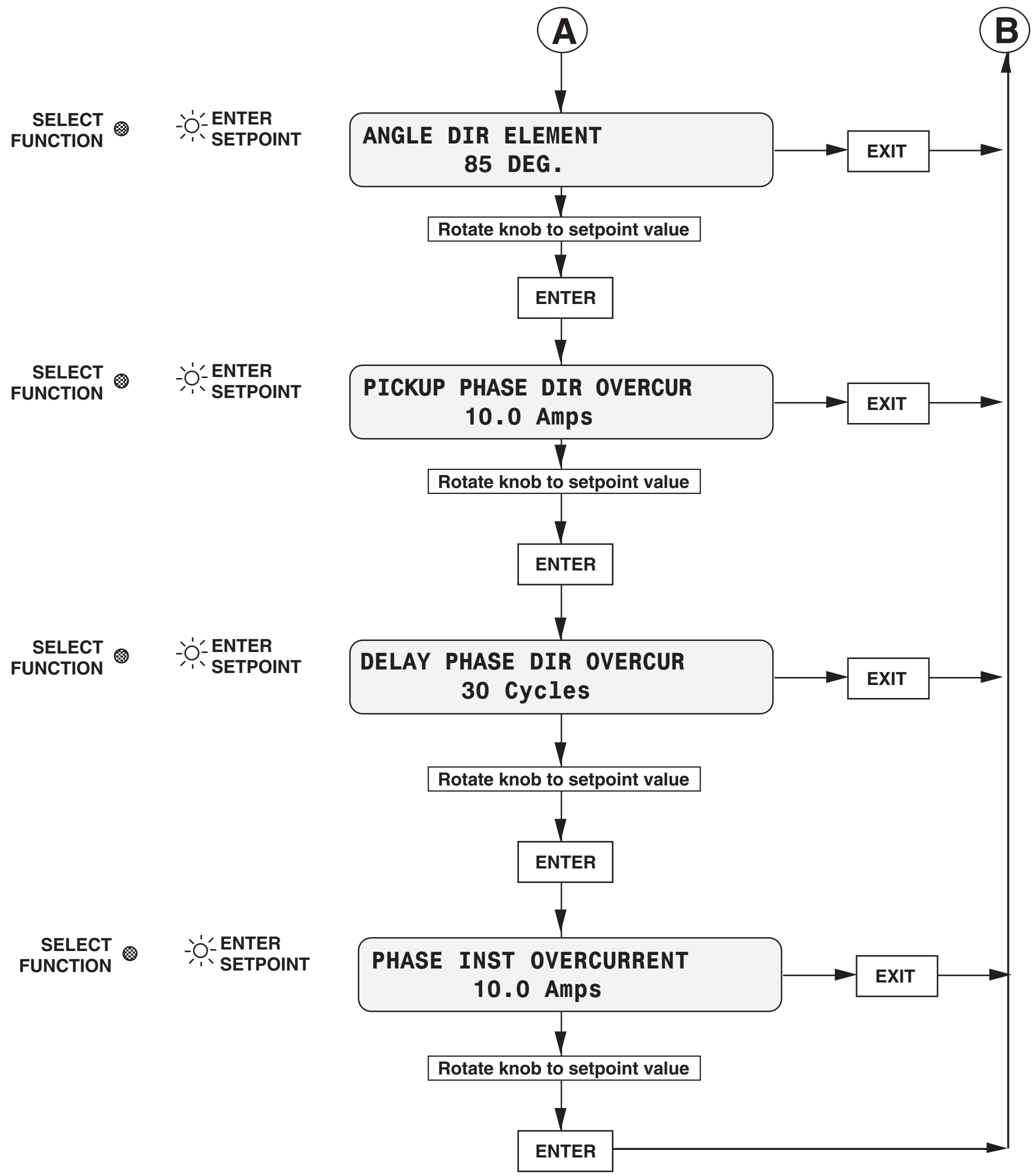


Figure 5-9 Current Relay: Inverse Time Overcurrent, 3-Phase (51V)
Instantaneous Overcurrent, 3-Phase (50)



■ **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)

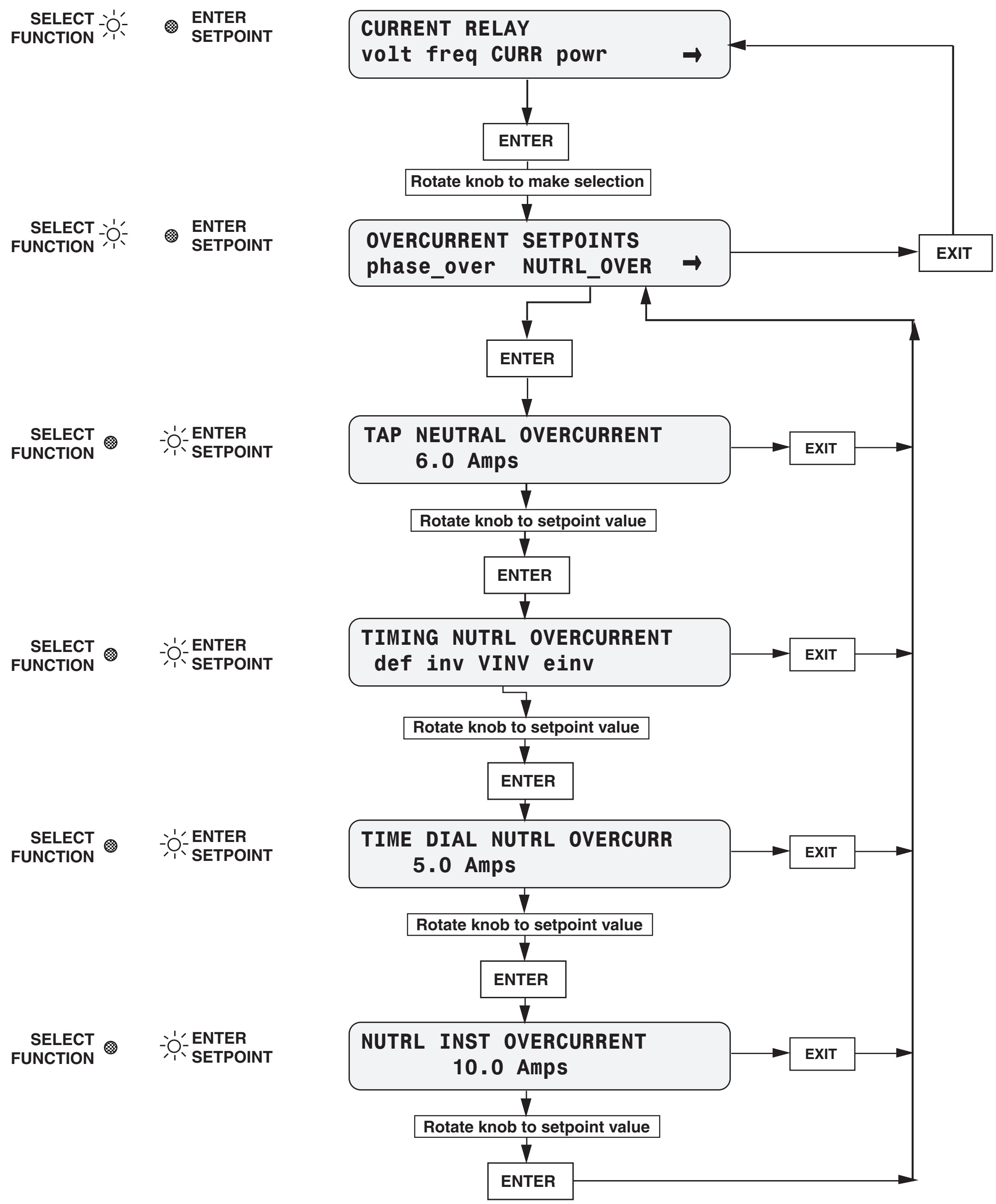


*Figure 5-11 Current Relay: Inverse Time Overcurrent, Neutral (51N)
Instantaneous Overcurrent, Neutral (50N)*

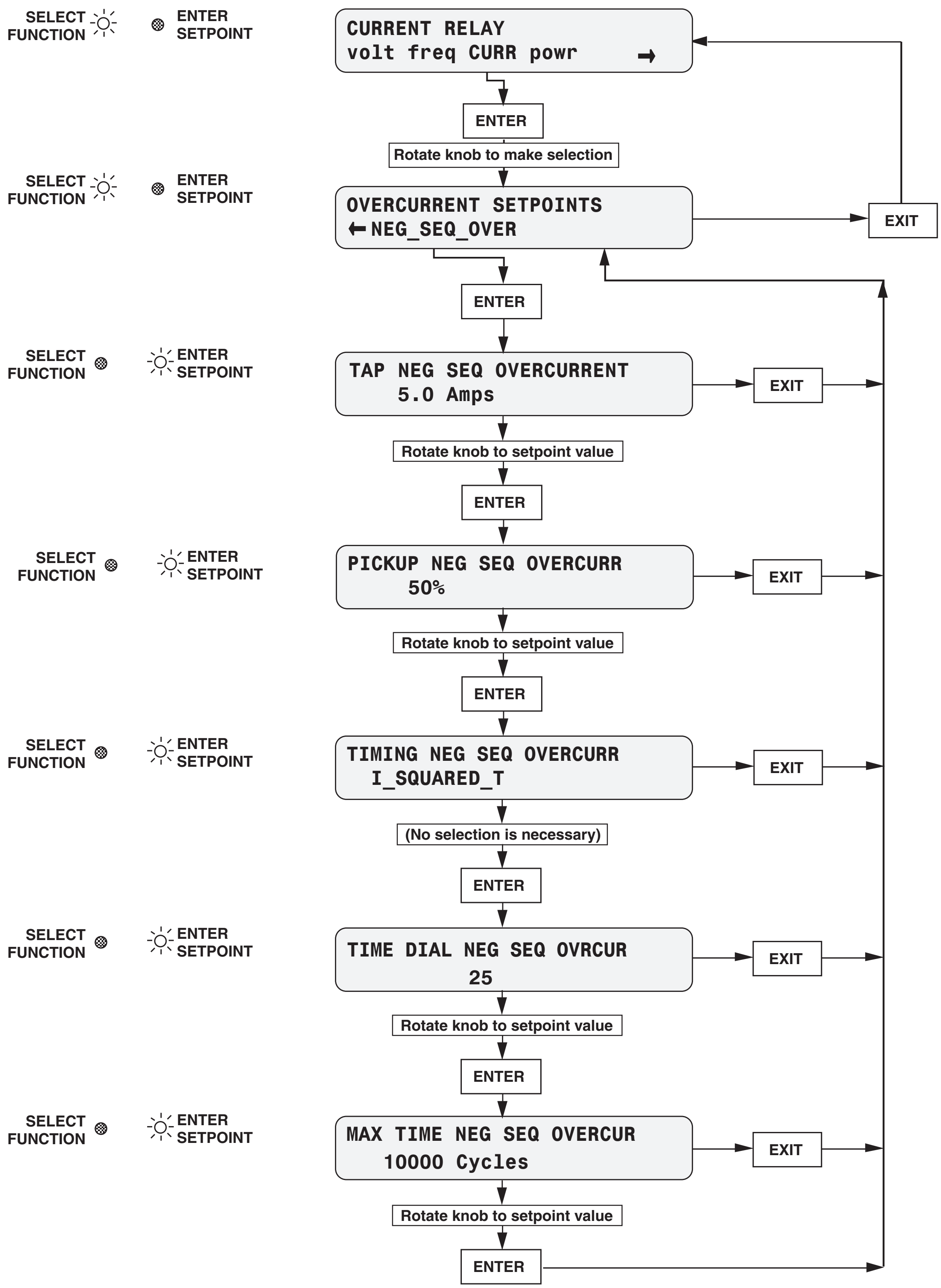


Figure 5-12   Current Relay: Negative Sequence Overcurrent (46)

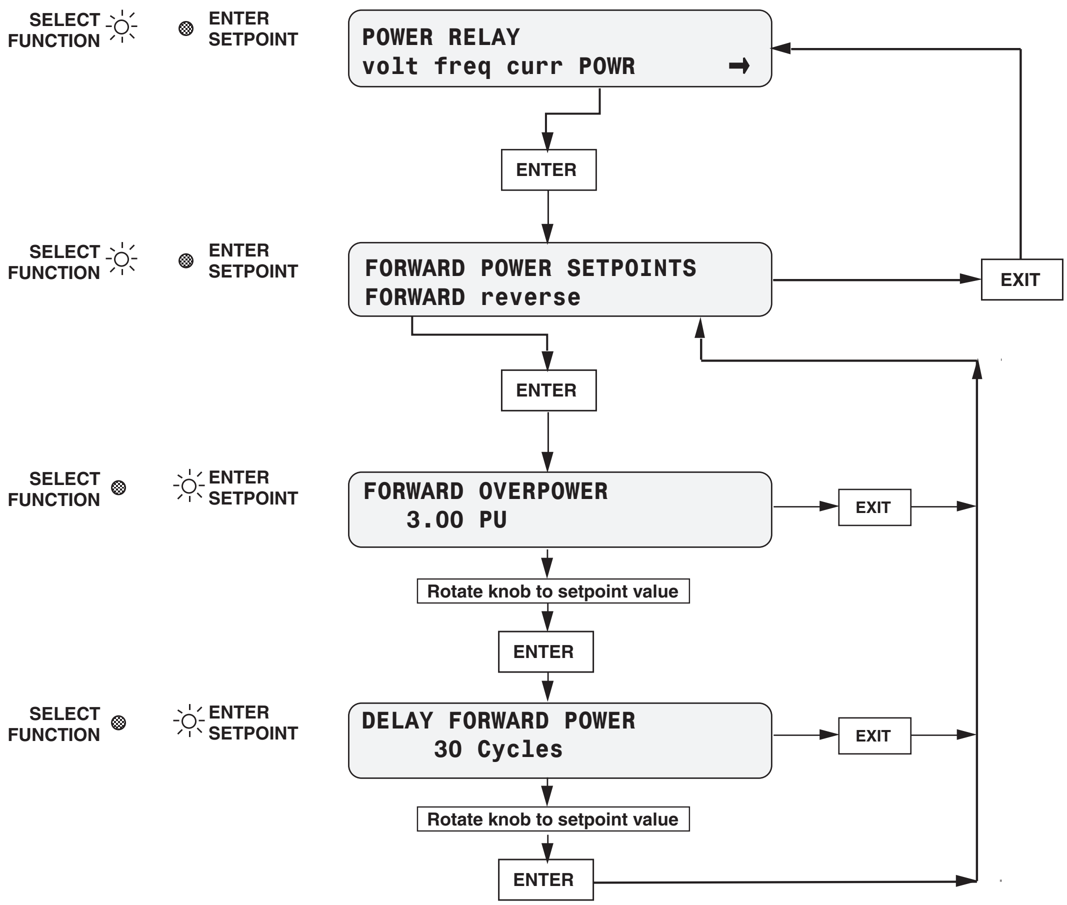


Figure 5-13 Power Relay: Forward Overpower (32F)

