Digtital Energy
Multilin

735 / 737 Feeder Protection Relay
Instruction Manual

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GE Multilin
215 Anderson Avenue, Markham, Ontario
Canada L6E 1B3
Tel: (905) 294-6222 Fax: (905) 201-2098
Internet: http://www.GEmultilin.com

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These instructions do not purport to cover all details or variations in equipment nor provide for every possible contingency to be met in connection with installation, operation, or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purpose, the matter should be referred to the General Electric Company.

To the extent required the products described herein meet applicable ANSI, IEEE, and NEMA standards; but no such assurance is given with respect to local codes and ordinances because they vary greatly.

Part numbers contained in this manual are subject to change without notice, and should therefore be verified by GE Multilin before ordering.

Part number: 1601-0048-DK (May 2010)

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735/737 Feeder Protection Relay

Chapter 1: Introduction

1.1 Overview

1.1.1 Features

Protection

- 3 separate phase time overcurrent (51) elements with 5 curve shapes:
  Definite time, moderately inverse, normal inverse, very inverse, extremely inverse.
- Phase instantaneous (50) element
- Ground time overcurrent (51G) with 5 curve shapes:
- Definite time, moderately inverse, normal inverse, very inverse, extremely inverse.
- Ground instantaneous (50G) element
- 10 curves for each shape
- 4 time multipliers for each curve
- 3 different curve types: ANSI, IAC, IEC/BS142

Indicators

Trip:

Phase A, B, C instantaneous
Phase A, B, C time overcurrent
Ground fault instantaneous
Ground fault time overcurrent

Status:

Relay in service
Service required
Phase pickup
Ground pickup

Current bargraph: 10 to 100%

Other

- Conventional 1 A or 5 A CT input
- Drawout case
- AC or DC control power
- Seal provision for tamper proof settings
- Output contacts:
  - Trip
  - Aux Trip
  - Service Required
  - *(737 only)* pickup, trip, cause of trip outputs;
  - 50A, 50B, 50C, 50N
  - 51A, 51B, 51C, 51N
- RS485 communications: settings, currents, status
- 86 lockout
- Programmable block instantaneous on autoreclose.
- Ground Fault trip programmable to Aux. Trip relay, separate from Main trip.

1.1.2 Product Description

The 735/737 is a microprocessor based relay used to perform primary circuit protection on distribution networks at any voltage level. Instantaneous and time overcurrent phase and ground protection features replace the equivalent of 8 separate protection devices. Each protection element can be selectively enabled by front panel dial settings. Flexible settings and selectable curve shapes enable accurate coordination with other devices. Cause of trip indications and a bar graph load monitor are provided on the front panel.

A momentary dry contact closure from the 735/737 relay is used to activate the breaker trip coil in the event of a fault. To help determine the cause of a trip, separate indicators are provided for phase instantaneous, phase time overcurrent, ground fault instantaneous, and ground fault time overcurrent. These latched indicators remain set after a breaker trip. They can be reset by the front panel CLEAR button.

A special feature of the 735/737 named "Trip Record" is the ability of the relay to sequentially display the last five causes of trips. To display the trips, press and hold the reset key. After 2 seconds, the front panel indicators will display the last 5 trips starting with the most recent.

The 735/737 has separately adjustable instantaneous and time overcurrent pickup levels. No intentional delay is added to the instantaneous trip. Five separate time overcurrent curve shapes can be selected: definite time, moderately inverse, normal inverse, very inverse, and extremely inverse. For each curve shape, 40 different curves to produce different time delay levels can be selected using the time multiplier settings and curve shift. These allow selection of optimum coordination with fuses, feeders, motors, transformers, etc. To monitor load current, a front panel bar graph indicator is provided. It gives an indication of 10% of CT rating to 100% of CT in steps of 10%. This is useful for monitoring breaker loading and during testing.

Ground level and time delay can be selected for coordination with upstream devices. The ground signal is normally derived as the residual sum of the 3 phase CTs, eliminating the need for an additional ground sensor. Alternatively, for more sensitive detection, an additional core balance (zero sequence) ground sensor, encircling the 3 phase conductors, can be used. Like time overcurrent phase protection, 5 separate curve shapes and 40 curves for each shape are available for ground fault protection.

To accommodate more complex control schemes the 737 has 8 additional output relays to provide a separate dry contact output for each different protection element. That is, in addition to the 2 common trip contacts, the 737 has contacts for trip from:

51A, 51B, 51C, 51N, 50A, 50B, 50C, and 50N

These eight additional outputs can be programmed to activate:

- as a separate trip output for each 50/51 protection element
- as a latched cause of trip output for fault diagnosis interface to a SCADA
- when phase/ground current exceeds the pickup setting to warn of an impending trip

Internal monitoring of the relay is continuous. When control power is applied and the relay is operating normally, the "RELAY IN SERVICE" LED is on. Should a fault be detected, the "SERVICE REQUIRED" LED will light to indicate a problem. In addition, the failsafe SERVICE relay output will change state signalling a malfunction to a remote monitoring device such as a programmable controller. In this case the 735/737 relay should be replaced and sent in for service. As long as the "SERVICE" LED is off and the "RELAY IN SERVICE" LED is on the relay is operating normally. If the test switch is on, the RELAY IN SERVICE LED will flash. When either the phase or ground time/overcurrent threshold is exceeded, a separate pickup indicator flashes which is useful for testing, and to warn of an impending trip.

Relay states can be monitored via the RS485 communication port. This allows relays to be linked together over a simple twisted pair wire to communicate with a PLC or computer using the Modbus protocol. Baud rate and a unique slave address are set via the front panel communications switches.

1.1.3 Theory of Operation

A block diagram of the 735/737 hardware is shown on the following page. A 16-bit single chip microcomputer handles data acquisition, input/output and control. Program memory, data RAM, 10 bit A/D and UART are internal to the microcomputer.

Phase and ground current are monitored via external CTs which are connected to internal interposing CTs for isolation and signal conditioning. Low pass filters, level shifters and gain amplifiers transform the input signal to a level suitable for conversion by the 10 bit A/D. A/D values are converted, using software, to the true RMS value of the input sinewave. Separate × 1 and × 10 gain amplifiers are continuously sampled by the A/D convertor with program logic dynamically choosing the appropriate range.

Eight rotary switches and 2 banks of DIP switches are periodically read and decoded to determine settings. Using the appropriate curve settings, the microcomputer computes instantaneous and time overcurrent values closing the trip relay when a trip value is reached. This relay will remain latched until all phase and ground currents have dropped to zero. True RMS current is calculated and bar graph segments are driven under program control to indicate the value. All output relays are driven in response to computed conditions. These drivers are opto-isolated and a separate relay supply is used to prevent noise coupling for external sources to the microcomputer.

To prevent possible lockup of the relay in case of abnormal transient conditions, a separate hardware timer is continuously reset by the microcomputer under normal conditions. In the event of the program hanging up, this external watchdog will time out and issue a system reset.

An internal UART buffered by an isolated RS485 driver controls the serial communications. Baud rate is selectable through an internal timer. Like all other inputs/outputs transient protection is applied to ensure reliable operation under real conditions.

A flyback switching power supply generates multiple isolated supply voltages of +12 I/O, +5 digital, +12 analog and +5 RS485. Two different versions are available to cover the range 20 to 60 V DC or 90 to 300 V DC. Front end rectification and filtering enable these supplies to also be used with 50/60Hz control power sources.

Structured firmware design running under a real time operating kernel ensures robust program operation under different conditions. It also contributes to bug free code maintenance.

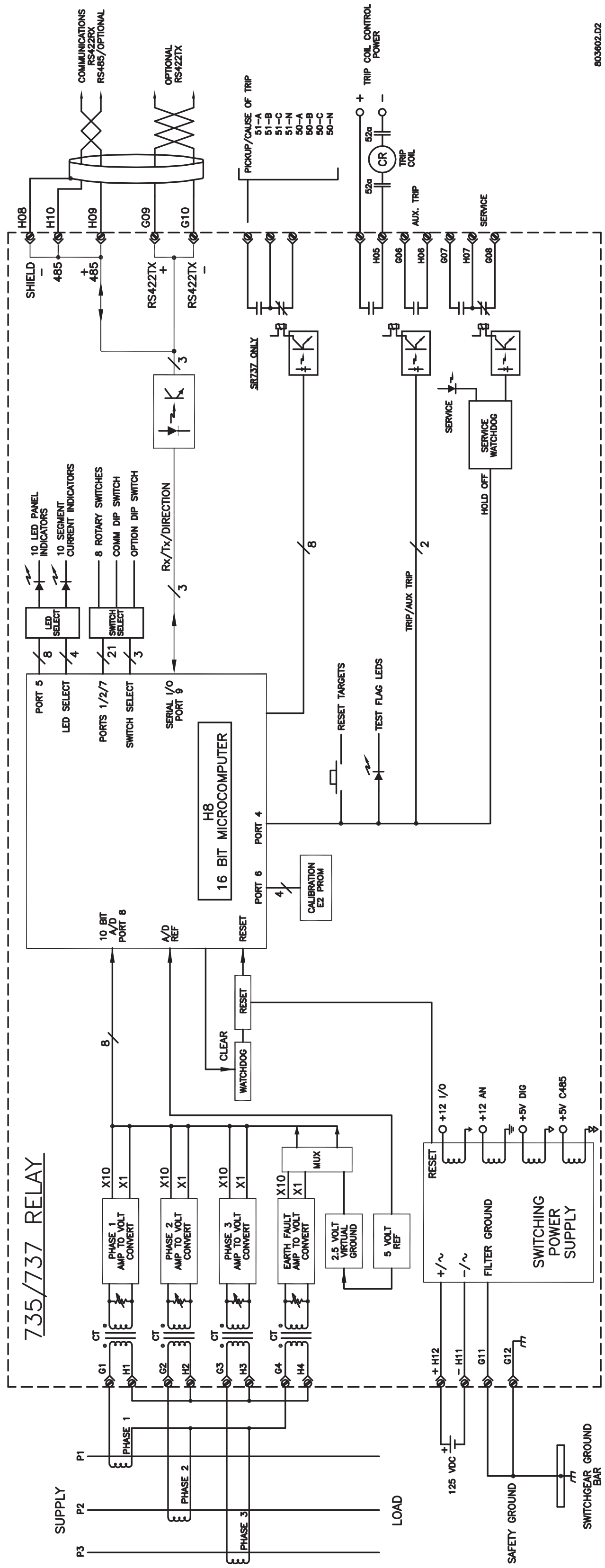

FIGURE 1–1: 735 Block Diagram

1.2 Ordering

1.2.1 Order Codes

The CT secondary must be specified with an order as 1 or 5 amps. The RS485 communications interface is available with RS422 as an option. For 19" rack mount applications, single and dual cutout panels for mounting one or two relays are available. These are 3 units high (10.5") for 19-inch rack mounting, made of 14 gauge steel and come in ASA 61 gray. See Section *2.1.1: Mounting* for dimensions of the relay and panels. For bench testing, the 735/737 can be ordered mounted in a portable case.