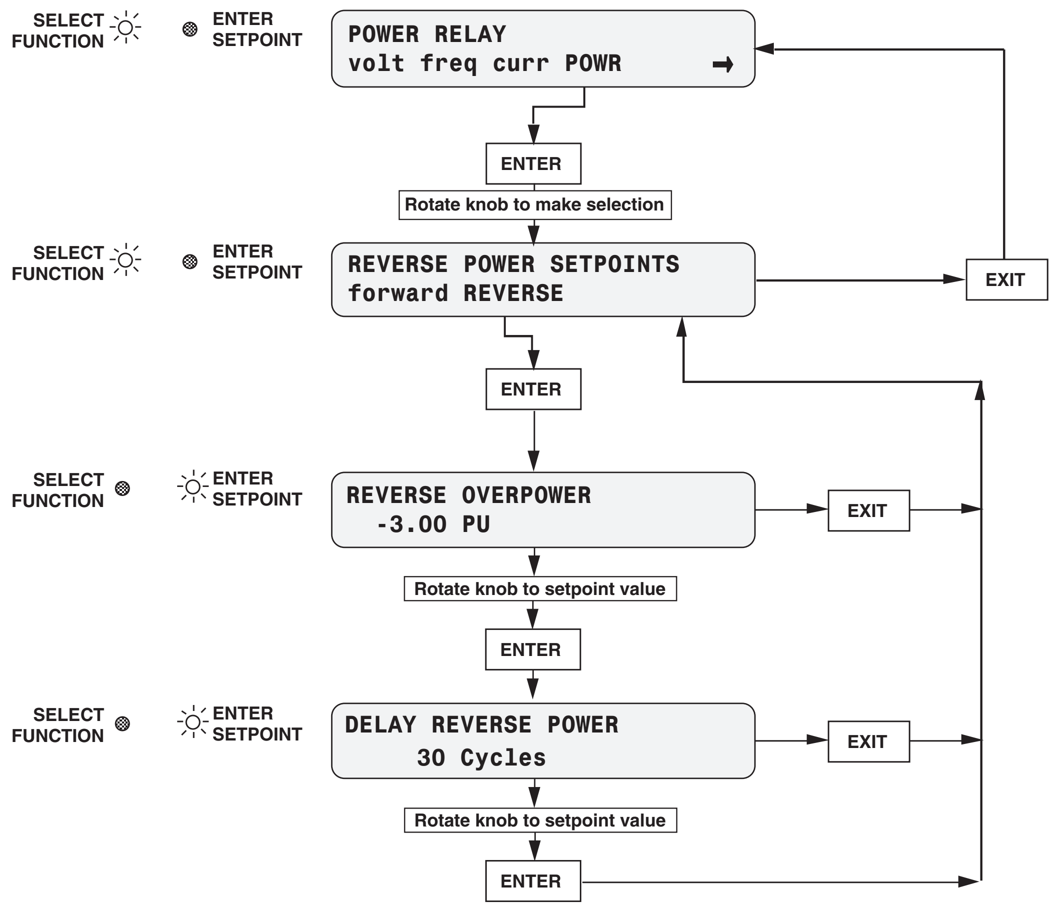


Figure 5-14 Power Relay: Reverse Overpower (32R)

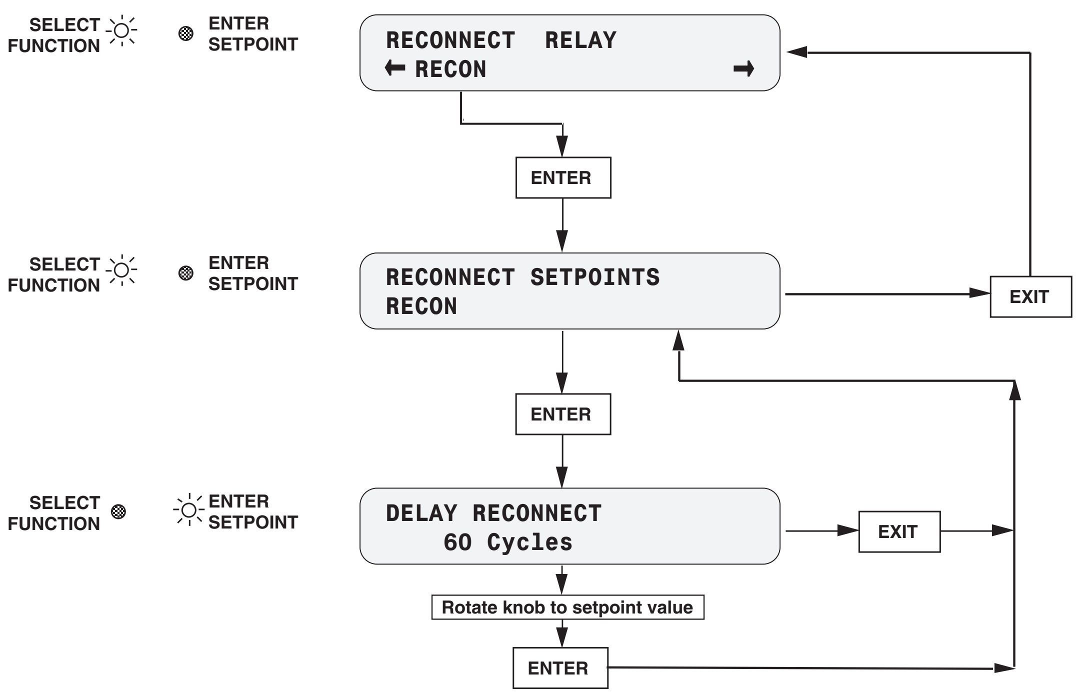


Figure 5-15 Reconnect Relay (79)

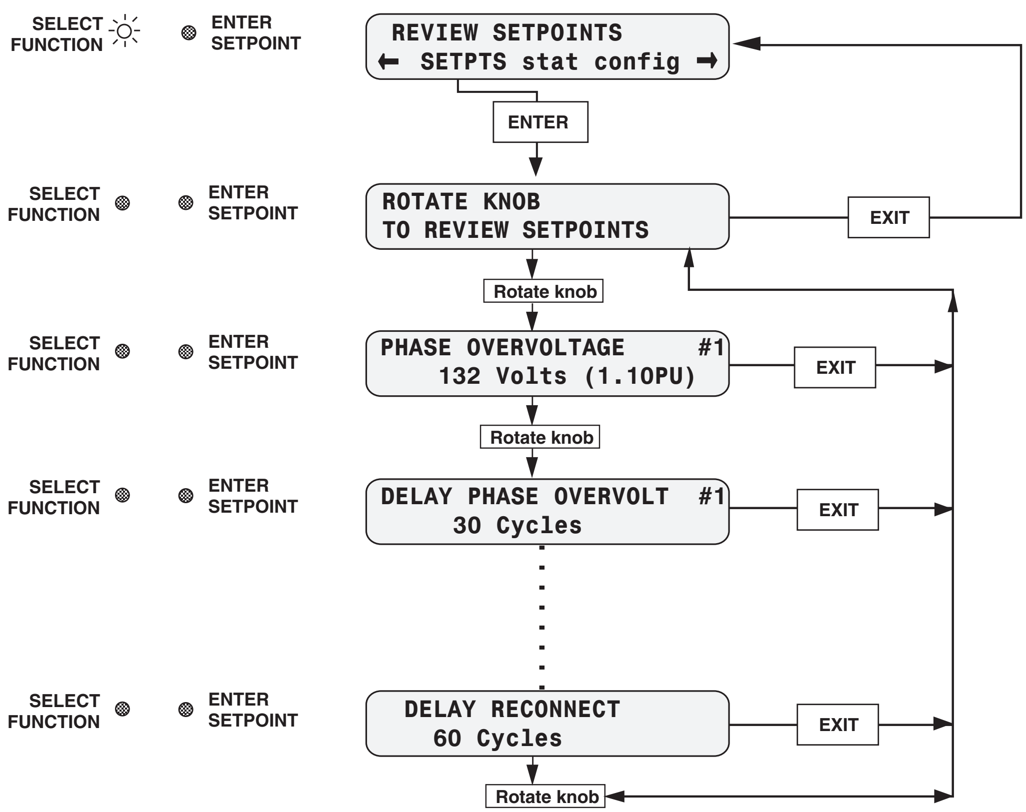


Figure 5-16 Review Setpoints

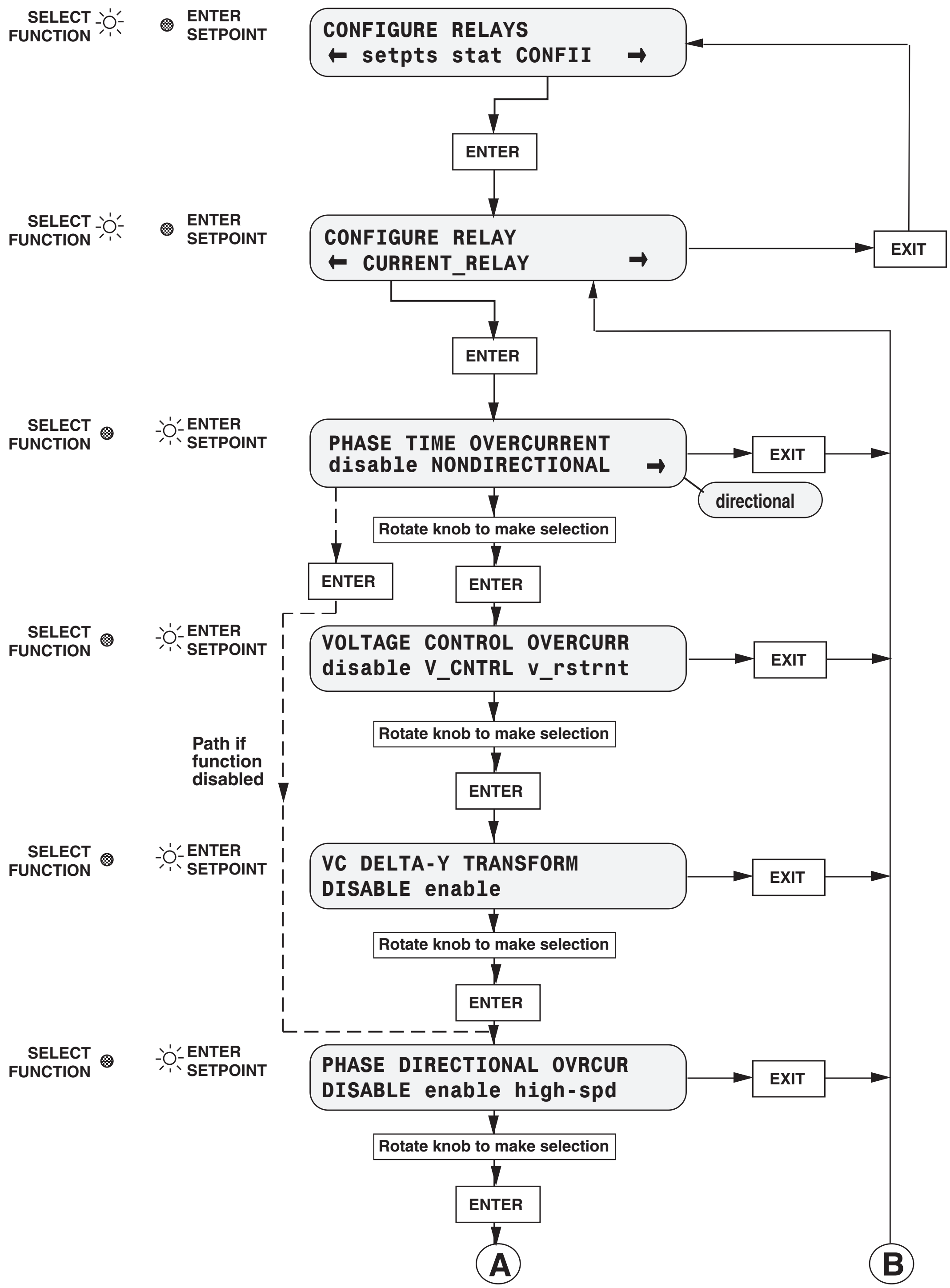


Figure 5-17 Configure Phase Overcurrent Relay–67 Enabled (Page 1 of 3)