The GE Multilin order code is as follows:

Table 1–1: Order Codes

	735 737	- S - S	- S - S	- S - S	- S - S	
Basic Unit	735					Standard 735 Relay with 50/51, 50G/51G protection
	737					737 Relay (same as 735 with 8 additional output relays)
Phase CT Secondary		1				1 A Phase CT secondaries
		5				5 A Phase CT secondaries
Ground CT Secondary			1			1 A Ground CT secondaries
			5			5 A Ground CT secondaries
Control Power				LO		20 to 60 V DC; 20 to 48 V AC at 50/60 Hz
				HI		90 to 300 V DC; 70 to 265 V AC at 50/60 Hz
Options					485	RS485 2-wire communications (standard)
					422	RS422 4-wire communications (optional)
					DEMO	735 Demo/Test case

1.2.2 Accessories

The following additional accessories are available:

- 19-1 PANEL: Single cutout panel
- 19-2 PANEL: Dual cutout panel
- SCI: RS232 to RS485 convertor
- 3" Collar: SR series collar 1009-0055
- $1\frac{3}{8}$" Collar: SR series collar 1009-0047
- Optional Mounting Kit: 1819-0030

1.3 Specifications

1.3.1 Protection

PHASE TIME OVERCURRENT (51)

Pickup level: ....LO: 20 to 100% of CT rating or OFF
HI: 110 to 220% of CT rating or OFF
Curve Types: ....ANSI, IAC, IEC/BS142
Curve shapes: ....definite time, moderately inverse, normal, inverse, very inverse, extremely inverse.
See time/overcurrent curves; curves apply up to 20 × pickup or 20 × CT, whichever is less.
Time multiplier: ....10 curves: #1 to #10 for each shape
4 shift multipliers: 0.5, 0.8, 1, 1.1
Definite time:....................100 ms to 1 sec. in steps of 100 ms.
Reset:....................Time reset to zero each time current level falls below pickup threshold
Accuracy: ....Level: ±3% of setting
Time: greater of ±3% or ±20ms at >150% of pickup

PHASE INSTANTANEOUS OVERCURRENT (50)

Pickup level: ....4, 5, 6, 8, 10, 12, 14, 16, 20 × CT or OFF
Accuracy: ....Level: ±3% of setting
Time: 35ms maximum at >150% of pickup setting

GROUND TIME OVERCURRENT (51G/51N)

Pickup level: ....LO: 15 to 55% of CT rating in steps of 5% or OFF
HI: 60 to 100% of CT rating in steps of 5% or OFF
Curve Types: ....ANSI, IAC, IEC/BS142
Curve shapes: ....definite time, moderately inverse, normal, inverse, very inverse, extremely inverse.
See time/overcurrent curves; curves apply up to 20 × pickup or 20 × sensor, whichever is less.
Time multiplier: ....10 curves: #1 to #10 for each shape
4 shift multipliers: 0.5, 0.8, 1, 1.1
Definite time:....................100 ms to 1 sec. in steps of 100 ms
Reset:....................Time reset to zero each time current level falls below pickup
Accuracy: ....Level: ±3% of setting
Time: greater of ±3% or ±20ms at >150% of pickup

GROUND INSTANTANEOUS OVERCURRENT (50G/50N)

Pickup level: ....0.1, 0.2, 0.4, 0.8, 1, 2, 4, 8, 16, × CT or OFF
Accuracy: ....Level: ±3% of setting
Time: 35ms maximum at >150% of pickup setting

1.3.2 Inputs

CURRENT INPUTS

Withstand Phase/Ground CTs:....................4 times rated current: continuous
20 times rated current: 5 second
40 times rated current: 2 second
Sensing:....................True RMS; 16 samples/cycle

Secondary:..1 A or 5 A (must be specified with order)
Accuracy:...greater of 3% of CT primary or 3% of displayed
Drift: ....No greater than 0.5% over 10 years

CT BURDEN
1 Amp inputs: ....0.02 VA at 1 A; 0.2 VA at 5 A; 10 VA at 20 A
5 Amp inputs: ....0.02 VA at 5 A; 0.2 VA at 20 A; 10 VA at 100 A
Conversion range:...0 to 20 times CT primary
Frequency response: ....48 to 300 Hz ± 3 dB

1.3.3 Outputs

TRIP, AUX TRIP OUTPUT RELAYS

Table 1–2:

VOLTAGE		MAKE/CARRY		BREAK	MAX LOAD
		CONTINUOUS	0.2 S		
DC Resistive	30 V DC	20 A	80 A	16 A	480 W
	125 V DC	20 A	80 A	0.8 A	100 W
	250 V DC	20 A	80 A	0.4 A	100 W
DC Inductive, L/R = 40 mS	30 V DC	20 A	80 A	5 A	150 W
	125 V DC	20 A	80 A	0.3 A	375 W
	250 V DC	20 A	80 A	0.2 A	50 W
AC Resistive	120 V AC	20 A	80 A	20 A	2400 VA
	250 V AC	20 A	80 A	20 A	5000 VA
AC Inductive PF = 0.4	120 V AC	20 A	80 A	8 A	960 VA
	250 V AC	20 A	80 A	7 A	1750 VA

Configuration:..Form A NO
Contact Material:..Silver Alloy

SERVICE, PICKUP/CAUSE OF TRIP OUTPUT RELAYS

Table 1–3:

VOLTAGE		MAKE/CARRY		BREAK	MAX LOAD
		CONTINUOUS	0.2 S		
DC Resistive	30 V DC	10 A	30 A	10 A	300 W
	125 V DC	10 A	30 A	0.5 A	62.5 W
	250 V DC	10 A	30 A	0.3 A	75 W
DC Inductive, L/R = 40 mS	30 V DC	10 A	30 A	5 A	150 W
	125 V DC	10 A	30 A	0.25 A	31.3 W
	250 V DC	10 A	30 A	0.15 A	37.5 W

Table 1–3:

VOLTAGE		MAKE/CARRY		BREAK	MAX LOAD
		CONTINUOUS	0.2 S		
AC Resistive	120 V AC	10 A	30 A	10 A	2770 VA
	250 V AC	10 A	30 A	10 A	2770 VA
AC Inductive PF = 0.4	120 V AC	10 A	30 A	4 A	480 VA
	250 V AC	10 A	30 A	3 A	750 VA

Configuration:..Form C NO/NC
Contact Material:..Silver Alloy

1.3.4 Power Supply

CONTROL POWER
DC supply:..HI: 125 V DC, 250 V DC nominal
LO: 48 V DC nominal
Range:..HI: 90 to 300 VDC, 70 to 265 V AC
LO: 20 to 60 V DC, 20 to 48 V AC
Power:..nominal 10W, maximum 25W

1.3.5 Miscellaneous

INDICATORS
Phase time overcurrent trip A,B,C (latched)
Phase instantaneous overcurrent trip A,B,C (latched)
Ground fault time overcurrent trip (latched)
Ground fault instantaneous overcurrent trip (latched)
Relay in service
Service required
Phase pickup
Ground pickup
Current level LED bargraph: 10-100%

ENVIRONMENT
Operating temperature range: ....–40°C to +70°C
Ambient storage temperature: ....–40°C to +80°C
Humidity:..up to 90%, non-condensing.

LONG-TERM STORAGE
Environment: ....In addition to the above environmental considerations, the relay should be stored in an environment that is dry, corrosive-free, and not in direct sunlight.
Correct storage: ....Prevents premature component failures caused by environmental factors such as moisture or corrosive gases. Exposure to high humidity or corrosive environments will prematurely degrade the electronic components in any electronic device regardless of its use or manufacturer, unless specific precautions, such as those mentioned in the Environment section above, are taken.

NOTE

It is recommended that 735 relays be powered up once per year, for one hour continuously, to avoid deterioration of electrolytic capacitors and subsequent relay failure.

TYPE TESTING

Insulation Resistance: ....per IEC 255-5 (500 V DC, 2000 MΩ)
Dielectric Strength: ....per IEC 255-5 and ANSI/IEEE C37.90 (2 kV at 60 Hz for 1 minute)
Impulse Voltage ....per IEC 255-5 (5 kV)
Surge Immunity:..per EN 61000-4-5 (common mode 4 kV, differential modes 2 kV)
Oscillatory Surge Withstand: ....per ANSI/IEEE C37.90.1, per Ontario Hydro A-28M-82
Voltage Dips...per IEC 61000-4-11 (0%, 40%, 70%)
Electrostatic Discharge:..............................per IEC 255-22-2 (4/4 kV)
Damp Heat (Humidity Cyclic):..................per IEC 68-2-30 (6 days)
Make and Carry for relays:........................per IEEE C37.90 (30 A)
Current Withstand: ....per ANSI/IEEE C37.90 (40 × rated 1 A for 2 seconds; *60 × rated 5 A for 1 second*)
RFI Radiated Immunity:..............................per IEC 255-22-3 (160 MHz, 460 MHz), per EN 61000-4-3 (10 V/m)
RFI Conducted Immunity:..........................per EN-61000-4-6 (10 V)
Temperature Cycle: ....−40°C, +60°C (per GE internal procedures)
Mechanical Stress:..2 g (per GE internal procedures)
Current Calibration:.....................................per GE internal procedures
10 A DC continuous relay current carry at 80°C per GE internal procedures

PRODUCTION TESTS

Dielectric Strength: ....1.9 kV AC for 1 second or 1.6 kV AC for 1 minute, per UL 508.

WARNING

DO NOT CONNECT FILTER GROUND TO SAFETY GROUND DURING ANY PRODUCTION TESTS!

735/737 Feeder Protection Relay

Chapter 2: Installation

2.1 Mechanical

2.1.1 Mounting

The 735 is a drawout relay that slides into the panel mounted case. A hinged door covers the front panel controls to allow protected access of the setting selector switches. This allows pickup levels and time delays to be quickly set or modified. The figure below shows the physical dimensions of the 735/737. A single cutout in the panel, as per the dimensions of FIGURE 2–2: *Single and Double Unit Panel Cutouts* is required to mount the fixed chassis. When mounting the 735, provision should be made for the door to open without hitting adjacent components mounted on the panel. For 19-inch rack mount applications, a 735 can be mounted individually on a panel or side-by-side with another SR series relay (such as the 760) for backup applications. Details are shown below.

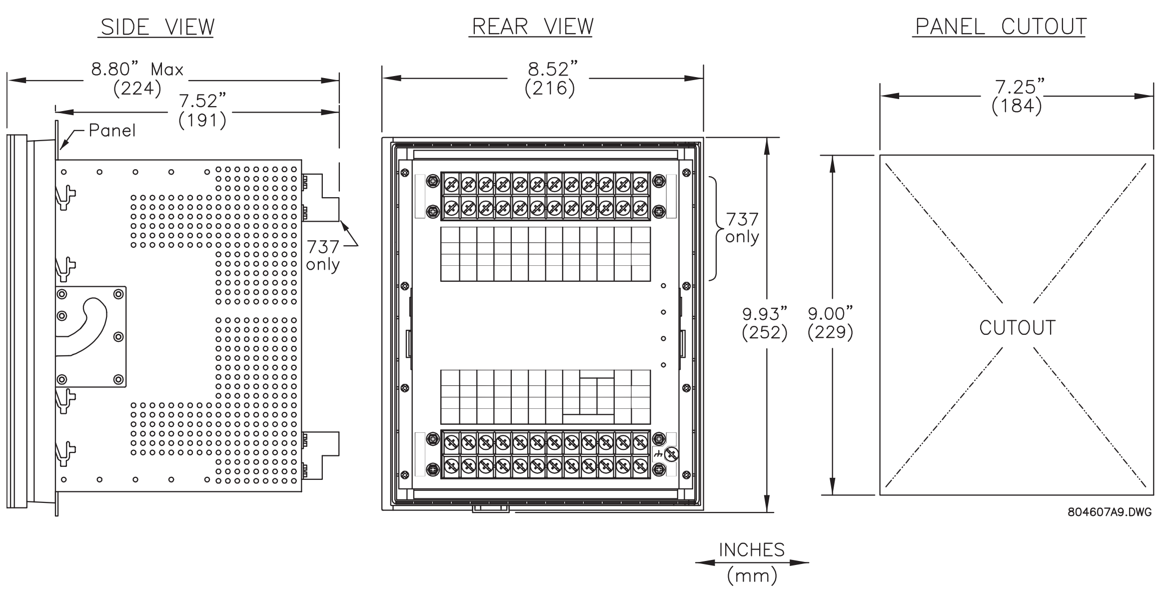

FIGURE 2–1: Dimensions

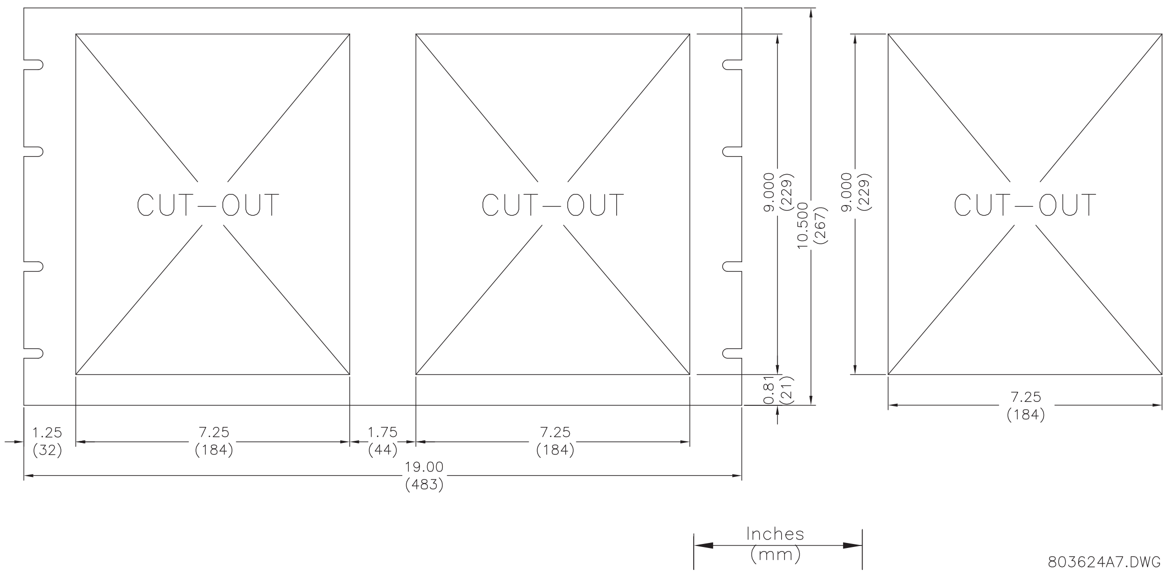

FIGURE 2–2: Single and Double Unit Panel Cutouts

Remove the relay from the case during mounting (see the following section). Slide the case into the cutout from the front of the panel as shown below. While firmly applying pressure from the front of the chassis to ensure the front bezel fits snugly, bend out the retaining tabs as shown below.

FIGURE 2–3: Sliding the Unit into the Panel

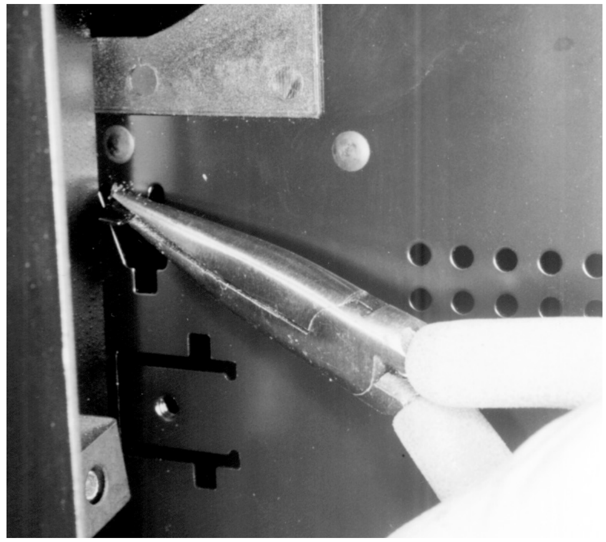

FIGURE 2–4: Bend Up Mounting Tabs

The retaining tabs will be sufficient to hold the chassis securely in place. If additional fastening is desired the SR optional mounting kit can be ordered. This kit provides additional support with adjustable mounting brackets. The captive chassis should now be securely mounted to the panel with no movement, ready for rear terminal wiring.

Drawout Relay

To remove the relay, open the door by grasping the right side at the top and pulling until the friction catch releases. There is a locking catch in the center of the handle. With a screwdriver or your finger placed horizontally in the center, squeeze the catch upwards until the catch disengages, then pull the handle outward so it rotates up, as shown below. Firmly grasp the handle and pull upwards to the vertical endstop until the relay completely disengages.

Press latch and pull to disengage handle

Rotate handle to vertical stop position and pull to withdraw

FIGURE 2–5: Relay Withdrawal

To insert the relay, raise the handle to the highest position. Slide the relay into the case until the guide pins engage in the slots on each side. Now press downward on the handle until it clicks and locks in the vertical position. An index pin at the back of the 737 captive chassis prevents the wrong model of relay from being inserted into a non-matching case. This will prevent the relay from being inserted all the way in as a safeguard. Check that the relay model matches the case type before insertion or if excessive force appears to be required.

FIGURE 2–6: Relay Insertion

2.1.2 Product Identification

Product attributes will vary according to the configuration and options installed based on the customer order. Before applying power to the relay, remove the relay by pulling up on the handle. Examine the labels on the unit and check that the correct options are installed.

The following section explains the information included on the labels.

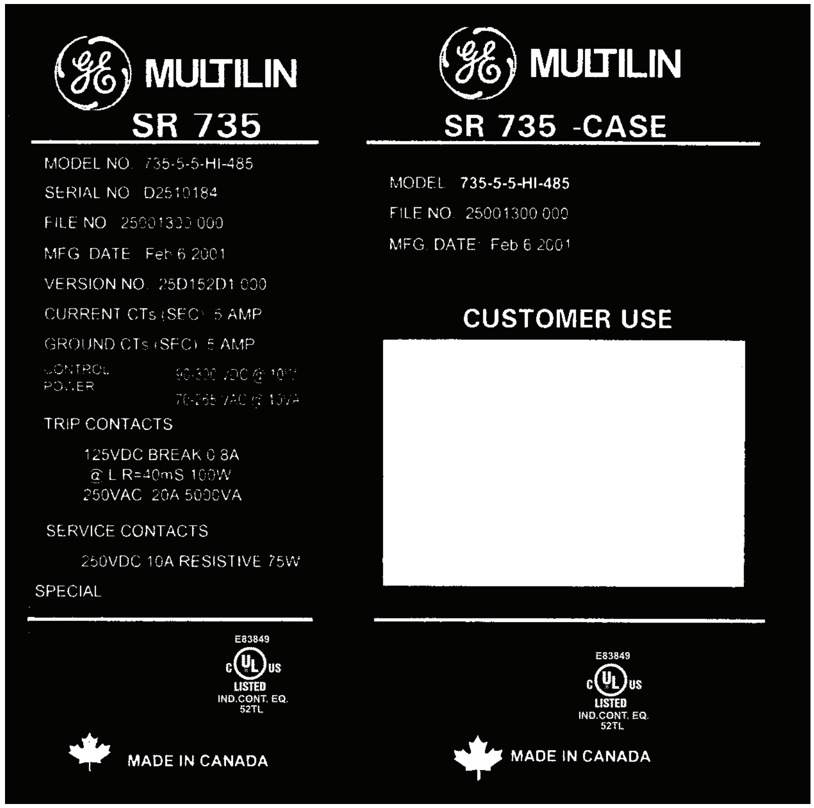

FIGURE 2–7: 735 Labels

1. **Model No**: The model number shows the configuration of the relay including phase CTs, ground CT, power supply voltage and communications.
2. **Serial No**: This is the serial number of the relay.
3. **File No**: This number indicates the configuration of the relay. It is important when inserting a relay into a case to ensure that the configuration file number is the same for both pieces.
4. **Mfg Date**: This is the date the relay was produced at the factory.
5. **Version No**: This indicates the revision of the firmware installed in the relay.
6. **Current Cts**: This indicates whether the phase CTs installed are 5 A or 1 A.
7. **Ground Ct**: This indicates whether the ground CT installed is 5 A or 1 A.
8. **Control Power**: This indicates the power supply input configuration installed in the relay.
9. **Trip & Service Contacts**: This section gives a brief description of the relay contacts. For a more detailed description, see Section *1.3.3: Outputs*.

2.2 Electrical

2.2.1 Wiring

Different connection schemes are possible depending on the application. Typical connections are shown on the following page where the 735/737 is used as primary protection. Ensure that the wiring diagram number on the drawout chassis label matches the number of the instruction manual wiring diagram. Terminals are numbered in rows.

Use the labels on the back of the relay to identify terminals with a row letter and position number. Terminal numbers and symbols on the back of the relay should match the wiring diagram in this manual.

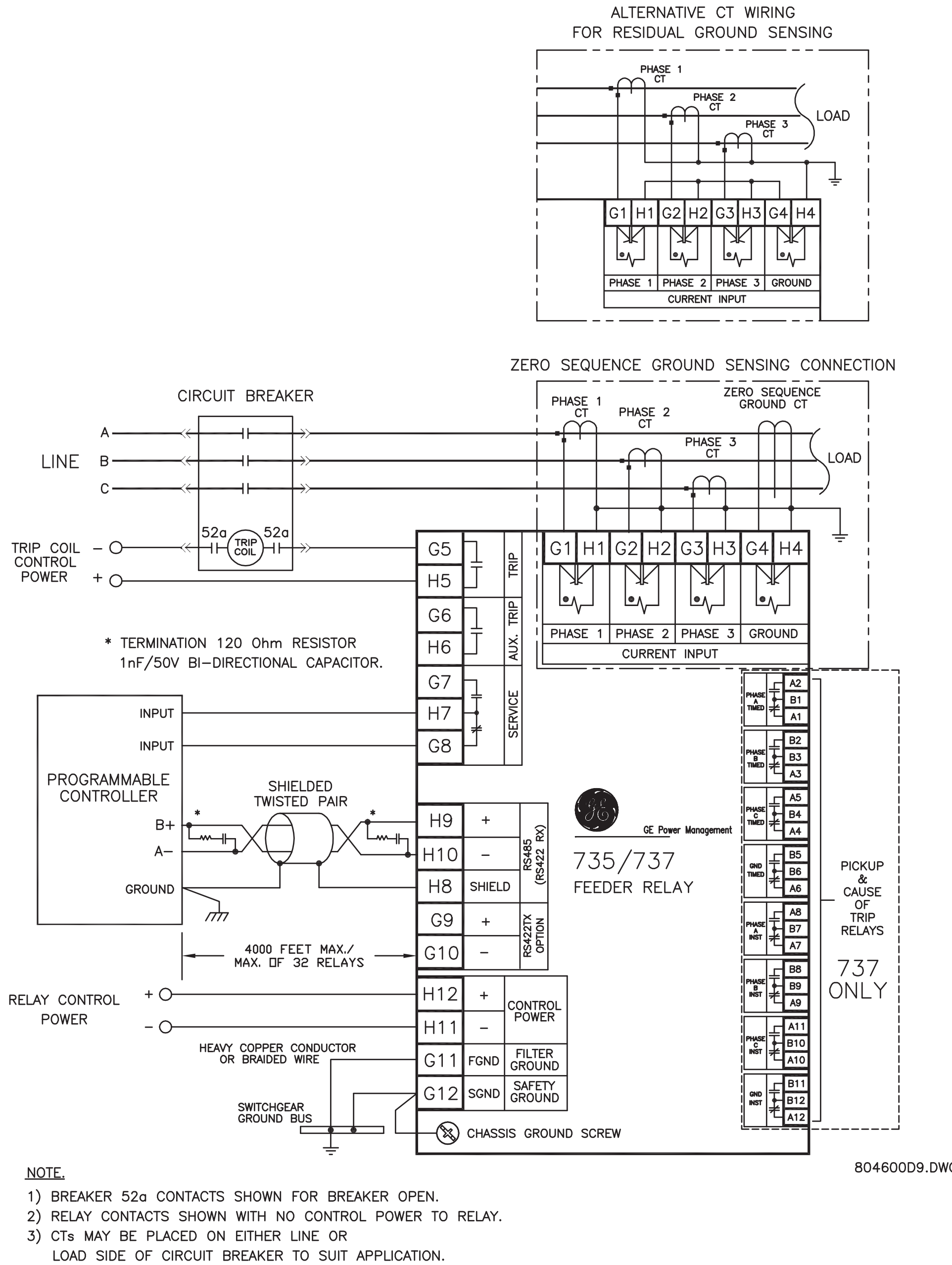

FIGURE 2–8: Typical Wiring Diagram

The following two figures show suggested wiring when the 735/737 is used as backup protection in conjunction with other relays. Select the appropriate scheme depending on whether ground sensing is by the residual method using the phase CTs or by the core balance method using a separate CT.