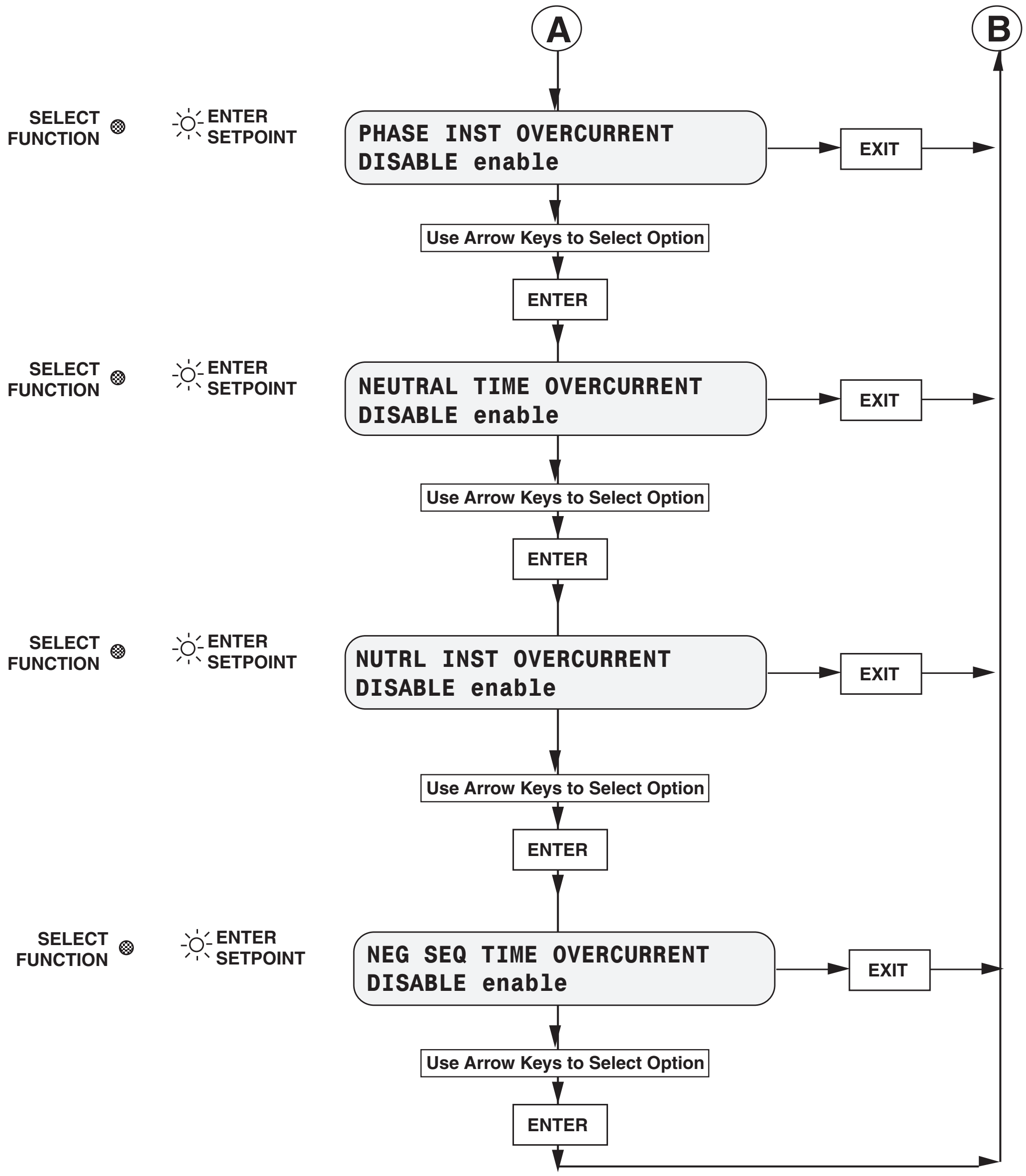


Figure 5-17 Configure Relays Phase Overcurrent Relay (Page 2 of 3)

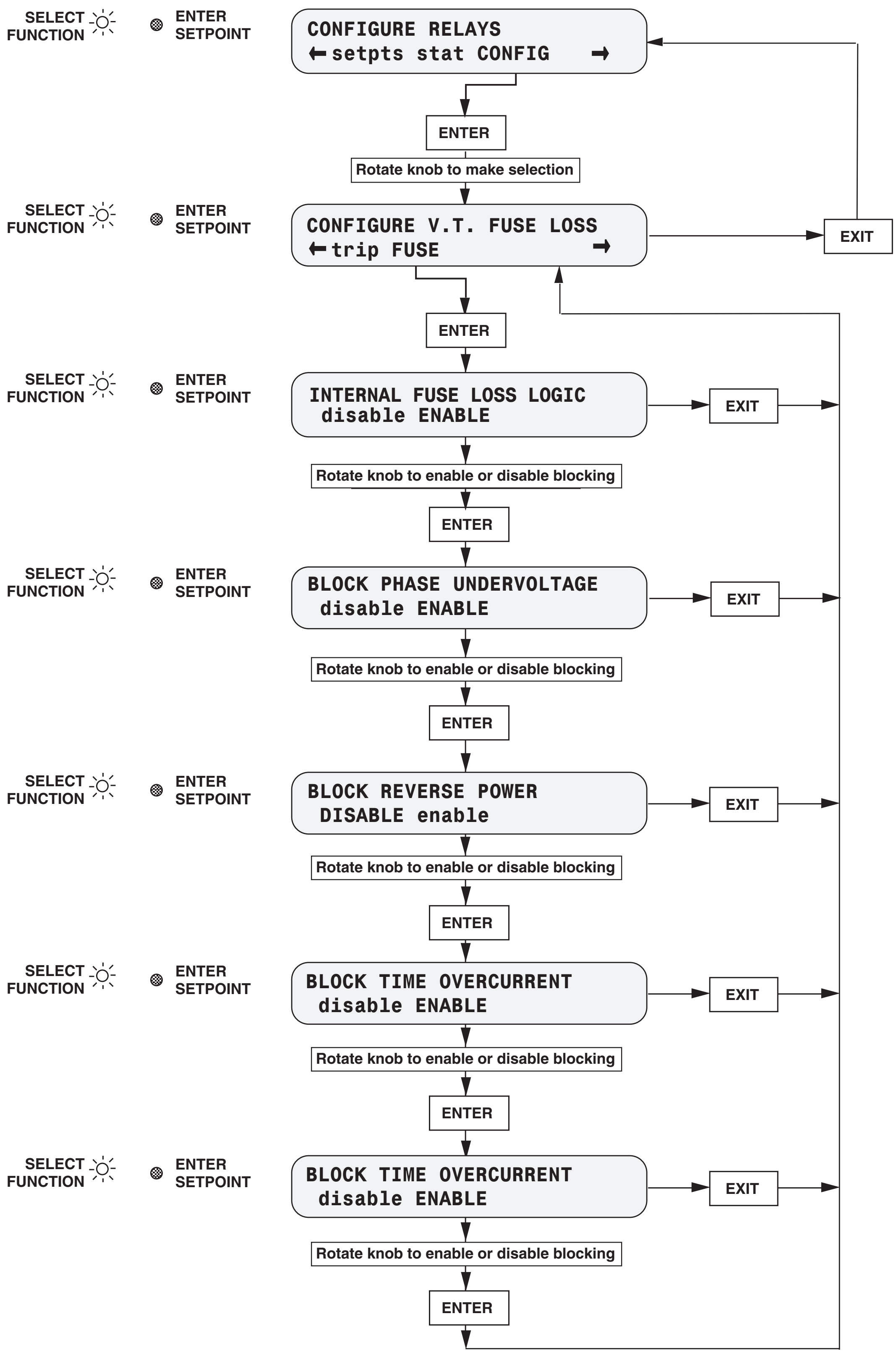


Figure 5-17 Configure Relays VT Fuse-Loss Blocking (Page 3 of 3)

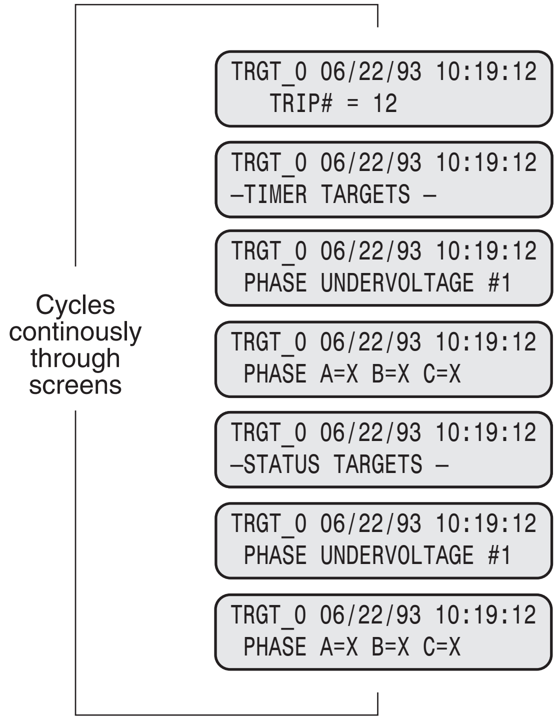


Figure 5-18 Example of Target History Screens

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6 Installation

6.1 Initial Setup Procedure 6–1

6.2 Commissioning Checkout 6–2

6.3 Dip Switches 6–4

6.4 Mechanical/Physical Dimensions 6–6

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6.1 Initial Setup Procedure

The M-0420 Multifunction Relay 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 relay, described in Chapter 3, **Front Panel Controls**, before you attempt the following procedure.

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

1. Connect power to the relay'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** button 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** button. 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 relay 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 button. 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 relay 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 relay 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.

6.2 Commissioning Checkout

During 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 ($V_{POS} \approx V_A \approx V_B \approx V_C$ or $V_{AB} \approx V_{BC} \approx V_{CA}$)

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=0.0 B=0.0 C=0.0
```

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.

6.3 DIP Switches

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

■ **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.

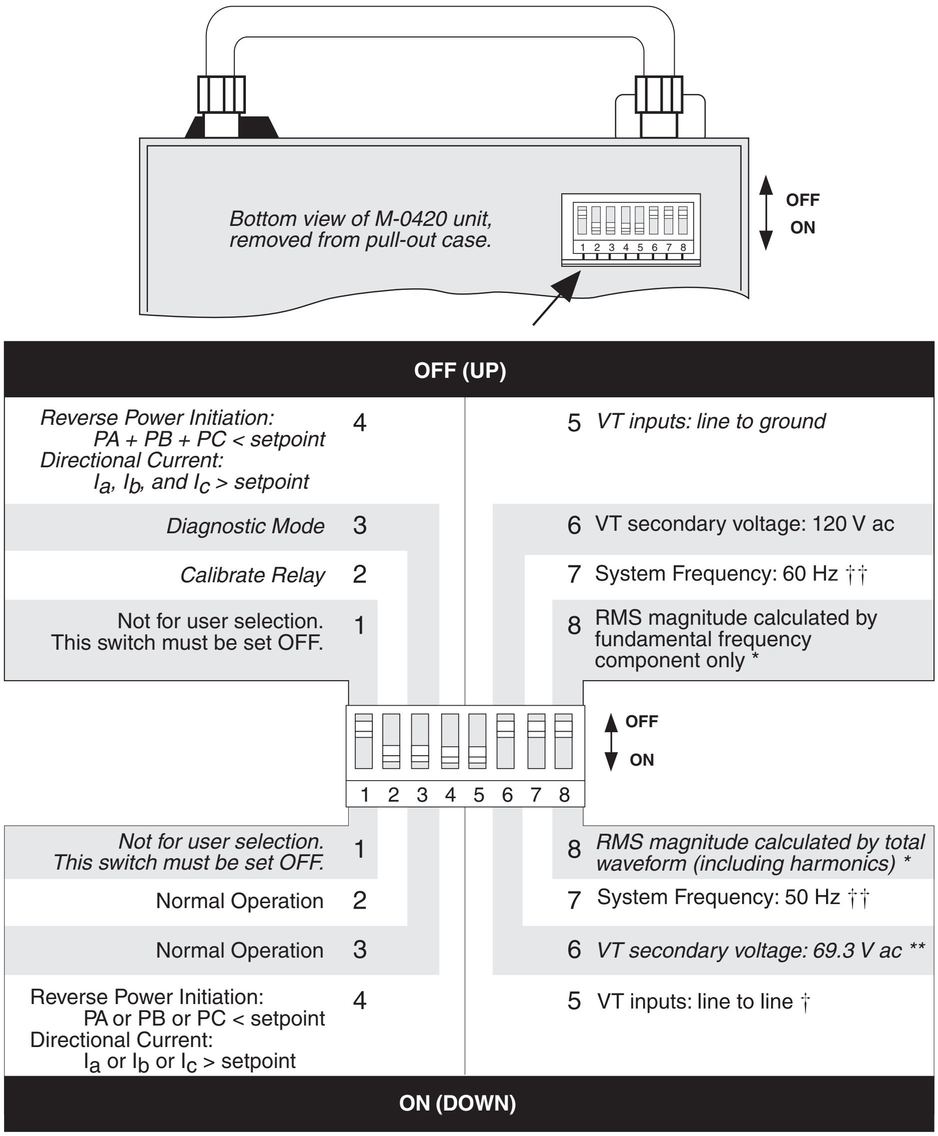
■ **NOTE**: Significant force is required to remove and replace the unit in its housing.

Switch	Description	ON (down)	OFF (up)
1	Not for user selection. This switch must be set **off**.		
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	I_a or I_b or I_c > setpoint	I_a, I_b, and I_c > 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	50 Hz	60 Hz
8	Basis for RMS Magnitude of Voltage and Current	Total Waveform** (including harmonics)	Fundamental Frequency component only

* When the 69.3 Vac 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.

6.4 Mechanical/Physical Dimensions

The M-0420 Multifunction Relay 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.

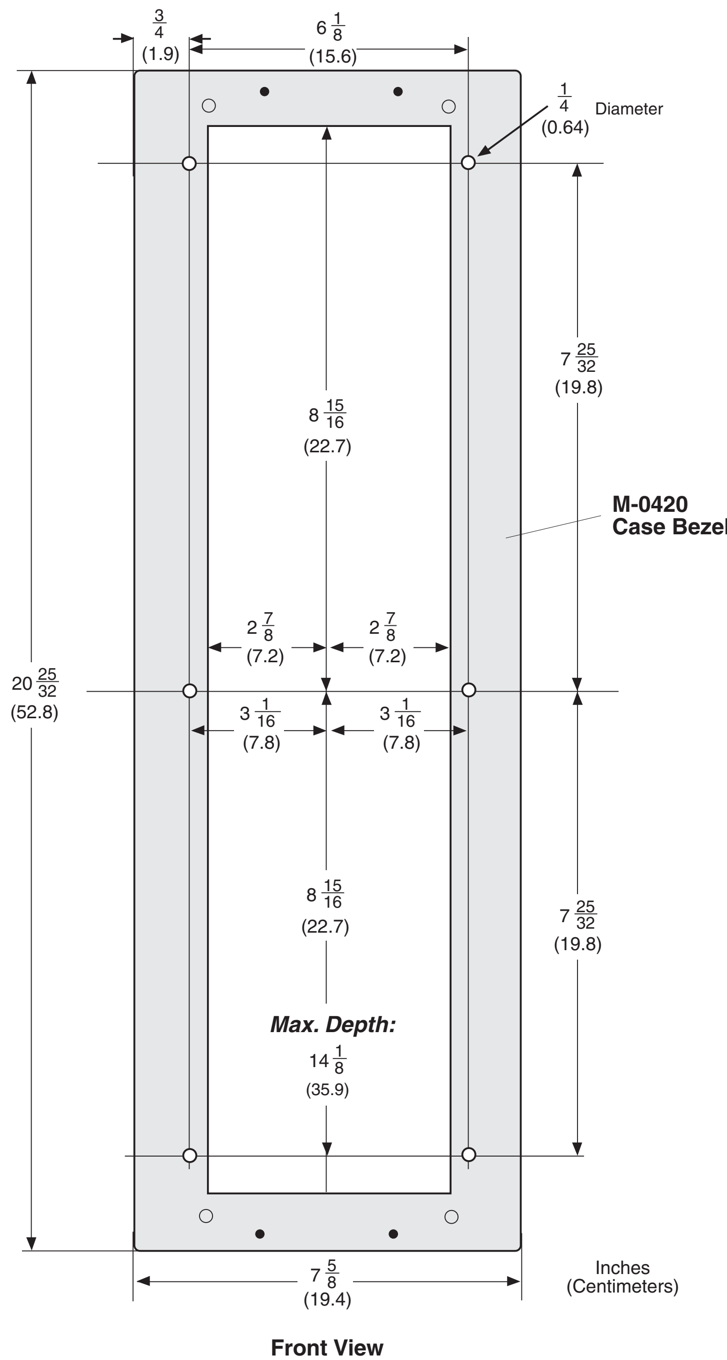


Figure 6-2 Mounting Dimensions for GE L-2 Cabinet

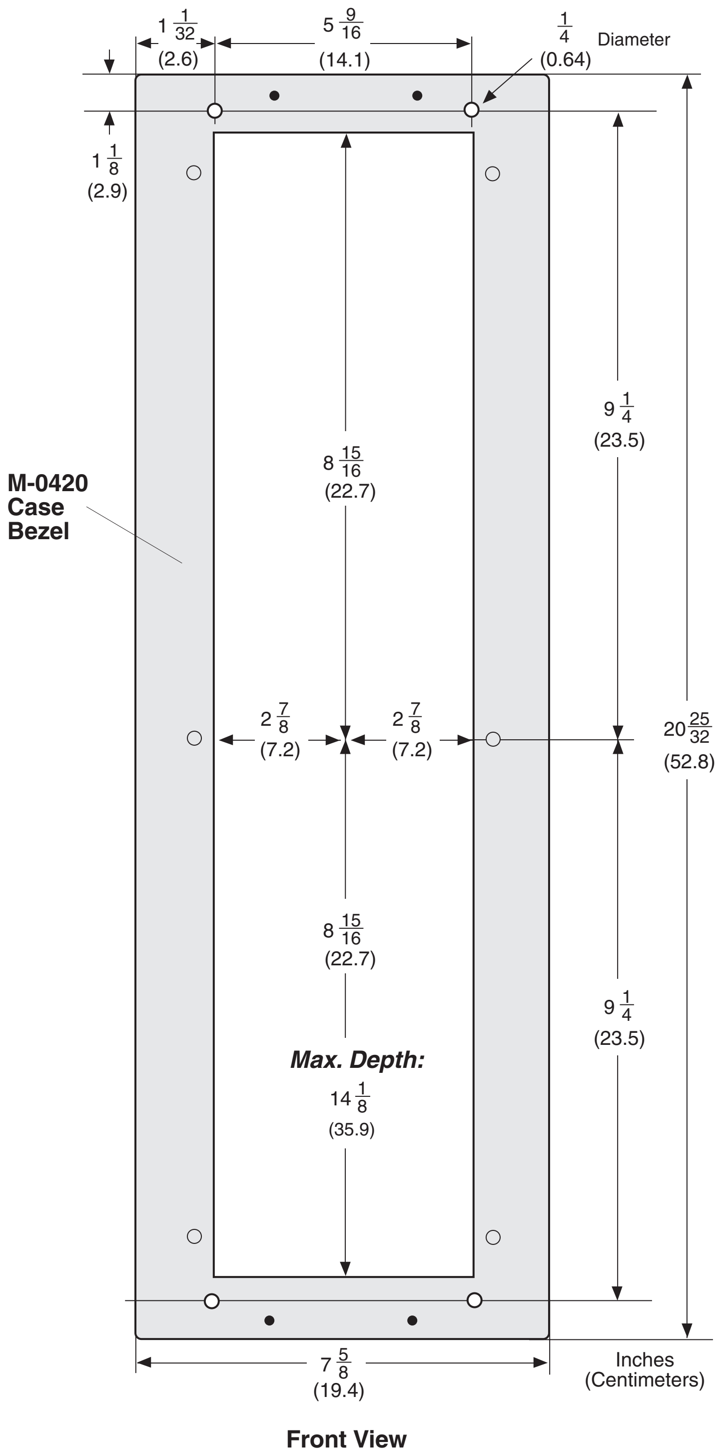
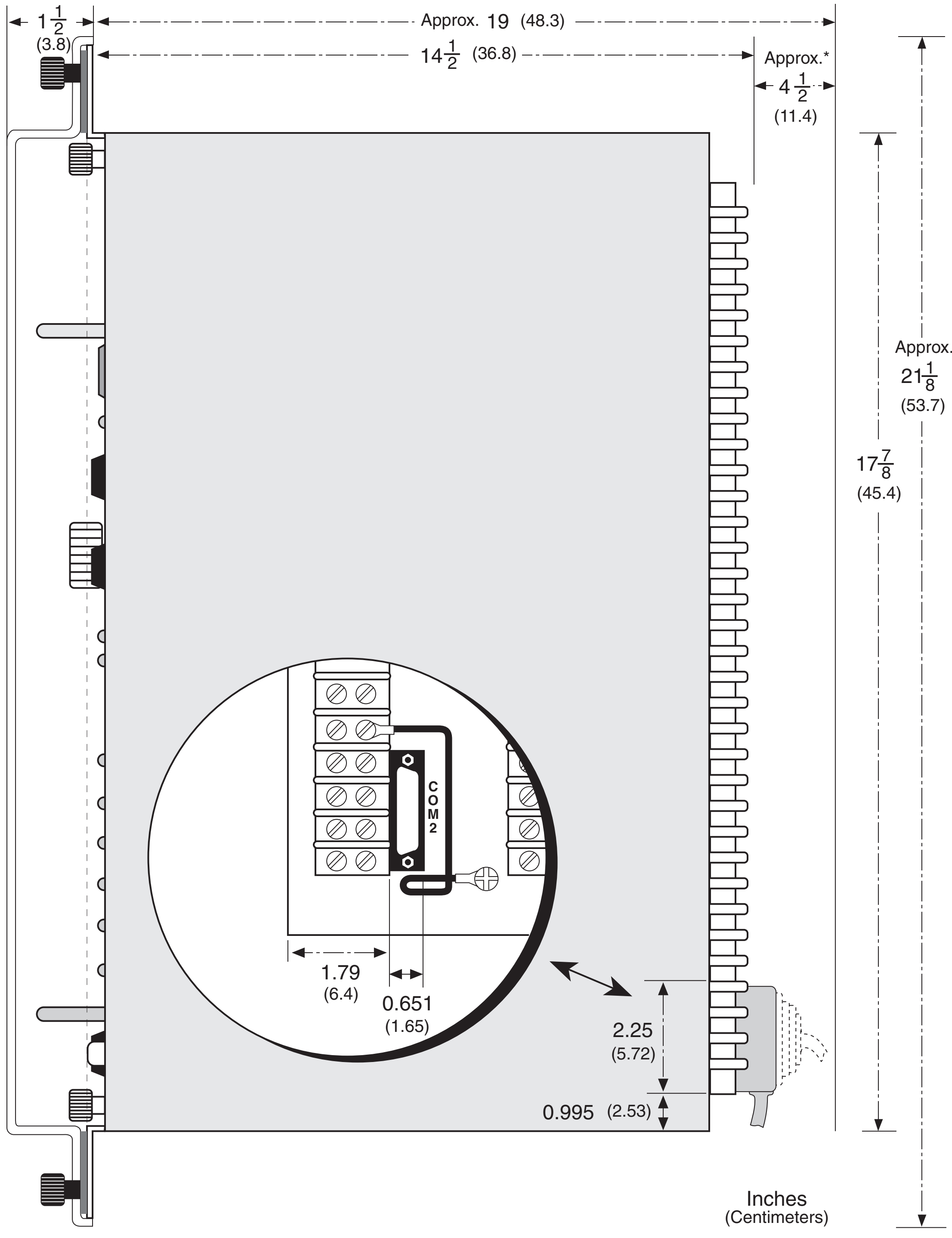
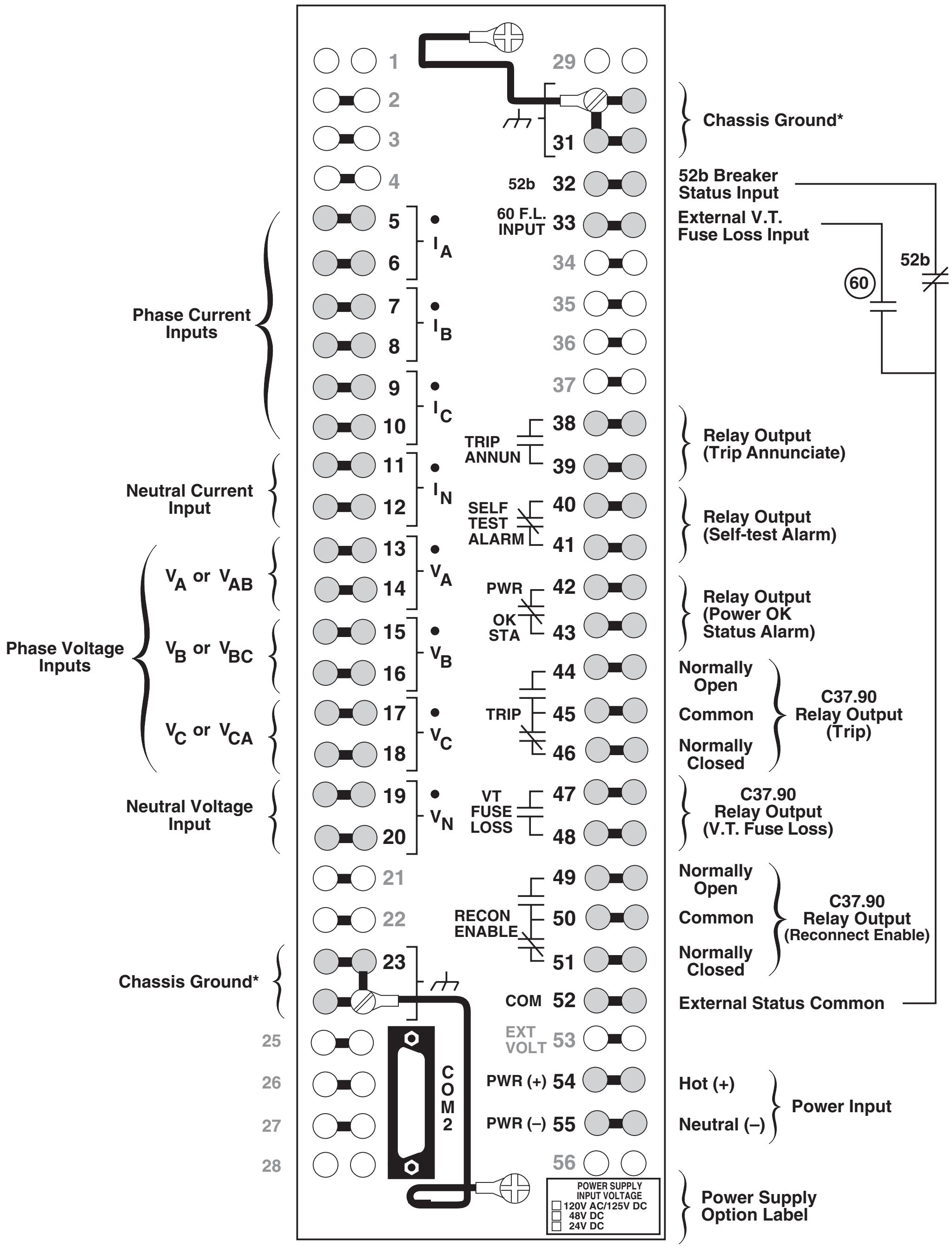


Figure 6-3 Mounting Dimensions for Westinghouse FT-41 Cabinet



■ **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



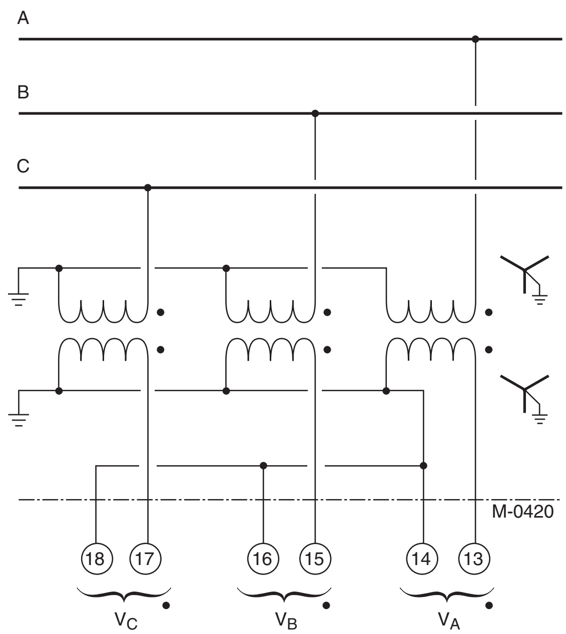
*▲ **CAUTION**: Always connect both locations (terminals 23 and 31) to external chassis ground.

■ **NOTES:**

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

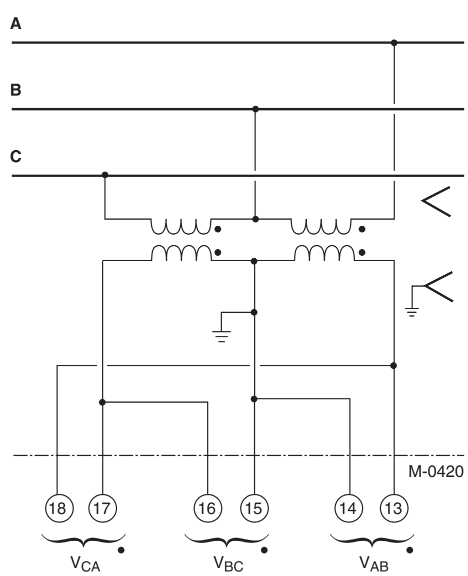
Figure 6-5 External Connections

6.5 Suggested VT Connections



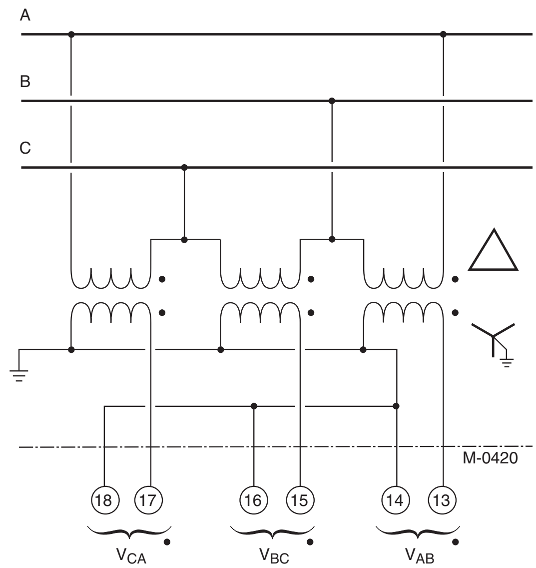
■ **NOTE**: On the internal configuration DIP switch, select line-to-ground for basic VT input and either 69.3 V ac or 120 V ac for VT secondary voltage.

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

6.6 UL-LISTED TERMINAL BLOCK CONNECTIONS

Serial Numbers 145 and above 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.

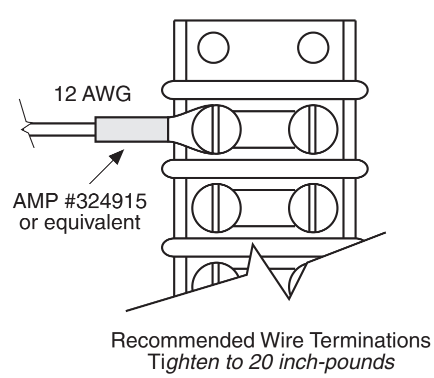


Figure 6-9 Wire Terminations for External Connections as Required for UL Listing

7 Test Procedures

7.1 Introduction 7–1

7.2 Unit Setup 7–1

7.3 Equipment Required 7–2

7.4 Test and Equipment Setup 7–2

7.5 Diagnostic Test Procedures 7–5

7.6 Self-Calibration Procedure 7–43

7.1 Introduction

This chapter presents step-by-step test procedures for each relay 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, buttons, 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).

7.2 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.

7.3 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.

7.4 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.

Function	Description	Magnitude	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**	106 V (0.90 PU)	30 Cycles
27N	**RMS Undervoltage, Neutral Circuit or Zero Sequence**	60 V (0.40 PU)	30 Cycles
81O	**Overfrequency**	60.50 Hz	30 Cycles
81U	**Underfrequency**	59.50 Hz	30 Cycles
50	**Instantaneous Overcurrent, 3-Phase**	10.0 A	
50N	**Instantaneous Overcurrent, Neutral**	10.0 A	
51V	**Inverse Time Overcurrent, 3-Phase, with Voltage Control and 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	
67	**Phase Directional Overcurrent (optional)**		
	Overcurrent Element		
	Magnitude	10.0 A	
	Time Delay	30 Cycles	
	Directional Element		
	Maximum Sensibility (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

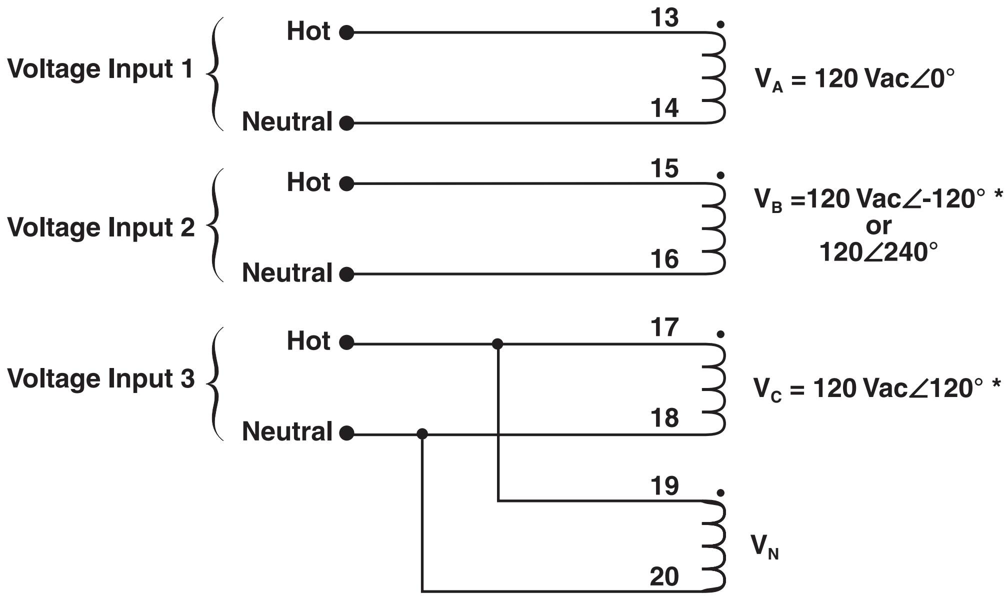


Figure 7-1 Voltage Input Configuration

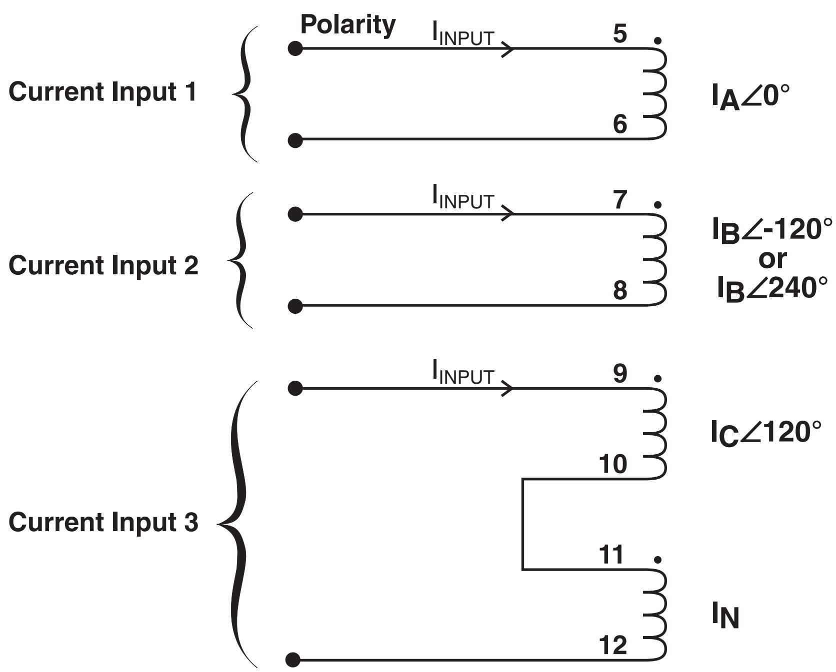


Figure 7-2 Current Input Configuration

*■ **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 Vac∠120° and V_C=120 Vac∠240°.

7.5 Diagnostic Test Procedures

The diagnostic procedures perform basic functional tests to verify the operation of the 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** button 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 button 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 buttons.

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 ∞ Ω.

   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 ∞Ω.

5. Use the right arrow button 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 ∞ Ω between terminals 44 and 45.

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

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