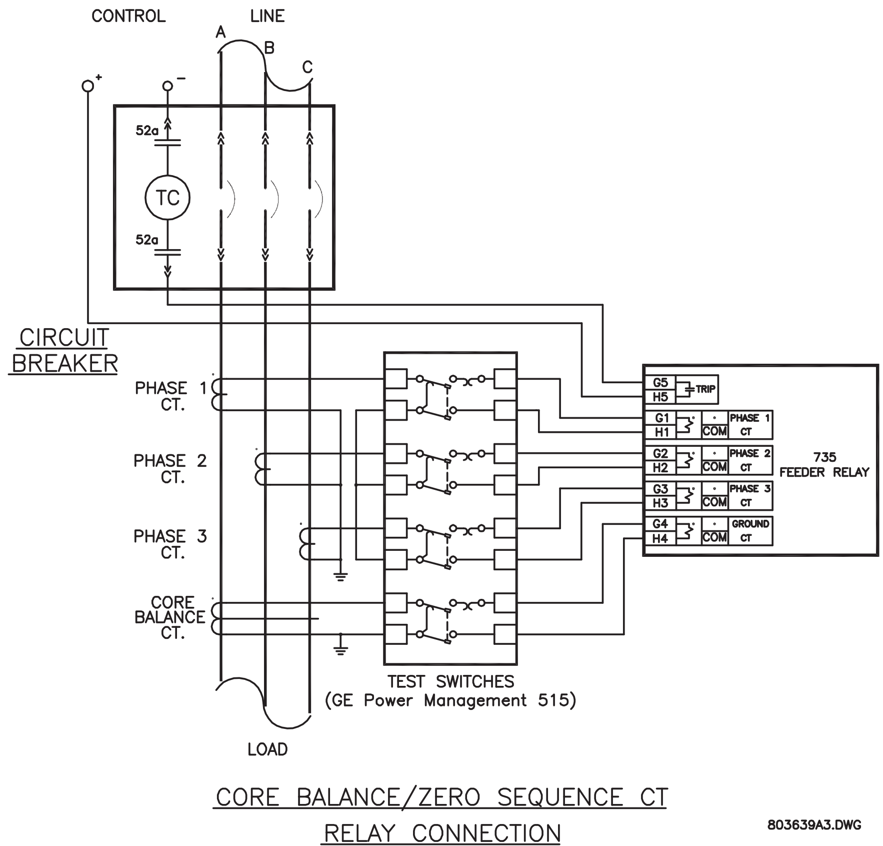

FIGURE 2–9: Backup Wiring – Core Balance

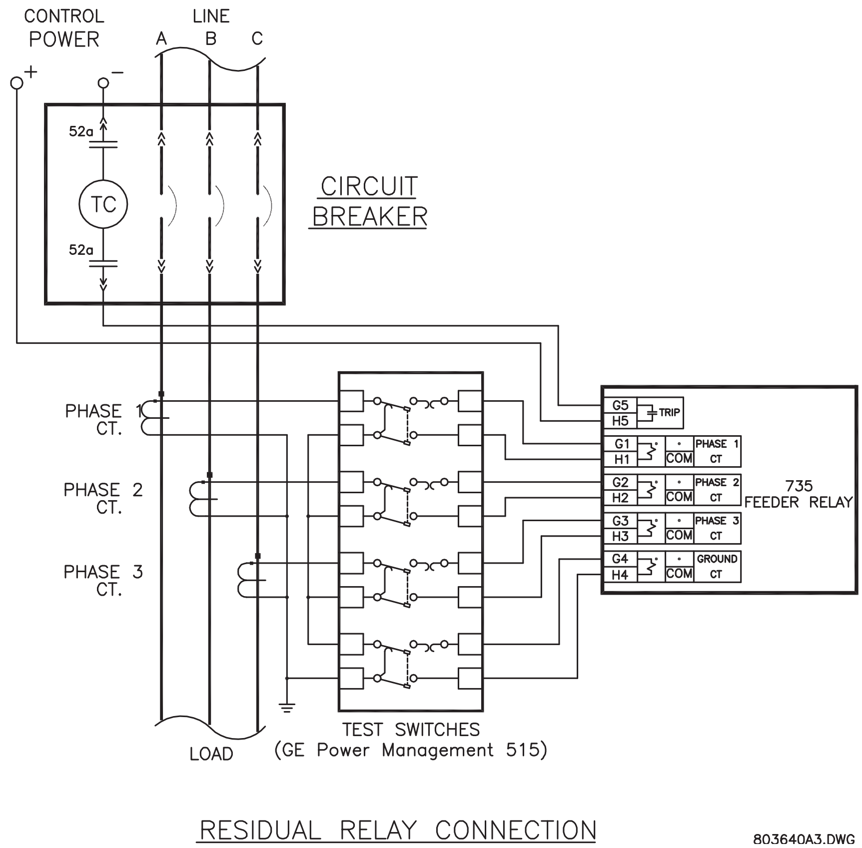

FIGURE 2–10: Backup Wiring – Residual

2.2.2 Current Transformers

Conventional 1 or 5 A current transformers are used for current sensing. A relaying class CT of the appropriate ratio with enough output to not saturate under short circuit conditions should be selected. For backup protection schemes, these CTs are wired in series with the primary protection relays and test switches, if installed. Typical primary/backup CT wiring is shown in the previous section.

Normally the 735 will be connected for residual ground fault sensing as shown in the ALTERNATIVE CT WIRING section of FIGURE 2–8: *Typical Wiring Diagram* on page 2–7. When the drawout chassis is removed, the CT secondaries are automatically connected together by the internal shorting fingers to prevent dangerous high voltages from open CTs. More sensitive ground fault detection can be achieved using a core balance (zero sequence) detection method as shown in the TYPICAL WIRING DIAGRAM. For this configuration the three phase cables (plus neutral if 4-wire system) pass through the window of a separate CT which senses the zero sequence component of the 3 currents. If a ground shield is present in the 3 phase cable, it must also pass inside the window of the ground fault sensing CT.

2.2.3 Output Relays

Three separate dry contact relays are provided: TRIP, AUX TRIP and SERVICE. TRIP and AUX TRIP are identical non-failsafe Form A contacts which both close whenever the relay trips. These contacts remain closed until the current in all three phases or ground drops to zero depending on their setup. The contacts remain latched for an additional 100 ms then open. The AUX TRIP relay can be programmed as a trip follower (main trip), as an 86 lockout relay, or as a separate Ground Fault relay. When AUX TRIP relay is set to work separately for ground fault currents, the relay can be reset after a ground fault is removed, even if the phase current is still present. FIGURE 2–8: *Typical Wiring Diagram* on page 2–7 shows the relay contact state as untripped with no control power applied. Typically the breaker 52a contact is wired in series with the TRIP relay contact to break the trip coil current. For large trip coils an auxiliary relay may be required.

The SERVICE relay is failsafe; that is, the contacts are normally picked up and drop out whenever the 735/737 detects an internal fault or control power is lost. These contacts are Form C. Contact ratings are shown in Section *1.3.3: Outputs*. Connect the SERVICE relay output to a warning device such as a SCADA monitor.

For more complex control schemes or for status signalling to a SCADA system, the 737 has 8 additional Form C relays. These can be programmed with option switches 6 and 7 to select the operating mode as: energize on trip (pulsed), latched cause of trip, phase/ground pickup or both pickup and cause of trip. See Section 3.4.2 *Option Switches [14]* for details.

2.2.4 Communications

Continuous monitoring and control of the 735/737 from a remote computer, SCADA system or PLC is possible using the serial communications port terminals.

Two-wire RS485 is the preferred standard. Four-wire RS422 is also available as an option. RS485 data trans-mission and reception are accomplished on a single twisted pair with transmit and receive data alternating over the same two wires. When the RS422 option is installed, separate twisted pairs are required for transmission and reception. The serial port protocol is a subset of the Modicon Modbus protocol as described in Chapter 4: COMMUNICATIONS.

Lightning strikes and ground surge currents can cause large momentary voltage differences between remote ends of the communication link. For this reason, surge protection devices are internally installed across the relay RS485/RS422 communication port terminals. A separate power supply with an optocoupled data interface is used internally to prevent noise coupling to the circuitry. The source computer/ PLC/SCADA system should have similar transient protection devices installed either internally or externally to ensure maximum reliability under fault conditions. Use shielded, twisted pair connecting wire to minimize communication errors from noise. A suitable type of wire is Belden #9841 which is shielded 24 AWG, stranded twisted pair having a characteristic impedance of 120 Ω. Ground the shield at one point only as shown in the following diagram to prevent ground loops.

Correct polarity is essential. Each relay must be connected with terminal H9 (labelled A+) connected to the same wire and terminal H10 (labelled B–) connected to the other wire. Terminal H8 (labelled shield) should be connected to the ground wire inside the shield. Each relay must be daisy chained to the next one. Avoid star or stub connected configurations. Observing these guidelines will result in a reliable communication system that is immune to system transients.

A maximum of 32 relays can be daisy-chained together on a communication channel without exceeding the driver capability. For larger systems, additional serial channels must be added. It is also possible to use commercially available repeaters to increase the number of relays on a single channel to more than 32. Different GE Multilin relays may be connected to the same twisted pair link providing they are all programmed with a unique address and the same baud rate.

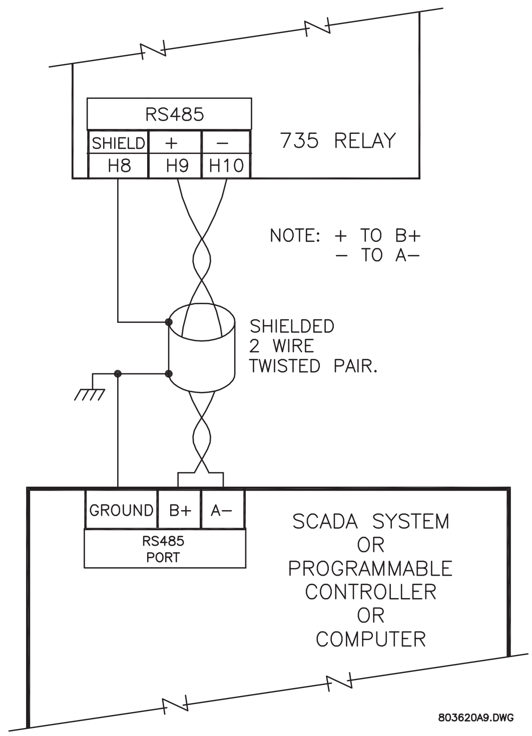

FIGURE 2–11: RS485 Connection

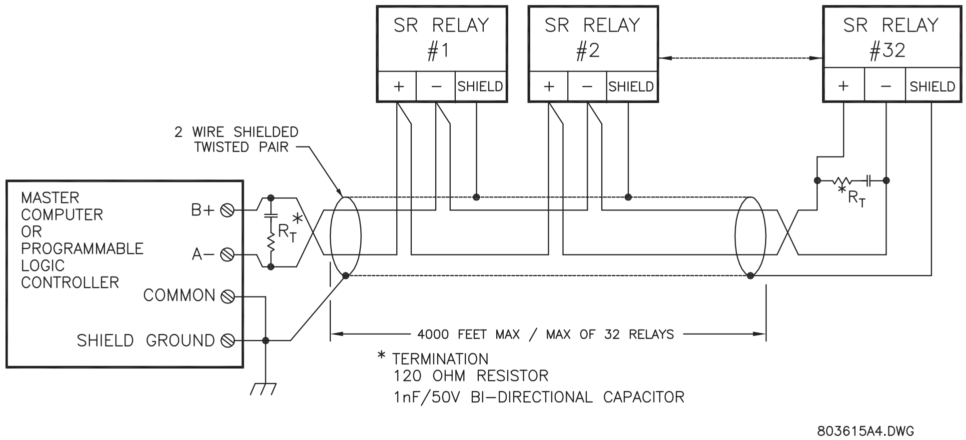

FIGURE 2–12: RS485 Termination

NOTE

Due to address limitations, only 31 735/737s can be put on a single channel. However a different model of GE Multilin relay could be added to the channel increasing the number of relays to 32.