```
RELAY NUMBER
off ON
```

8. Use the left arrow button 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 ∞ Ω between terminals 44 and 45.

The normally closed output contacts should close: the DMM should read ∞ Ω 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.

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	60FL 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 INPUT led button→
```

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

```
INPUT NUMBER
1
```

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

```
INPUT 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	59N Neutral Overvoltage	10	51N Neutral Overcurrent
4	27N Neutral Undervoltage	11	50N Neutral Instantaneous Overcurrent
5	81 Overfrequency	12	46 Negative Sequence Overcurrent
6	81 Underfrequency	13	32 Directional Overpower
7	Fault Recorded	14	Breaker Closed

*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 lit continously (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 buttons. As each button 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/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** button 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 BACKLIT 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.

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

```
BACKLITE TEST
OFF on
```

5. Press the right arrow button to highlight **ON**. The unit should display

```
BACKLITE TEST
off ON
```

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

```
BACKLITE TEST
BACKLITE ON
```

   and the backlight should turn on.

7. 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 loopback 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 loopback 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 loopback 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

```
COM2 TEST
CONNECT LOOPBACK PLUG
```

3. Connect the loopback 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
←BBRAM 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
← bbram 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:

Cycles continously through screens

```
TRGT_0 06/22/93 10:19:12
   TRIP# = 12
```

```
TRGT_0 06/22/93 10:19:12
–TIMER TARGETS –
```

```
TRGT_0 06/22/93 10:19:12
 PHASE UNDERVOLTAGE #1
```

```
TRGT_0 06/22/93 10:19:12
 PHASE A=X B=X C=X
```

```
TRGT_0 06/22/93 10:19:12
–STATUS TARGETS –
```

```
TRGT_0 06/22/93 10:19:12
 PHASE UNDERVOLTAGE #1
```

```
TRGT_0 06/22/93 10:19:12
 PHASE A=X B=X C=X
```

■ **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 RELAY
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 (1.10 PU)
```

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

```
PHASE OVERVOLTAGE #1
126 Volts (1.05 PU)
```

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

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

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

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

59 RMS OVERVOLTAGE, 3-PHASE (CONT)

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 (1.05 PU)
```

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

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

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

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

—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
Functions 59, 59I	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

```
OVERVOLTAGE SETPOINTS
PHASE_OVER phase_under →
```

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

```
DELAY NEUTRAL 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 NEUTRAL OVERVOLT #1
1 Cycle
```

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 **59 N 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

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

59N RMS OVERVOLTAGE, NEUTRAL CIRCUIT OR ZERO SEQUENCE (CONT)

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 powr →
```

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 nutrl_under
```

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

```
DELAY NEUTRAL OVERVOLT #1
1 Cycle
```

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 NEUTRAL OVERVOLT #1
5 Cycles
```

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

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

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

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

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 1.10pu
(132 V rms for a sinusodial input)
Time Delay #1 1 cycle
Function 59 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

```
OVERVOLTAGE 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 Cycle
```

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

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

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 ±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

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

59I PEAK OVERVOLTAGE (CONT)

Time Delay Accuracy Test

Test Settings:

Magnitude #1	1.10 pu
(132 V rms for a sinusodial input)	
Time Delay #1	5 cycles
Function 59	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 Cycle
```

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

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

15. Increase the input voltage on Phase A to 136 V ac and start timing. The unit should trip after 5 cycles ±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

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

—END—

27 RMS UNDERVOLTAGE, 3-PHASE

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 (.90 PU)
```

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 Cycle
```

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

```
BECKWITH ELECTRIC CO.
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

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

27 RMS UNDERVOLTAGE, 3-PHASE (CONT)

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 (.90 PU)
```

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
300 Cycles
```

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

```
BECKWITH ELECTRIC CO.
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

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

—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	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

```
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 (.50 PU)
```

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

```
DELAY NEUTRAL UNDERVOLT#1
30 Cycles
```

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

```
DELAY NEUTRAL UNDERVOLT#1
1 Cycle
```

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

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

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.

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

27N RMS UNDERVOLTAGE, NEUTRAL CIRCUIT OR ZERO SEQUENCE (CONT)

Time Delay Accuracy Test

Test Settings:

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

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

```
NEUTRAL UNDERVOLTAGE #1
60 Volts (.50 PU)
```

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

```
DELAY NEUTRAL UNDERVOLT#1
30 Cycles
```

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

```
DELAY NEUTRAL UNDERVOLT#1
5 Cycles
```

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

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

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

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

—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 ∞ Ω (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 0.00 Ω (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 ∞ Ω (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—

81O OVER FREQUENCY

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

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

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

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

Time Delay Accuracy Test

Test Settings:

Magnitude #1	60.50 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** until the unit displays

```
DELAY OVERFREQUENCY #1
2 Cycles
```

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

```
DELAY OVERFREQUENCY #1
30 Cycles
```

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

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

13. Rapidly increase the frequency of the three-phase test set to 61.00 Hz and start timing. The unit should trip after 30 cycles ±1 cycle time delay.
14. The **81 OVERFREQUENCY** LED should turn on and the unit should rotate displays

```
-TRGT- 06/22/93 10:19:12
Trip# = 13
```

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

15. Set the frequency to 60.00 Hz.
16. Press **TARGET RESET/LAMP TEST**. The **81 OVERFREQUENCY** LED should turn off. The unit should display

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

—END—

81U UNDER FREQUENCY

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 button, and then **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 **ENTER** until the unit displays

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

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
UNDERFREQUENCY #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

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

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 button, and then **ENTER** until the unit displays

```
DELAY OVERFREQUENCY #1
2 Cycles
```

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

```
DELAY OVERFREQUENCY #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 **81 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 **81 UNDERFREQUENCY** LED should turn off. The unit should display

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

—END—

50 INSTANTANEOUS OVERCURRENT, 3-PHASE

Magnitude Accuracy Test

TEST SETTINGS:

Magnitude #1	9 A
Function 46	Disable
Function 51	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
10.0 Amps
```

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

4. Turn the knob counterclockwise until the unit displays

```
PHASE INST OVERCURRENT
9.0 Amps
```

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

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

6. Slowly increase the current on Phase A until the relay trips. The unit should trip at 9.00 A ±0.27 A.
7. The **50 INSTANTANEOUS OVERCURRENT** LED should turn on and the unit should rotate displays

```
-TRGT- 06/22/93 10:19:12
Trip# = 16
```

```
-TRGT- 06/22/93 10:19:12
PHASE INST. OVERCURRENT
```

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

8. Reduce the input current to 8.50 A.
9. Press **TARGET RESET/LAMP TEST**. The **50 INSTANTANEOUS OVERCURRENT** LED should turn off. The unit should display

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

–END–

Time Delay Accuracy Test

TEST SETTINGS:

Magnitude #1	9 A
Function 46	Disable
Function 51	Disable

10. Increase the current input on Phase A rapidly to 9.50 A. The unit should trip instantaneously (2 cycles).
11. The **50 INSTANTANEOUS OVERCURRENT** LED should turn on and the unit should rotate displays

```
-TRGT- 06/22/93 10:19:12
Trip# = 17
```

```
-TRGT- 06/22/93 10:19:12
PHASE INST. OVERCURRENT
```

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

12. Reduce the input current to 0.00 A.
13. Press **TARGET RESET/LAMP TEST**. The **50 INSTANTANEOUS OVERCURRENT** LED should turn off. The unit should display

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

—END—

50N INSTANTANEOUS OVERCURRENT, NEUTRAL

Magnitude Accuracy Test

TEST SETTINGS:

Magnitude #1	9 A
Function 46	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 ntrl_over→
```

6. Turn the knob clockwise until the unit displays

```
OVERCURRENT SETPOINTS
phase_over NTRL_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

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

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

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

50N INSTANTANEOUS OVERCURRENT, NEUTRAL (CONT)

Time Delay Accuracy Test

TEST SETTINGS:

Magnitude #1	9 A
Function 46	Disable

14. Rapidly increase the current on Phase C to 9.50 A. The unit should trip instantaneously (2 cycles).
15. **50N INSTANTANEOUS OVERCURRENT** LED should turn on and the unit should rotate displays

```
-TRGT- 06/22/93 10:19:12
Trip# = 17
```

```
-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

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

—END—

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 ntrl_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

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

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

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

51 INVERSE TIME OVERCURRENT, 3-PHASE (CONT)

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=X B=  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

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

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=X B=  C=
```

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

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

—END—

51VC INVERSE TIME OVERCURRENT WITH VOLTAGE CONTROL, 3-PHASE

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 O/C	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 nutrl_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 →
```

51VC INVERSE TIME OVERCURRENT WITH VOLTAGE CONTROL, 3-PHASE (CONT)

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_CNTRL v_rstrnt
```

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

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

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=  C=
```

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

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

—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 nutrl_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**. The unit should display

```
TIMING PHASE OVERCURRENT
DEF inv vinv einv
```

7. Turn the knob clockwise until the unit displays

```
TIMING PHASE OVERCURRENT
def inv VINV einv
```

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 display shows 5.0.

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

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

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
```

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

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_rstnt
```

21. Turn the knob clockwise until the unit displays

```
VOLTAGE CONTROL OVERCURR
disable v_cntl V_RSTNT
```

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

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

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 ±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

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

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 ±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

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

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 ±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

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

—END—

51N INVERSE TIME OVERCURRENT, NEUTRAL

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 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 nutrl_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 nutrl_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
1.0 Amps
```

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

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

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 **51N 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 **51N OVERCURRENT** LED should turn off. The unit should display

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

—END—

46 NEGATIVE SEQUENCE OVERCURRENT

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	Enable

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 **STAT**. The unit should display

```
MONITOR STATUS
← setpts STAT config →
```

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

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

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

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

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°, I_B=5A –180°, I_C=5A –0°. 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

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

9. Timing Accuracy Calculations

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 A

   $I_2 = I_2'$/Tapsetting = 10/5 = 2,

   where I_2 = Negative Sequence Current in multiples of the tap setting.

   $K = I_2^2t$

   $t = k/I_2^2 = 25/(2)^2 = 25/4 = 6.25$ sec.

   Input Current Setting = 10(3/2) = 15 A, for example: I_A=15A –0°, I_B=15A –180°, I_C=15A –0°.

10. Set the input current to 15.00 A and start timing. The unit should trip after 6.25 ±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

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

■ **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—

67 PHASE DIRECTIONAL OVERCURRENT

Time Delay Accuracy Test
TEST SETTINGS:

Angle Dir Element (MSA) 0°	
Pickup	5 A
Delay	30 Cycles
Tap Neutral	
Overcurrent	10 A
Function 51V,46	Disable
Function 67	Enable

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

```
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 nutrl_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
PHASE_OVER nutrl_over→
```

67 PHASE DIRECTIONAL OVERCURRENT (CONT)

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

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

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

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

24. Set the phase angle between the voltage and current inputs to 180°:

    V_A=120Vac∠0°; V_B=120Vac∠240°; V_C=120Vac∠120°;

    I_A=6A ∠180°, I_B=6A –60°, I_C=6A ∠300°.

    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

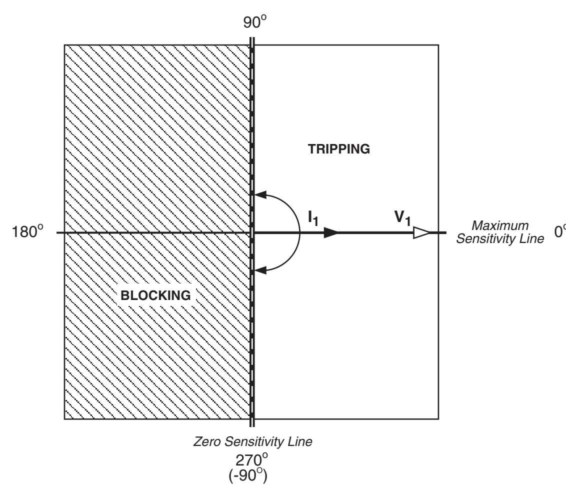
```
-TRGT- 06/22/93 10:19:12
Trip# = 28
```

```
-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

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

28. The tripping and blocking regions of the directional elements are shown in the following figure.



–END–

32F DIRECTIONAL POWER, FORWARD POWER, 3-PHASE

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 POWR →
```

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 Cycle
```

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

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

6. Slowly increase the input current until the relay trips. The unit should trip at 15A ±0.1A.
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

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

–END–

32F DIRECTIONAL POWER, FORWARD POWER, 3-PHASE (CONT.)

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 POWR →
```

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

```
DELAY FORWARD POWER
1 Cycle
```

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

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

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

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

—END—

32R DIRECTIONAL POWER, REVERSE POWER, 3-PHASE

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 powr →
```

2. Turn the knob clockwise until the unit displays

```
POWER RELAY
volt freq curr POWR →
```

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 Cycle
```

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

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

8. Set the phase angle between the voltage and current inputs to 180°:

   V_A=120Vac∠0°; V_B=120Vac∠240°; V_C=120Vac∠120°;

   I_A=2A∠180°, I_B=2A∠60°, I_C=2A∠300°.

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

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

–END–

32R DIRECTIONAL POWER, REVERSE POWER, 3-PHASE (CONT.)

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 Cycle
```

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

```
BECKWITH ELECTRIC CO.
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—

7. 6 Self-Calibration Procedure

The M-0420 Multifunction Relay has been fully calibrated at the factory. There is no need to recalibrate 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:

- Two digital multimeters (DMM) with 10 A current range.
- A source of 24 V dc, 48 V dc, 125 V dc, and 120 V ac conforming to the power input specifications.
- A source of variable ac voltage from zero to 240 V ac.
- A source of variable current from zero to 20 amperes.

*The Doble, AVO, and PowerTec family of test equipment may be used.

Test Setup

1 Disconnect system power (if connected) and pull the unit out of its housing.

2. Set DIP switch 2 (see Figure 6-1) to OFF (up). For self-calibration, all DIP switches should be OFF except for switch 3.

3. Place the unit back in the case and verify that the unit assembly is secured properly to the housing.

4. Connect and configure the voltage inputs (V_A, V_B, V_C and V_N) according to Figure 7-3.

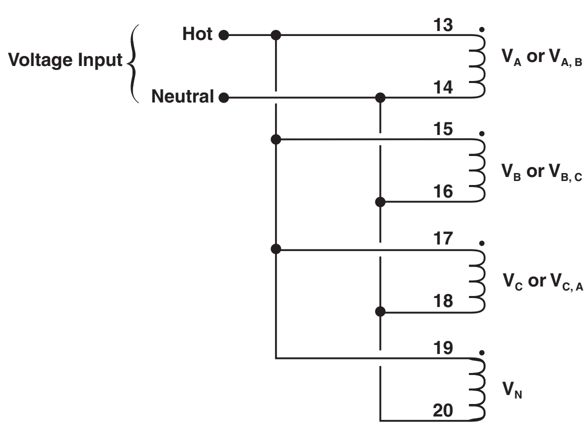


Figure 7-3 Single-Phase Voltage Input Configuration for Calibration

5. Connect and configure the current inputs (I_A, I_B, I_C and I_N) according to Figure 7-4.

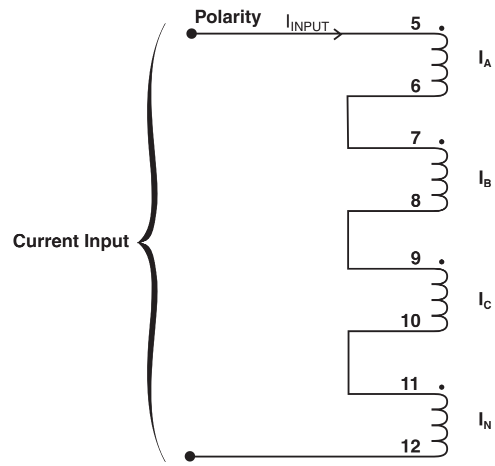


Figure 7-4 Single-Phase Current Input Configuration for Calibration

6. Verify that the system power supply's rating meets specification requirements, and connect it to terminals 54 and 55.

7. 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.

8. 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.

9. Connect a DMM to measure the test equipment output voltage.

10. Connect a DMM to measure the test equipment output current.

Calibration Procedure

1. Apply nominal system power to the unit on terminals 54 and 55.
2. The unit will turn on and display the following:

```
CALIBRATION MODE
```

```
CONNECT REFERENCE INPUTS
PRESS ENTER TO RECAL
```

3. Apply 120 V ac test input voltage to terminals 13 (hot) and 14 (neutral).
4. Apply 5 A current input to terminals 5 (polarity) and 12.
5. 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 -
```

6. Press **EXIT**. The unit will display

```
RETURN CAL MOD DIP SW
PRESS ANY KEY TO RESTART
```

7. Turn off the test voltage and current, and the system power.
8. Pull the unit from its case.
9. Set DIP switch 2 to **ON** (down), and verify that the other switches are in the correct positions for your application.
10. Put the unit back in its case and make sure that the connections are seated properly.
11. Apply system power and the test voltage and current.
12. 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 Vac

    Negative Sequence Voltage: 0.0 Vac

    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

13. Disconnect power from the unit.
14. Remove test input wiring and measurement leads.

–END–

8 Design Changes

8.1 Introduction 8–1
8.2 Host Processor Software Versions 8–1

8.1 Introduction

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 The first four numbers after the "V" constitute the DSP Software Version Number, and the last two numbers constitute the Host Processor Software Version Number

8.2 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.

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 (51VR)
- Delta-Y Transform (51VC/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 ECO 955

- 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.

D-0020V04.04-32 ECO 1032 & 1125

- Improved power-up self test sequence
- Added more point reads for BECOCOM® communication.
- Reduced the occurrence of Error 23 (Checksum Error EEPROM0) and Error 49 (Failure of DSP to enter run mode).

A Theory of Operation

A.1 Introduction A–1

A.2 System Block Diagram A–2

A.3 Discrete Fourier Transform A–3

A.4 Acknowledgments A–7

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A.1 Introduction

One early presumption in the design of the M-0420 Multifunction Relay was that the pursued approach would 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.

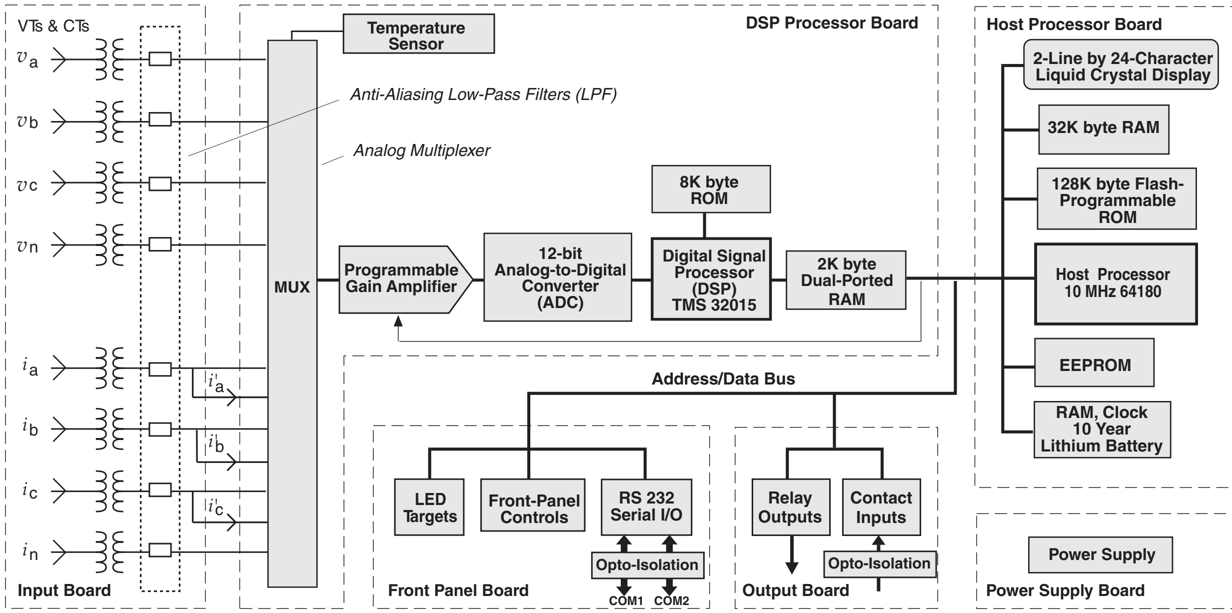

Figure A-1 System Block Diagram

A.2 System Block Diagram

As shown in Figure A-1, the inputs to the relay, 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.