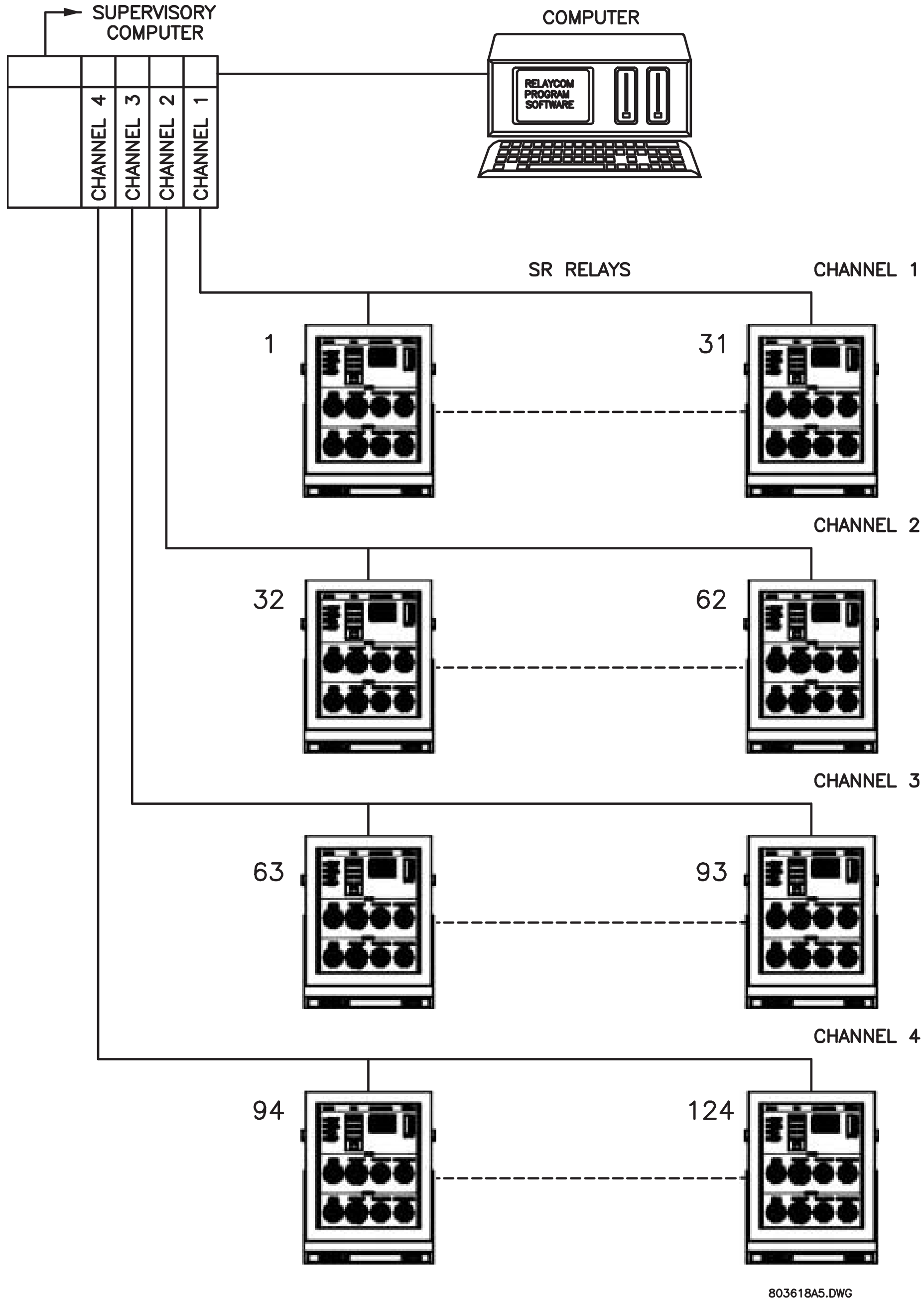

FIGURE 2–13: 4 Channel, 124 Relay System

If the communications option is used, a disk with the `735SETUP.EXE` software (`737SETUP.EXE` for the 737) is provided. When a PC running this program is connected to the 735/737, actual values and settings can be read and printed and relay operation can be simulated for training/testing purposes. To use this software, the computer RS232 serial port is connected through an RS232 to RS485 converter as shown below. This can be a commercially available model or the GE Multilin RS232/RS485 converter module. Set the relay front panel communication switches to 9600 baud, address 1, test ON. Apply power to the computer, RS232/ RS485 converter, and relay. Install the setup disk in a personal computer and type "`A:735SETUP`" ("`A:737SETUP`" for the 737) to run the software. See Section 3.5 *Setup Program* for an explanation of menu items and program operation.

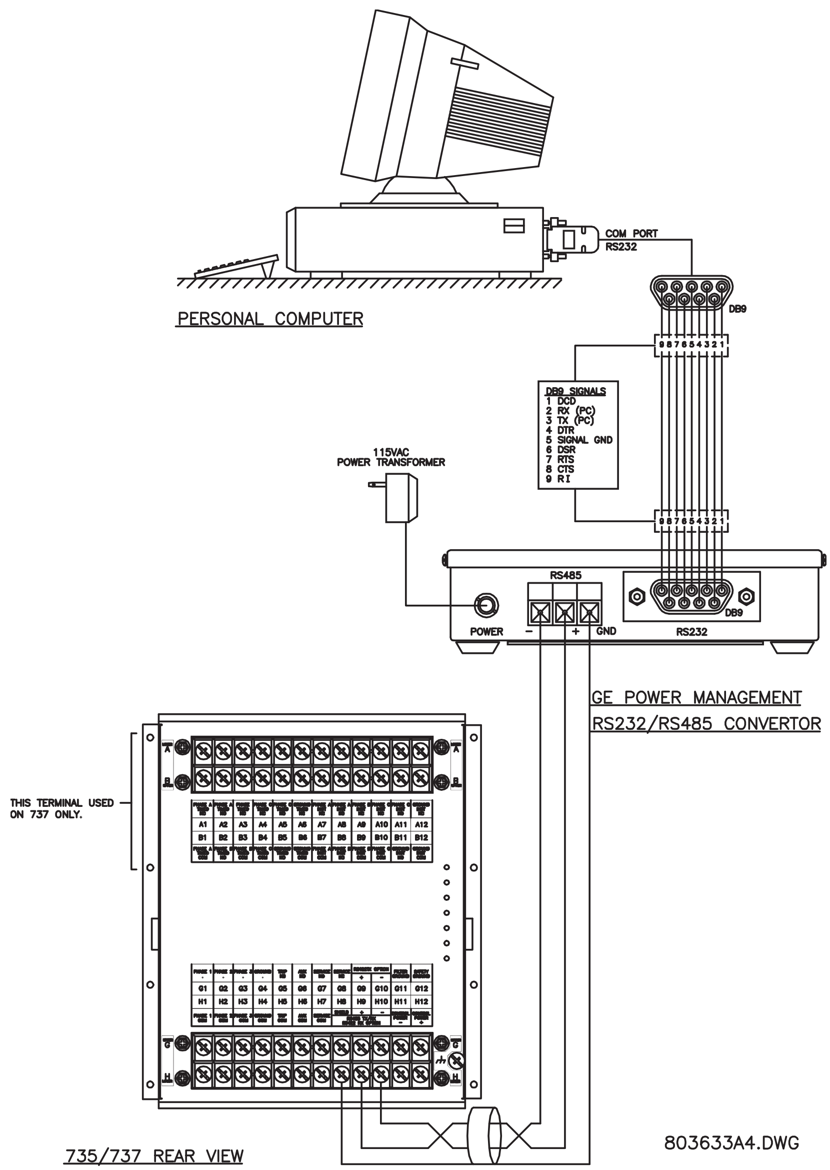

FIGURE 2–14: RS232/485 Converter

2.2.5 Control Power

Control power supplied to the 735/737 must match the switching power supply installed or damage to the unit will occur. Consult the order code from the label on the side of the drawout chassis. It will specify the nominal control voltage as:

Table 2–1:

NOMINAL	RANGE
24/48	20 to 60 V DC; 20 to 28 V AC at 50/60 Hz
125/250	90 to 300 V DC; 70 to 265 V AC at 50/60 Hz

WARNING

Ensure applied the control voltage and rated voltage on drawout case terminal label match to prevent damage.

For example, the 125/250 power supply will work with any voltage from 90 to 300 V DC or AC voltage from 70 to 265 V AC. The internal fuse may blow if too high a voltage is applied resulting in a completely dead relay. If this occurs the RELAY IN SERVICE indicator will be off and the service output contacts will indicate a relay malfunction. Polarity is not important with DC voltage.

2.2.6 System Grounding

Two separate grounds are brought out to rear terminals. The safety ground (terminal G12) makes a solid electrical connection to all internal metal chassis parts and causes a fuse to blow should a short develop to the case. It ensures operator safety in the event of a fault. A separate green ground screw is also provided on the back of the chassis for the safety ground.

Surge suppression components are grounded to a separate filter ground (terminal G11). These components are designed to conduct during transients at input terminals to prevent nuisance operation or damage to internal components. For reliable operation both grounds must be tied directly to the ground bus bar of the switchgear which is itself connected to a solid ground. Braided cable or heavy solid copper wire (such as 10 gauge) should be used for optimum transient protection. Do not rely on a ground connection to a part of the metal switchgear enclosure because a low impedance to ground cannot be guaranteed.

2.2.7 Hi-pot Testing

Prior to leaving the factory, all terminals except filter ground and communications are hi-pot (dielectric strength) tested. If hi-pot testing is to be performed on an installed relay for insulation verification. The hi-pot potential is applied between the wired together terminals and the enclosure ground according to the figure below. A potential of 1.9 kV AC is applied for 1 second, or 1.6 kV AC applied for 1 minute (per UL 508) to test dielectric strength. To effectively clamp transient voltages at a level sufficient to protect the internal circuitry, the internal transient protection devices conduct below the hi-pot voltages used for insulation testing. Consequently, the filter ground terminal G11 must be left floating for this test.

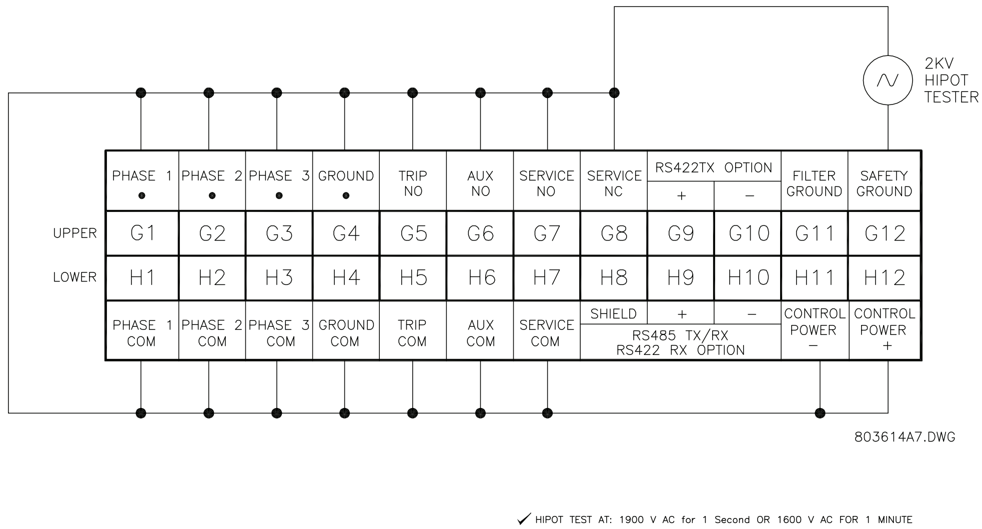

FIGURE 2–15: HI-POT Testing Connections

WARNING

Disconnect the communications terminals and filter ground during dielectric strength testing (hipot) or damage to the internal surge protection devices may occur.

Digital Energy
Multilin

735/737 Feeder Protection Relay

Chapter 3: Setup And Operation

3.1 Front Panel

3.1.1 Description

A front panel view of the 735 relay is shown below. An explanation of each of the numbered controls/indicators is contained in the following sections.

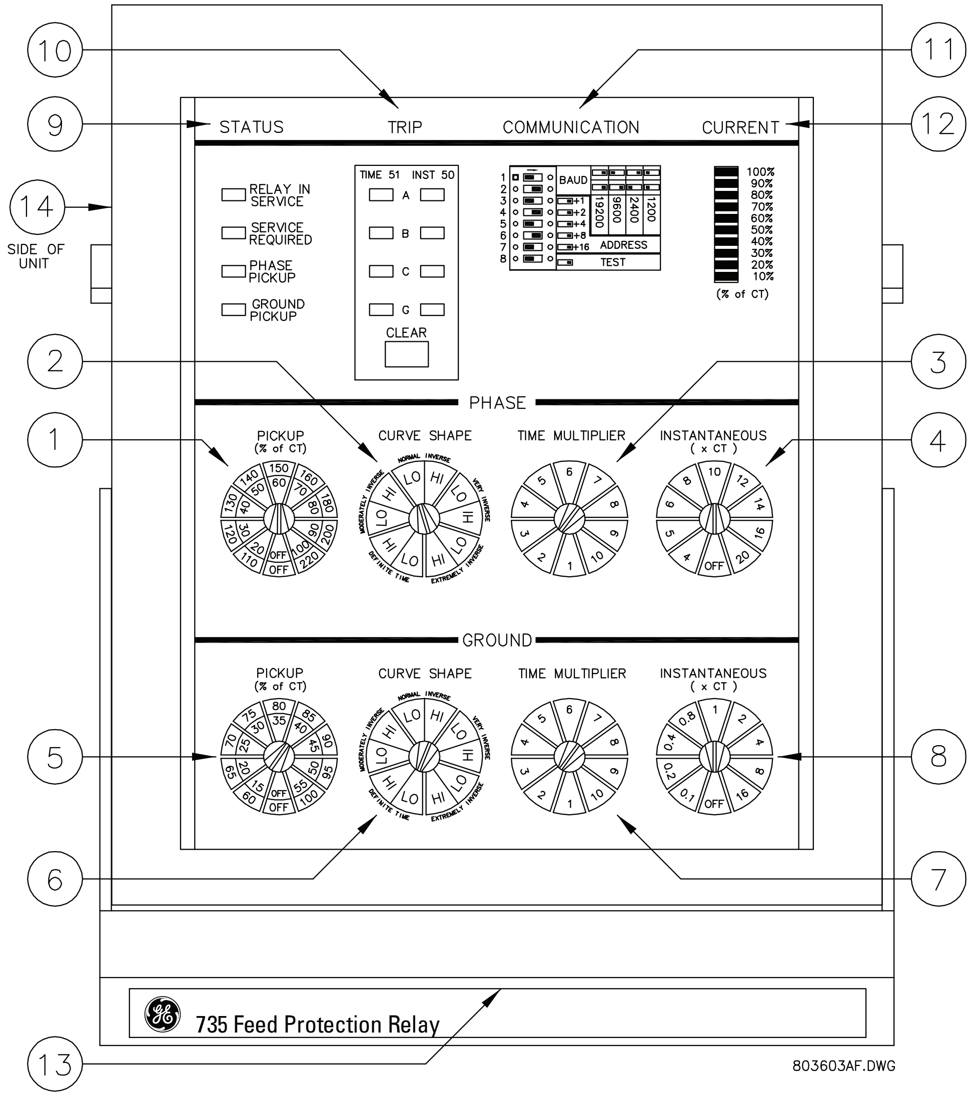

FIGURE 3–1: Front Panel Controls and Indicators

3.2 Controls

3.2.1 Phase Pickup [1]

This control determines the pickup current for overcurrent timeout for any phase curve shape and curve multiplier. It is set as a percentage of phase CT rating. Read the pickup current from the inner LO band when the phase CURVE SHAPE is set to a LO range (20 to 100%). Use the outer HI band if the phase CURVE SHAPE is set to a HI range (110 to 220%). Select the OFF position to disable phase time overcurrent.

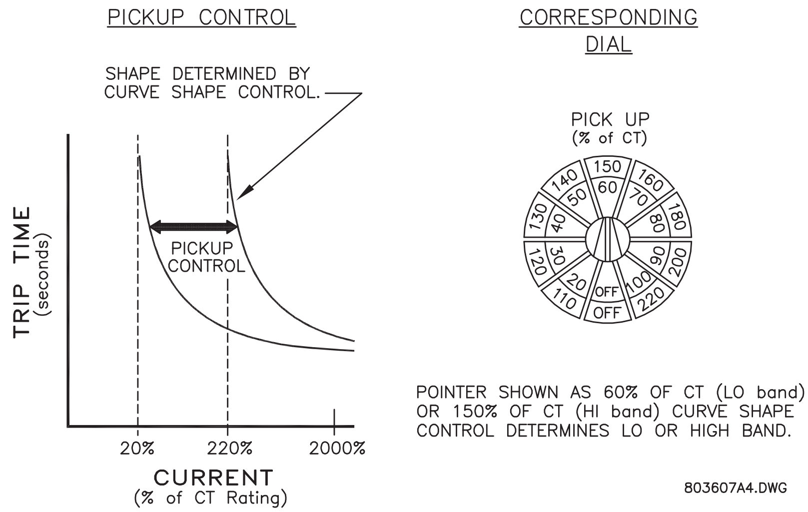

FIGURE 3–2: Phase Pickup Setting

3.2.2 Phase Curve Shape [2]

Five different curve shapes can be selected for the phase time overcurrent to provide the required coordination. These are definite time, moderately inverse, normal inverse, very inverse and extremely inverse. For each curve, either the LO band or HI band of the phase pickup setting (Control 1) is selected. See the time overcurrent figures for actual curves and curve values in table form.

For example: CURVE SHAPE: normal inverse
PICKUP CURRENT: 480 A
PHASE CT RATIO: 600:5
PHASE CURVE SHAPE: normal inverse LO
PHASE PICKUP: 80/180 (480 A = 80% of 600 A)

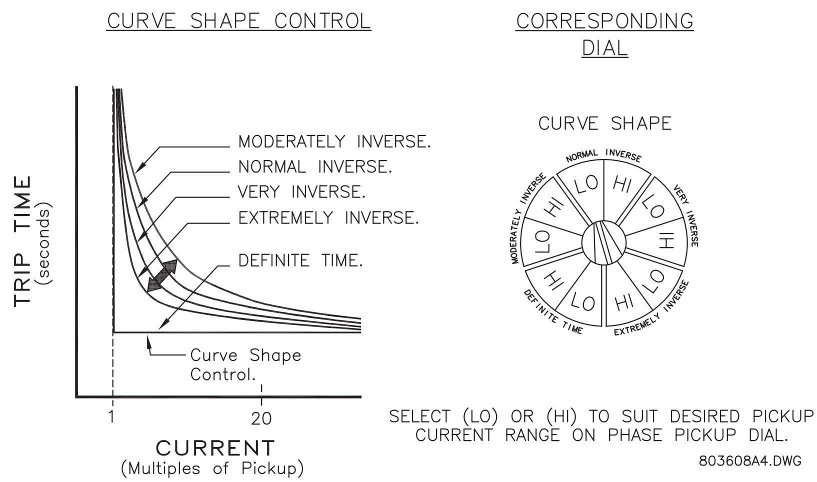

FIGURE 3–3: Phase Curve Shape Setting

3.2.3 Phase Time Multiplier [3]

The time multiplier dial allows selection of a multiple of the base curve shape for every curve. It is adjustable from 1 to 10 in increments of 1. Unlike the electromechanical time dial equivalent, trip times are directly proportional to the time multiplier setting value. For example, all trip times on multiplier curve 10 are 10 times curve 1. Use the phase time multiplier shift option switches to move the selected curve up or down (see Section *3.4.2: Option Switches [14]*). Curves are shown in Chapter 5 for overlays and visual inspection. Formulas and tabular data are also given for use with computer software or manual plotting on other co-ordination curves.

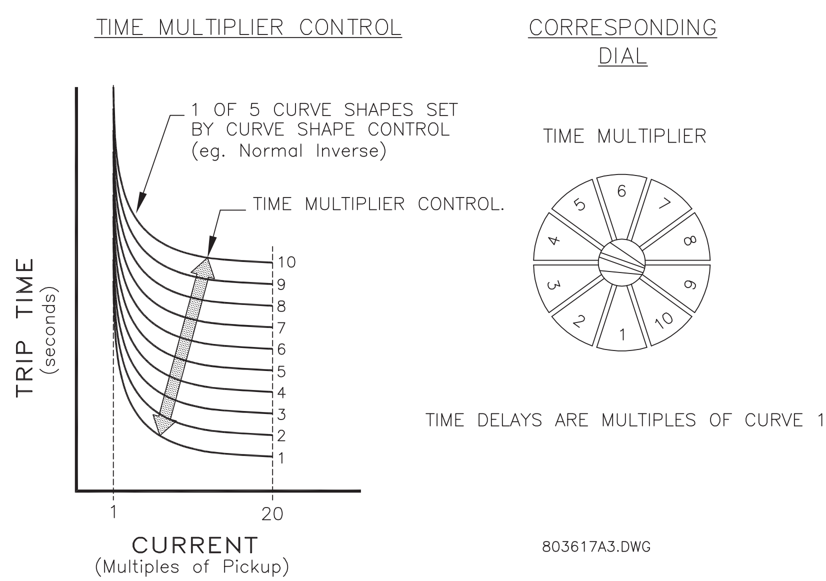

FIGURE 3–4: Phase Multiplier Time Setting

3.2.4 Phase Instantaneous [4]

Instantaneous phase trip level with no intentional delay (35 ms max) is set with the phase instantaneous dial as a multiple of the CT sensor. This setting is independent of the pickup dial setting.