A.3 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 Multifunction Relay 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_o = 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 (Zr_k) and imaginary (Zi_k) components of the complex phasor ($\overline{Z}$) are as follows:

$$Z_{r_k} = \frac{2}{N} \sum_{r=0}^{N-1} Z_{k-r} \cos \frac{2\pi r}{N}$$

$$Z_{i_k} = \frac{2}{N} \sum_{r=0}^{N-1} Z_{k-r} \sin \frac{2\pi r}{N} \qquad (1)$$

where $z_{-1}, z_{-2}, \ldots z_{-(N-1)}$ 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:

$$Z_{r_k} = Z_{r_{k-1}} + \frac{2}{N} (Z_k - Z_{k-N}) \cos \frac{2\pi k}{N}$$

$$Z_{i_k} = Z_{i_{k-1}} + \frac{2}{N} (Z_k - Z_{k-N}) \sin \frac{2\pi k}{N} \qquad (2)$$

where $z_{-1}, z_{-2}, \ldots z_{-N}$ 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 $|\overline{Z}|$ and phase angle (θ) of the phasor can be obtained as follows:

$$|\overline{Z}| = \sqrt{Z_r^2 + Z_i^2} \text{ and } \theta = \tan^{-1} (Z_i/Z_r) \qquad (3)$$

The peak Z_{1_p} and rms value $Z_{1_{rms}}$ of the fundamental frequency component are given by:

$$Z_{1p} = |Z| \text{ and } Z_{1rms} = \frac{|Z|}{\sqrt{2}} \qquad (4)$$

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.

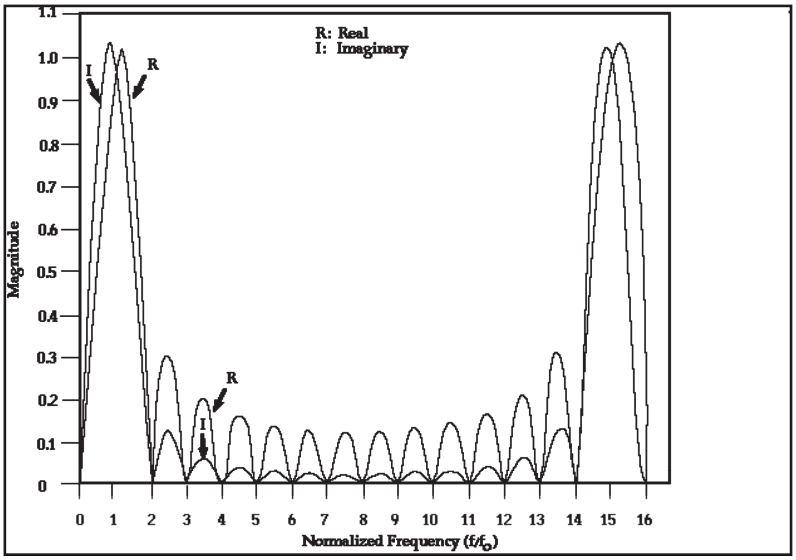

Figure A-2 Frequency Response of the DFT Algorithm

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 nth 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:

$$\begin{bmatrix} Z'_{r_n} \\ Z'_{i_n} \end{bmatrix} = \begin{bmatrix} \cos(-(n-1)\Delta\theta) & \sin(-(n-1)\Delta\theta) \\ -\sin(-(n-1)\Delta\theta) & \cos(-(n-1)\Delta\theta) \end{bmatrix} \begin{bmatrix} Z_{r_n} \\ Z_{i_n} \end{bmatrix}, \ n = 2,3....9 \qquad (5)$$

where $z_{r_n} + jz_{i_n}$ is the original phasor and $z'_{r_n} + jz'_{i_n}$ 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:

$$Z_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} z^2(t)dt} \qquad (6)$$

In discrete form, the rms value of a sampled signal, z_k, can be obtained as:

$$Z_{rms_k} = \sqrt{\frac{1}{N} \sum_{r=0}^{N-1} z^2_{k-r}} \qquad (7)$$

where $z_{-1}, z_{-2},...z_{-(N-1)} = 0$.

The quantity Z_{rms_k} represents the rms value of the entire signal considering dc, fundamental and up to the nth 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:

$$Z'_{rms_k} = Z'_{rms_{k-1}} + z_k^2 - z_{k-N}^2 \qquad (8)$$

where: $Z'_{rms_{-1}} = 0$ and $z_{-1}, z_{-2}, \ldots z_{-N} = 0$

Now the rms value is given by:

$$Z_{rms_k} = \sqrt{\frac{Z'_{rms_k}}{N}} \qquad (9)$$

Instantaneous Peak Voltage

Instantaneous peak value (Z_p) of a sampled signal z_k can be calculated as follows:

$$Z_p = \text{Max. of} \left[Z_{k-r} \right]_{r=0}^{N-1} \qquad (10)$$

where $z_{-1}, z_{-2}, \ldots z_{-(-N-1)} = 0$.

The value Z_p should be distinguished from the value Z_{1_p}. The value Z_p is the instantaneous peak value of the unfiltered signal whereas Z_{1_p} 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:

$$\theta_k \approx \theta_{k-1} + \frac{\Delta f \, 2\pi}{f_0 N} \qquad (11)$$

and

$$\Delta f \approx \frac{d\theta}{2\pi dt} \approx \frac{1}{2\pi} (\theta_k - \theta_{k-1}) f_0 N \qquad (12)$$

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.

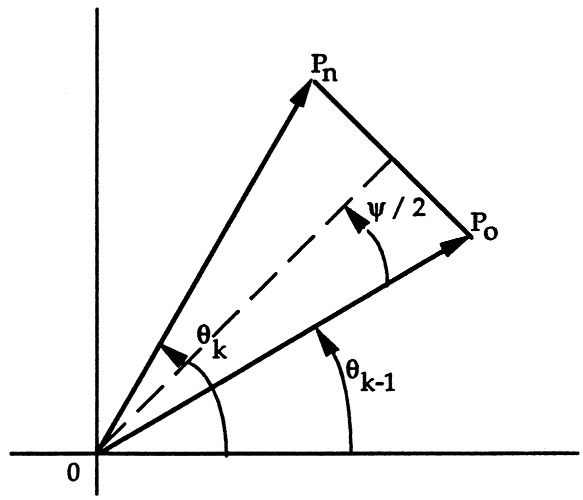

Figure A-3 Phasor Diagram

The angle $\psi = \theta_k - \theta_{k-1}$ is calculated every cycle as:

$$\psi = \tan^{-1} \left| \frac{\frac{1}{2}\left(\overline{OP}_n - \overline{OP}_0\right)}{\frac{1}{2}\left(\overline{OP}_n + \overline{OP}_0\right)} \right| \qquad (13)$$

From the calculated value of ψ, the frequency can be obtained as:

$$f \approx f_0 + \frac{\Psi}{2}\left(\frac{f_0 N}{\pi}\right) \qquad (14)$$

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 V_a, V_b and V_c be the estimated phasors of the three phase voltages. Then, the positive $\overline{V}_1$, negative $\overline{V}_2$ and zero sequence $\overline{V}_0$ components of the three phase voltages are given by:

$$\begin{bmatrix} \overline{V}_0 \\ \overline{V}_1 \\ \overline{V}_2 \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} \overline{V}_a \\ \overline{V}_b \\ \overline{V}_c \end{bmatrix} \qquad (15)$$

where phasor $\overline{V} = (V_r + jV_i)$ and $\alpha = -0.5 + j0.866$ or $1 \angle 120°$.

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 $\overline{V}$ and $\overline{I}$ represent complex phasors of voltage and current signals measured across a load. Then the complex power $(\overline{S})$ delivered to the load is given by:

$$\begin{aligned} \overline{S} = \overline{V}\,\overline{I}^* &= P + jQ \\ &= VI\cos\theta + jVI\sin\theta \end{aligned} \qquad (16)$$

where real power is given by the real part of $\overline{V}\,\overline{I}^*$ and the reactive power is given by the imaginary part of $\overline{V}\,\overline{I}^*$, 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.

$$P_T + jQ_T = \sum_{\ell = a, b, c} \overline{V}_\ell \, \overline{I}_\ell^* \qquad (17)$$

The power factor is computed to make possible its display as:

$$pf = \frac{P_T}{|\overline{S}|} = \frac{P_T}{\sqrt{P_T^2 + Q_T^2}} \qquad (18)$$

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:

$$\int_{t_0}^{t} f(I)dt \geqq K \qquad (19)$$

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:

$$U_k = U_{k-1} + f(I_k) \qquad (20)$$

and if we say the relay is operated when the running sum reaches a threshold value (K_{tv}), then the relay operating time (T_0) for a constant magnitude of current is given by:

$$T_0 = \frac{K_{tv}T}{f(I_k)} \qquad (21)$$

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]:

$$f'(I^2) = A_0 + A_1(I^2) + A_2(I^2)^2 \qquad (22)$$

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.

A.4 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.

A.5 References

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[7] Murty V.V.S. Yalla, "*Design and Implementation of Digital Relays for Power System Protection*," Ph.D. Dissertation, University of New Brunswick, Canada, Nov. 1987, (Chapter 3).

[8] Murty V.V.S. Yalla, "*A Digital Multifunction Protective Relay*," IEEE Transactions on Power Delivery, Vol. 7, No. 1, January 1992, pp. 193–201.

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B Appendix – 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-port 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 (1 of 3)

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 feature
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-port RAM fail, host side
43	Dual-port 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 (2 of 3)

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 (3 of 3)

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C Communications

C.1 Introduction C–1

C.2 The BECOCOM Protocol C–1

C.3 Communications Ports C–1

C.4 Direct Terminal Connections Via COM1 .... C–2

C.1 Introduction

The M-0420 Multifunction Relay 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, data available to the operator through the front panel of the relay 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 BECOPLOT® User Guides.

C.2 The BECOCOM Protocol

The relay and the communications software both 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

C.3 Communication Ports

The relay 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 communications-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

C.4 Direct Terminal Communications via COM1

The M-0420 Multifunction Relay provides a limited communications ability via the front panel COM1 port. A subset of the status parameters and control functions may be executed via a standard "dumb" terminal. This function may be used during testing or while the unit is on-line. The unit must not be in local mode while using this function.

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 may 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 settings must match the settings of the relay. The relay 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 use and may result in unpredictable operation.

Procedure for Terminal Communications via COM1

1. Set the baud rate and parity in the Configure COM1 menu of the relay
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 uppercase.*	

Table C-2 Terminal Commands

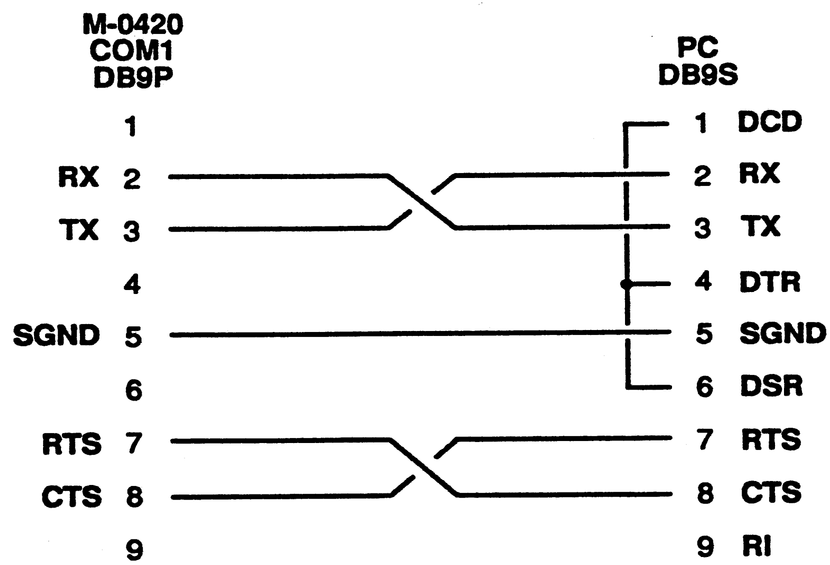

Figure C-1 Null Modem Cable: M-0420 COM1 to PC (9-pin)

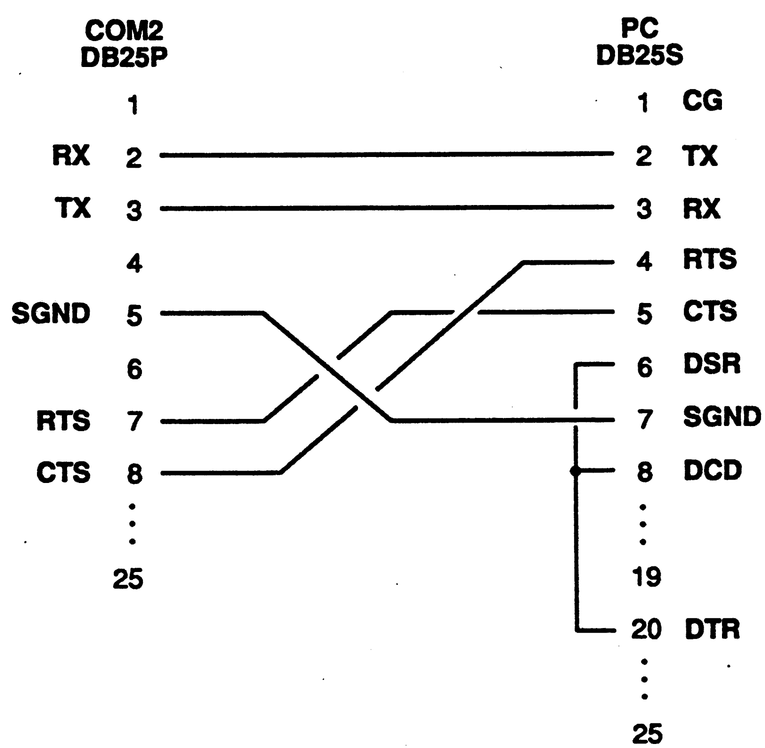

Figure C-2 Null Modem Cable: M-0420 COM2 to PC (25-pin)