For example: CT RATING: 500:5
INSTANTANEOUS TRIP: 5000 A
INSTANTANEOUS SETTING: 10 (i.e. 10 × 500 = 5000 A)

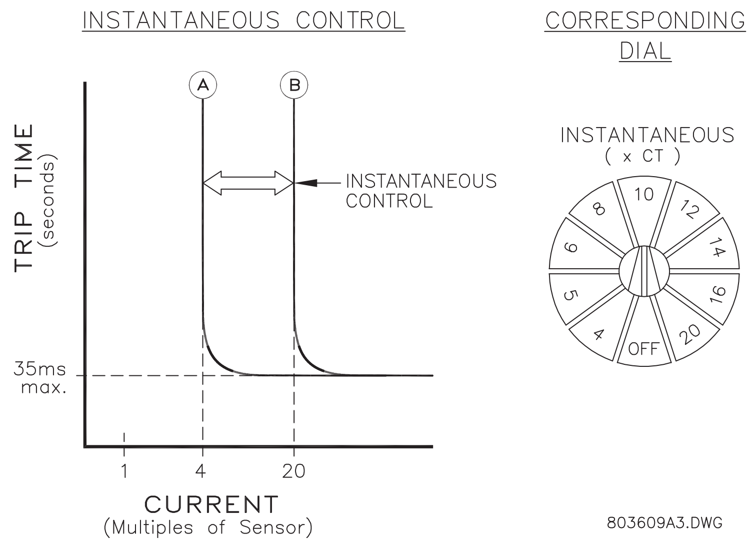

FIGURE 3–5: Phase Instantaneous Trip Setting

3.2.5 Ground Pickup [5]

For any ground curve shape and curve multiplier, the pickup current for overcurrent timeout is determined by this control. It is set as a percentage of sensor CT rating which is the phase CTs for residual sensing or the core balance CT for zero sequence sensing. Read the pickup current from the inner LO band when the ground CURVE SHAPE is set to a LO range (15 to 55%). Use the outer HI band if the ground CURVE SHAPE is set to a HI range (60 to 100%). Select OFF to disable ground time overcurrent pickup and trip.

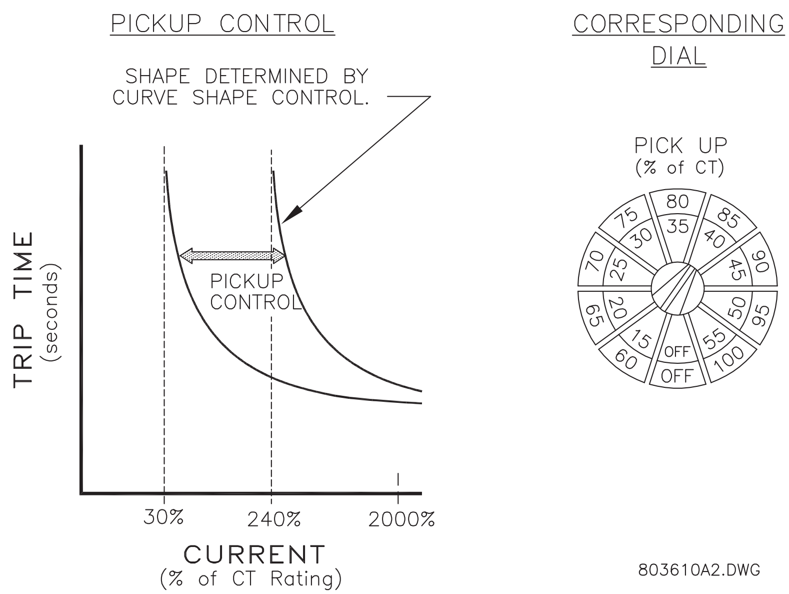

FIGURE 3–6: Ground Time Pickup Setting

3.2.6 Ground Curve Shape [6]

Five different curve shapes can be selected for the ground time overcurrent to provide the required coordination. These are definite time, moderately inverse, normal inverse, very inverse and extremely inverse. For each curve, either the LO band or HI band of the ground pickup setting is selected. See Chapter 5 for actual curves and curve values in table form.

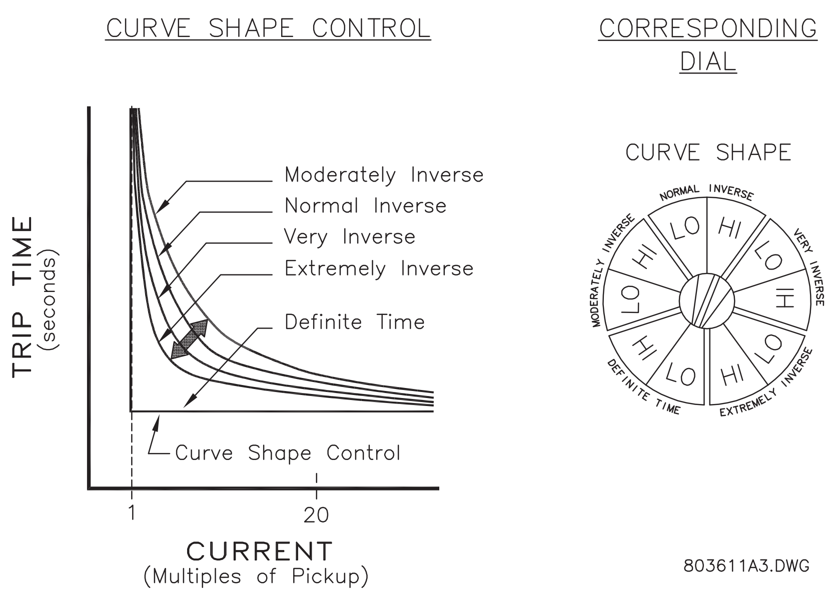

FIGURE 3–7: Ground Curve Shape Setting

3.2.7 Ground Time Multiplier [7]

The ground time multiplier selects a multiple of the base curve shape for each curve. It is adjustable from 1 to 10 in steps of 1. Unlike the electromechanical time dial equivalent, trip times are directly proportional to the time multiplier values. For example, all trip times on multiplier curve 10 are 10 times Curve 1. Curves are shown in Chapter 5 for overlays and visual inspection. Formulas and tabular data are also given for use with computer software or manual plotting on other co-ordination curves. Use the ground time multiplier option switches to move the curve up or down (see Section *3.4: Switches*).

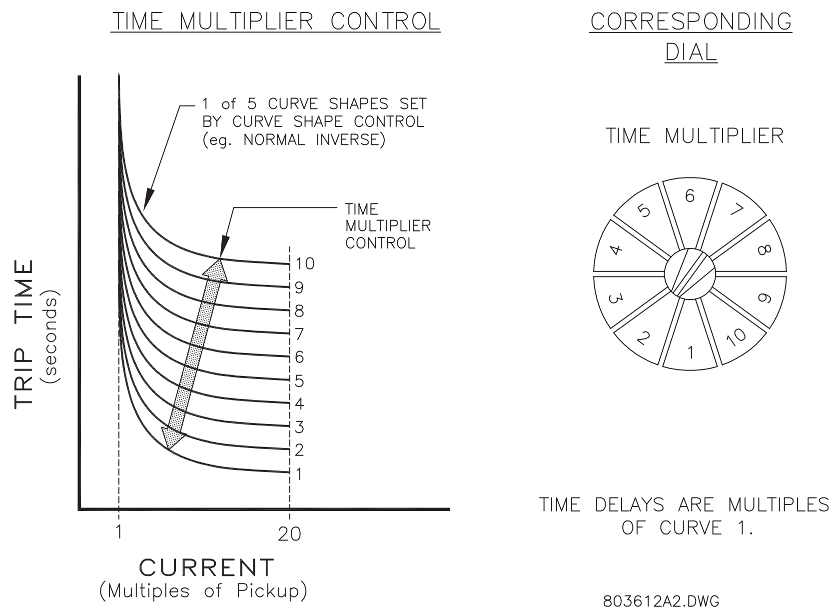

FIGURE 3–8: Ground Time Multiplier Setting

3.2.8 Ground Instantaneous [8]

Instantaneous ground current trip level with no intentional delay (35 ms max.) is set with the ground instantaneous dial as a multiple of the ground CT sensor. For residually connected phase CT ground sensing, the setting is a multiple of the phase CTs. This setting is independent of the GROUND PICKUP dial setting ranges from 0.1 to 16 times the ground CT rating.

For example: PHASE CT RATING: 100:5 (residual ground sensing); GROUND FAULT TRIP: 400 A
SETTINGS: Ground Fault Instantaneous = 4 ($4 \times 100 = 400$ A)

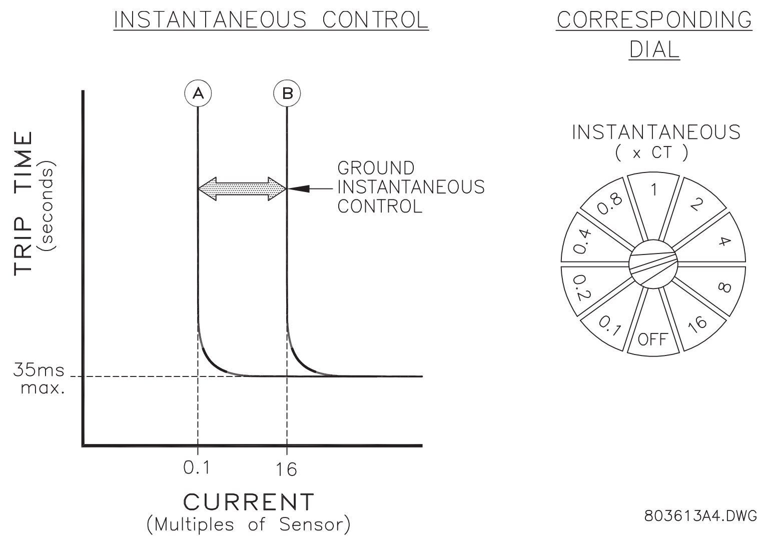

FIGURE 3–9: Ground Instantaneous Trip Setting

3.3 Indicators

3.3.1 Status Indicators [9]

Relay in Service

Immediately after applying control power, the 735/737 relay performs a series of self checks. Assuming all checks are successful, the RELAY IN SERVICE indicator comes on and protection is operational. Continuous checks are also made by the relay of its internal circuitry. If an internal failure is detected at any time, the RELAY IN SERVICE light goes out. The SERVICE REQUIRED indicator and the SERVICE output relays are activated to warn that protection is not functioning correctly. This is a serious condition that requires immediate attention since the relay may not respond correctly to a fault. Arrangements should be made to check or replace the relay. During simulation mode, this LED will be flashing.

Service Required

If self checks by the internal microprocessor detect a fault with the relay, this indicator goes on and the SERVICE output relay is activated to warn that protection is not functioning correctly. Failsafe operation of the SERVICE output relay by having the coil continuously energized under normal conditions, ensures that a SERVICE output will be obtained on loss of control power or when the relay is drawn out, even though the SERVICE REQUIRED indicator would be off under those conditions. This is a serious condition that requires immediate attention since the relay may not respond correctly to a fault. Arrangements should be made to check or replace the relay.

Phase Pickup

When the current in any phase exceeds the PHASE PICKUP control setting, this indicator flashes. If the condition persists, the 735/737 will time out and trip with the TRIP 51-A/B/C indicator on.

Ground Pickup

Flashes when ground (neutral) current from the residual phase CT or separate core balance CT input (depending on ground sensing connection) exceeds the GROUND PICKUP control setting. If the ground overcurrent persists, the 735/737 will time out and trip with the TRIP 51-N indicator on.

3.3.2 Trip Indicators [10]

Fault indicators are provided to determine the cause of trip. Each indicator is latched and remains set after a trip until cleared with the CLEAR key while control power is applied. When a trip occurs, the TRIP relay contacts are closed until the three-phase and neutral currents are all zero. The trip output relays seal in for a further 100 ms then open. After the trip relay opens, the trip LED will remain on steady until reset by pressing the CLEAR key at which time all the trip indicators go off. For example, if indicator INSTANTANEOUS-N is on, the last trip was caused by a ground (neutral) instantaneous trip.