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D Board Interconnections

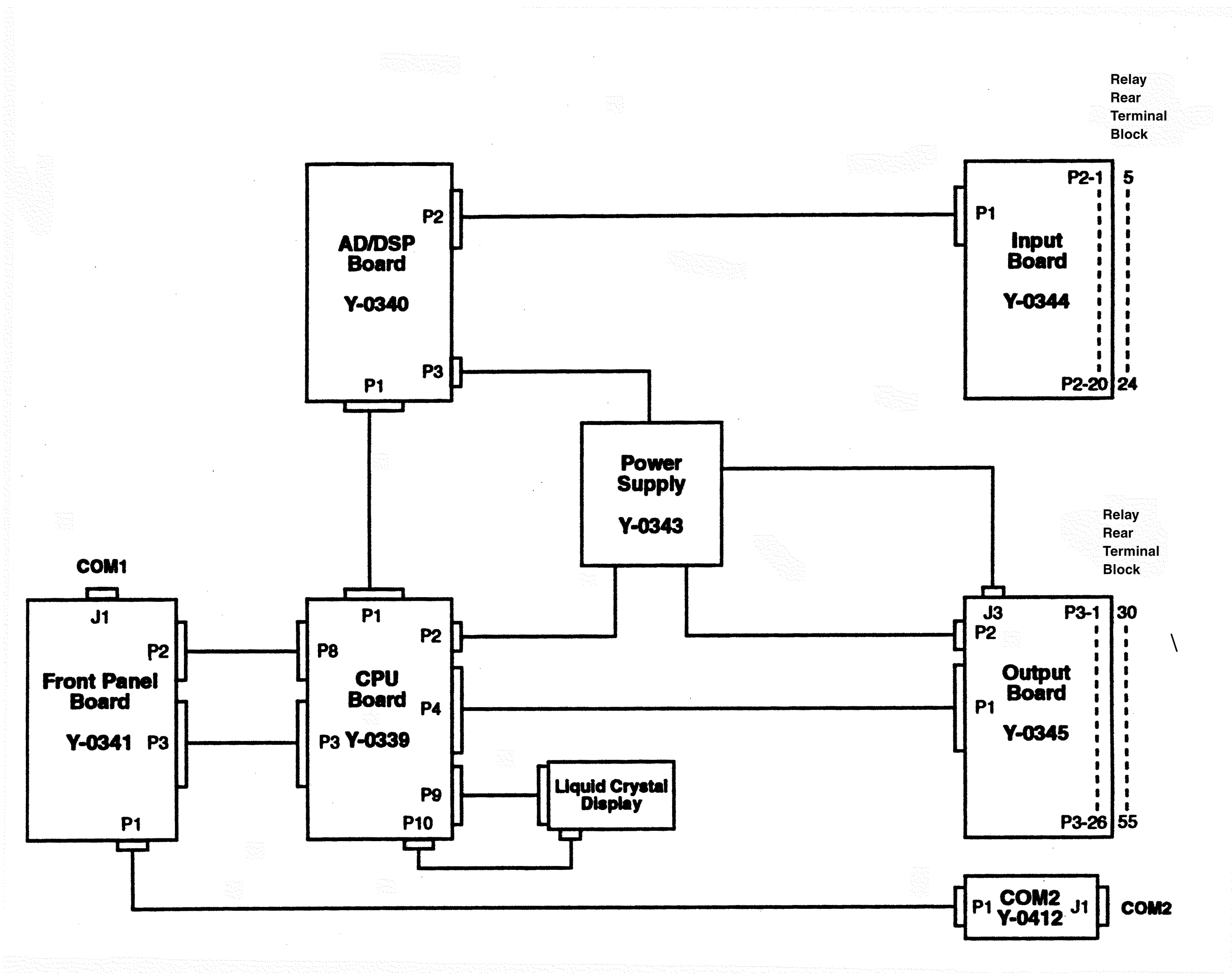

Figure D-1 M-0420 Board Interconnections

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E Configuration Record Forms

This appendix contains forms that you can photocopy for recording and keeping on file the configuration of your relay.

The first form is the Functional Configuration Record. This form reproduces the **CONFIGURE RELAYS** series of menus accessible from the 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. Disabled functions will have no visible setpoint configuration windows.

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.

Functional Configuration:

(59)

```
PHASE OVERVOLTAGE #1
disable ENABLE
```

```
PHASE OVERVOLTAGE #2
DISABLE enable
```

Setpoint Configuration:

(59)

```
PHASE OVERVOLTAGE #1
122.5 Volts (1.02 PU)
```

```
DELAY PHASE OVERVOLT #1
300 Cycles
```

```
PHASE OVERVOLTAGE #2
_____ Volts (____ PU)
```

```
DELAY PHASE OVERVOLT #2
_____ Cycles
```

CONFIGURE RELAYS
← setpts 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

CONFIGURE RELAY
← current_relay →

51V PHASE TIME OVERCURRENT
disable nondirectional directional

* VOLTAGE CONTROL OVERCURR
disable v_cntrl v_rstrnt

** VC DELTA-Y TRANSFORM
disable enable

(*** 67) PHASE DIRECTIONAL OVRCUR
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

CONFIGURE VT FUSE LOSS
← trip FUSE

60FL 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

* 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.

By: ______________________

Date: ______________________

Serial Number: ______________

Location: ___________________

Figure E-1 M-0420 Functional Configuration Record

VOLTAGE RELAY
VOLT freq curr powr →

59

OVERVOLTAGE SETPOINTS
PHASE_OVER phase_under →

PHASE OVERVOLTAGE #1
________ Volts (____PU)

DELAY PHASE OVERVOLT #1
________ Cycles

PHASE OVERVOLTAGE #2
________ Volts (____PU)

DELAY PHASE OVERVOLT #2
________ Cycles

27

UNDERVOLTAGE SETPOINTS
phase_over PHASE_UNDER →

PHASE UNDERVOLTAGE #1
________ Volts (____PU)

DELAY PHASE UNDERVOLT #1
________ Cycles

PHASE UNDERVOLTAGE #2
________ Volts (____PU)

DELAY PHASE UNDERVOLT #2
________ Cycles

27N

UNDERVOLTAGE SETPOINTS
← nutrl_over NUTRL_UNDER

NEUTRAL UNDERVOLTAGE #1
________ Volts (____PU)

DELAY NEUTRL UNDERVOLT #1
________ Cycles

NEUTRAL UNDERVOLTAGE #2
________ Volts (____PU)

DELAY NUTRL UNDERVOLT #2
________ Cycles

59I

PEAK OVERVOLTAGE #1
________ PU

DELAY PEAK OVERVOLT #1
________ Cycles

PEAK OVERVOLTAGE #2
________ PU

DELAY PEAK OVERVOLT #2
________ Cycles

59N

OVERVOLTAGE SETPOINTS
← NUTRL_OVER nutrl_under

NEUTRAL OVERVOLTAGE #1
________ Volts (____PU)

DELAY NEUTRL OVERVOLT #1
________ Cycles

NEUTRAL OVERVOLTAGE #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: ____________

Location: ______________

Figure E-2 Voltage Relay Setpoint Configuration Record

FREQUENCY RELAY
volt FREQ curr powr →

81O

OVERFREQUENCY SETPOINTS
OVER under

OVERFREQUENCY #1
________ Hz

DELAY OVERFREQUENCY #1
________ Cycles

OVERFREQUENCY #2
________ Hz

DELAY OVERFREQUENCY #2
________ Cycles

81U

UNDERFREQUENCY SETPOINTS
over UNDER

UNDERFREQUENCY #1
________ Hz

DELAY UNDERFREQUENCY #1
________ Cycles

UNDERFREQUENCY #2
________ Hz

DELAY UNDERFREQUENCY
________ Cycles

By: ____________________

Date: ____________________

Serial Number: ____________

Location: ________________

Figure E-3 Frequency Relay Setpoint Configuration Record

CURRENT RELAY
volt freq CURR powr →

OVERCURRENT SETPOINTS
PHASE_OVER ntrl_over →

51V* TAP PHASE OVERCURRENT
________ Amps

TIMING PHASE OVERCURRENT
def in VINV einv

TIME DIAL PHASE OVERCURR
____

VOLTAGE CONTROL OVERCURR
________ Volts (____PU)
OR
linear restraint

(67***) ANGLE DIR ELEMENT
________ Deg

PICKUP PHASE DIR OVERCURR
________ Amps

DELAY PHASE DIR OVERCURR
________ Cycles

50 PHASE INST OVERCURRENT
________ Amps

OVERCURRENT SETPOINTS
phase_over NTRL_OVER →

51N TAP NEUTRAL OVERCURRENT
________ Amps

TIMING NUTRL OVERCURRENT
def in VINV einv

TIME DIAL NUTRL OVERCURR
____

50N NUTRL INST OVERCURRENT
________ Amps

OVERCURRENT SETPOINTS
← NEG_SEQ_OVER

46 TAP NEG SEQ OVERCURRENT
________ Amps

PICKUP NEG SEQ OVERCURR
________ %

TIMING NEG SEQ OVERCURR
I_SQUARED_T

TIME DIAL NEG SEQ OVRCUR
____

MAX TIME NEG SEQ OVERCUR
________ Cycles

* See note concerning 69.3 V VT secondary ratio on Voltage Relay configuration record form.
** Optional.

By: ____________________

Date: ____________________

Serial Number: ____________

Location: ______________

Figure E-4 Current Relay Setpoint Configuration Record

POWER RELAY
volt freq curr POWR →

RECONNECT RELAY
← RECON

32F

FORWARD POWER SETPOINTS
FORWARD reverse

FORWARD OVERPOWER
________ PU

DELAY FORWARD POWER
________ Cycles

32R

REVERSE POWER SETPOINTS
forward REVERSE

REVERSE OVERPOWER
________ PU

DELAY REVERSE POWER
________ Cycles

79

RECONNECT SETPOINTS
RECON

DELAY RECONNECT
________ Cycles

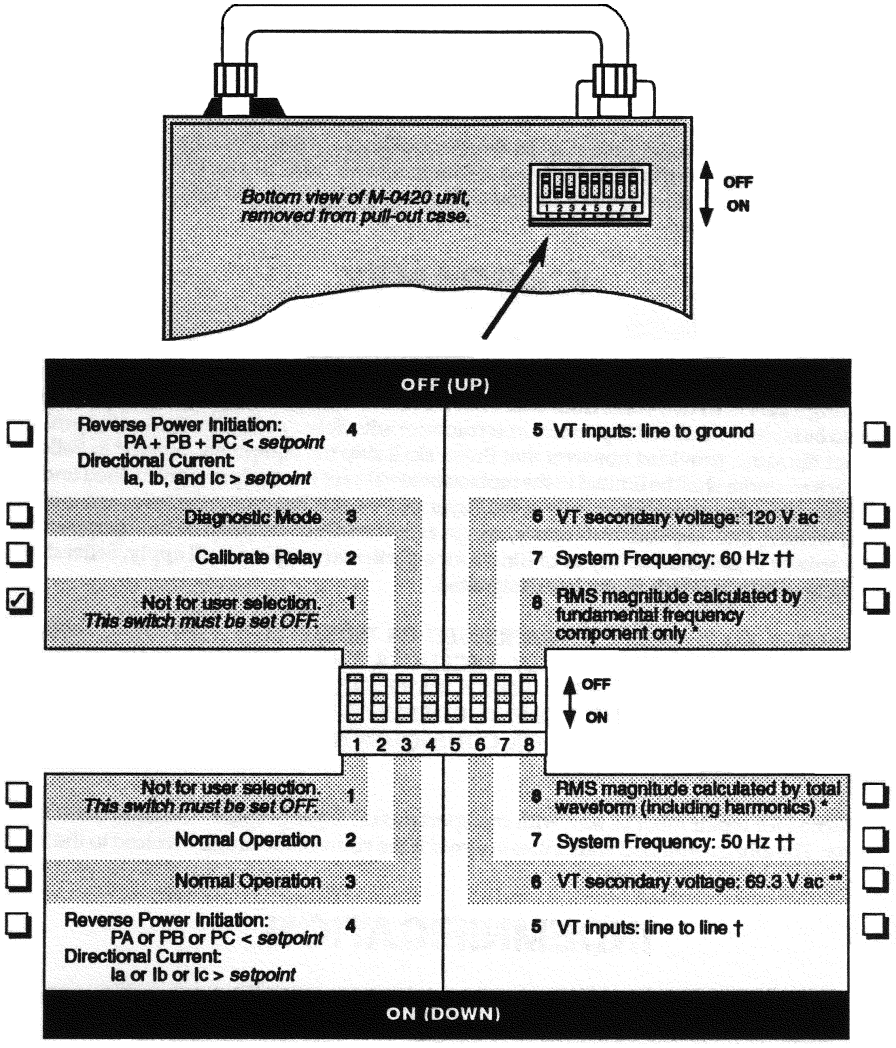
By: ____________________

Date: ____________________

Serial Number: ____________

Location: ________________

Figure E-5 Power and Reconnect Relay Setpoint Configuration Record



■ **NOTES**: Check the box adjacent to the switch settings you have chosen. For additional reference, shade in the corresponding DIP switch positions.

* 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: ______________________

Location: ______________________

Figure E-6 Internal DIP Switch Configuration Record

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