Indicators are set for all phases or ground that exceeded the time overcurrent pickup or instantaneous setting at time of trip. Thus if indicators INSTANTANEOUS A and C are both on, a phase A to phase C fault occurred. If the breaker is closed after a trip without pressing the CLEAR key, the cause of trip indicator will remain on steady. However, at the next trip, the previous cause of trip indicator will be cleared so that only the most recent cause of trip indicator is on.

Hold the CLEAR key down for 2 seconds and the trip indicators will display in sequence the last five causes of trips, starting with the most recent. This trip record is useful for analyzing a recurring fault.

Phase Time O/C – A, B, C Trip Indicators

If the PHASE PICKUP level is exceeded long enough by any phase current to cause a trip according to the selected phase time overcurrent curve, a trip occurs and the corresponding A, B, or C indicator will be set to indicate a phase time overcurrent trip.

Phase Instantaneous A, B, C Trip Indicators

When the current in any phase exceeds the PHASE INSTANTANEOUS setting, the relay will trip and the corresponding A, B, or C indicator will be set to indicate a phase instantaneous trip.

Ground Time O/C Trip

If the ground (neutral) current exceeds the GROUND PICKUP level long enough to cause a trip according to the selected ground fault time overcurrent curve this indicator will be set to indicate a ground overcurrent trip.

Ground Instantaneous Trip

When the ground (neutral) current exceeds the GROUND INSTANTANEOUS setting, the relay will trip and this indicator will be set to indicate ground instantaneous trip.

3.3.3 Phase Current Indicator [12]

Maximum RMS current in any phase as a percentage of CT primary rating for the range 10 to 100% is displayed on this bargraph indicator. If current in all phases is below 10% of CT rating, all segments will be off. For currents above 100% of CT rating all segments will be on. All segments up to the actual current will be on for values between 10 and 100%.

For example:
CT RATING: 200:5
PHASE PICKUP: 70% of CT (LO)
PHASE CURVE: Normal inverse-LO
ACTUAL CURRENT: 165 A
DISPLAY: 165/200 = 83%
10% - 80% on
83% > 70% pickup so PHASE PICKUP indicator is flashing

3.4 Switches

3.4.1 Communication [11]

Switches are used to set the communication parameters. Move the switch to the right for a 1 or ON. To use the communications capability of the 735/737, a unique address must be chosen and the baud rate must match the system selected. Available baud rates of 1200, 2400, 9600, and 19200 are selected using switches 1 and 2 as follows: (ON = switch to right).

SWITCH 2	SWITCH 1	BAUD RATE
OFF	OFF	1200 baud
OFF	ON	2400 baud
ON	OFF	9600 baud
ON	ON	19200 baud

Chapter 4: COMMUNICATIONS describes the required data frame and message structure. Up to 31 relays (slaves) can be connected on a twisted pair communications link to a single master. Each relay must have a unique address from 1 to 31 or address conflicts will occur. Address 0 is reserved for broadcast mode and should not be used.

To select a given address, set switches 3 to 7 so the indicated numbers add up to the correct address. For example, address 14 = 2 (4 on) + 4 (5 on) + 8 (6 on), with remaining switches 3 (=0) and 7 (=0) off. When switch 8 "TEST" is on, the 735/737 will accept communication commands to simulate different dial settings with computer controlled phase and ground currents for testing and training purposes. Protection is disabled in the test position once simulation commands are received from the communication port. Set this switch OFF to disable simulation during normal operation.

3.4.2 Option Switches [14]

The option switches are selected according to the following table:

Table 3–1: Option Switches

SWITCHES								FUNCTION
1	2	3	4	5	6	7	8	
PHASE TIME OVERCURRENT SHIFT								
OFF	OFF	---	---	---	---	---	---	phase time overcurrent shift × 1.0
ON	OFF	---	---	---	---	---	---	phase time overcurrent shift × 0.5
OFF	ON	---	---	---	---	---	---	phase time overcurrent shift × 0.8
ON	ON	---	---	---	---	---	---	phase time overcurrent shift × 1.1

Table 3–1: Option Switches

SWITCHES								FUNCTION
1	2	3	4	5	6	7	8	
GROUND TIME OVERCURRENT SHIFT								
---	---	OFF	OFF	---	---	---	---	ground time overcurrent shift × 1.0
---	---	ON	OFF	---	---	---	---	ground time overcurrent shift × 0.5
---	---	OFF	ON	---	---	---	---	ground time overcurrent shift × 0.8
---	---	ON	ON	---	---	---	---	ground time overcurrent shift × 1.1
SYSTEM FREQUENCY								
---	---	---	---	OFF	---	---	---	frequency: 60 Hz
---	---	---	---	ON	---	---	---	frequency: 50 Hz
PICKUP/TRIP RELAYS – 737 ONLY								
---	---	---	---	---	OFF	OFF	---	pulsed trip only
---	---	---	---	---	ON	OFF	---	latched cause of trip only
---	---	---	---	---	OFF	ON	---	pickup only
---	---	---	---	---	ON	ON	---	pickup & latched cause of trip
CUSTOM SCHEME								
---	---	---	---	---	---	---	OFF	standard factory defaults
---	---	---	---	---	---	---	ON	programmed option settings

Phase Time Multiplier Shift

Although only 10 discrete curves can be selected for phase time overcurrent using the time multiplier dial, the trip times can be shifted to effectively create additional curves. This allows for more accurate coordination. To change the curve shift value, the relay must be drawn out from the captive chassis and the option switches on the side of the relay set according to the table above.

Use the following procedure to select the correct shift value:

- ▷ Plot the required curve for coordination.
- ▷ Select the closest curve shape
- ▷ Select the appropriate Time Multiplier and Phase Shift overcurrent combination to match the required curve trip times (refer to the examples below for details).

EXAMPLE 1:

The plotted curves falls on normally inverse curve number 4.

- ▷ Select:

  CURVE SHAPE: Normal Inverse
  TIME MULTIPLIER: 4

- ▷ Set the OPTION SWITCHES for a phase overcurrent shift of 1 (switches 1 and 2 both OFF).

EXAMPLE 2:

The plotted curve is approximately halfway in-between Very Inverse curves 5 and 6. In this case, select values for Phase Time O/C Shift and Time Multiplier that most closely match the required curve so that:

Time Multiplier x Phase Shift = 5.5

To meet this requirement, set Time Multiplier = 7 and Phase Time O/C Shift = 0.8. The selected curve will have an approximate time multiplier of 7 × 0.8 = 5.6. Select:

CURVE SHAPE: Very Inverse
TIME MULTIPLIER: 7

and set the option switches for a phase overcurrent shift of 0.8 (switch 1 OFF and switch 2 ON).

Ground Multiplier Shift

Ground time multiplier shift works exactly the same way as the phase shift time multiplier except that it affects the selected ground curve.

Frequency

Nominal system frequency should be set to determine the sample rate for optimum current measurement.

Pickup/Cause of Trip Relays (737 Only)

The 737 has 8 additional output relays fir more complex control schemes or for status signalling to a SCADA system. These are programmed with option switches 6 and 7 to energize on:

1. PULSED TRIP ONLY: In addition to the two form A common trip output contacts, a separate contact for each protection element will also activate. This makes the 737 the equivalent of 8 separate protection relays for interfacing to more complex protective relaying schemes. Relay output contacts for the 50/51 protection element that is causing the trip operate in the same manner as the common trip output contacts.
2. LATCHED CAUSE OF TRIP ONLY: After a trip, the relay(s) corresponding to the 50/51 element that caused the trip will be latched until the front panel CLEAR key is pressed or a "reset cause of trip" command is received through the communications port. The output relays energized will be the same as the TRIP indicators on the front panel. This is useful for interface to a SCADA system to diagnose the cause of trip.
3. PICKUP ONLY: Output relays activate when any phase/ground current is above the pickup setting. Relays automatically reset if the ground/phase current drops below the pickup level. This is useful for interface to a SCADA system to warn of faults which could lead to a trip if not corrected.
4. PICKUP OR CAUSE OF TRIP: Either pickup or latched cause of trip will energize the relays. This is the same as items 2 and 3 together.

Custom Scheme

In addition to basic protection, the 735/737 can be field configured to perform more complex protection logic using an internal non volatile setpoint memory. When "custom scheme" switch 8 on the side of the drawout relay is set to off, all custom scheme features are defeated so that the factory default shown for each option is active. Use the switch 8 off setting unless any of the special options listed here are required. With switch 8 set on, the internal setpoint memory settings described here are active. These can be factory preset at customer request or changed in the field using the `735SETUP` program running on a computer connected to the serial port.

If switch 8 is set on, use the `735SETUP` program to view settings by selecting the `Communicate > Setpoints > Custom Scheme` menu and modifying the settings as required. Interpretation of the entries from the `735SETUP` program screen is as follows:

CUSTOM SCHEME: Factory Default: DISABLED (switch 8 off)

This is a status indication only of the custom scheme enable switch #8 on the side of the drawout relay. It will read: DISABLED if switch 8 is off and ENABLED if switch 8 is on.

TIME OVERCURRENT CURVE SHAPE: Factory Default: ANSI

Selection of ANSI, IAC or IEC/BS142 time overcurrent curve shapes is specified with this setpoint. Consult the appropriate curve in Chapter 5 to determine trip times for the selected curve. Depending on the setting, phase and ground curve shape dials will be defined as:

Table 3–2:

ANSI	IAC	IEC/BS142
Moderately Inverse	Short Time	Short Time
Normal Inverse	Inverse	IEC A
Very Inverse	Very Inverse	IEC B
Extremely Inverse	Extremely Inverse	IEC C
Definite Time	Definite Time	Definite Time

BLOCK INSTANTANEOUS ON AUTORECLOSE: Factory Default: Disabled

When the 735 is used in conjunction with an autoreclose scheme, it may be desirable to block instantaneous trips after an autoreclosure operation. This prevents nuisance trips due to the normally high inrush currents typically experienced in these situations and allows a coordinated clearance of permanent faults by fuses or inverse-time overcurrent relays. A programmable phase and ground instantaneous trip block time from 0 to 180 seconds can be programmed with this setpoint. If this setpoint is enabled, when the 735 first detects current in any phase, it disables phase and ground instantaneous trips for the duration of this time setting. Time overcurrent protection however is enabled during this time.

AUX TRIP RELAY: Factory Default: MAIN TRIP (AUX relay follows TRIP relay)

The Auxiliary relay can be set to MAIN TRIP, 86 LOCKOUT, or GROUND TRIP.

- If MAIN TRIP is enabled the AUX relay follows the TRIP relay.

- If 86 LOCKOUT is enabled the AUX relay with output contacts connected to terminals G6 and H6 is programmed to act as an 86 Lockout relay. When untripped, the contacts are normally closed enabling the breaker close coil circuit. (If control power to the relay is not present, this contact opens effectively creating a lockout condition.) When a trip occurs, the trip contacts (G5/H5) will momentarily pulse to trip the breaker while the 86 Lockout contacts (G6/H6) will latch open preventing the close coil contacts from being activated. To restore the 86 Lockout contacts to the normally closed condition, either the front panel CLEAR key must be pressed to clear the trip condition and indicators, or a “Trip Reset” command must be received via the communications serial port. If the 86 Lockout relay is not reset and control power is lost, the 86 Lockout contacts will remain in the lockout condition after power is restored.
- If GROUND TRIP is enabled the AUX relay will respond only to TIMED or INSTANTANEOUS Ground Faults. Phase O/C Trips will only trip the TRIP relay. Ground Fault Trips will only trip the AUX relay.

3.5 Setup Program

3.5.1 Description

The `735SETUP` program can be run for training/testing purposes to read relay actual values, print out settings and simulate operation of the relay from a computer running MS-DOS. See Section 2.2.4 *Communications* for installation procedures. When the relay is properly connected for communications, put the setup disk in the current drive and type: "`735SETUP`" ("`737SETUP`" for 737 unit).

Menus are used to select the desired operation. Use a mouse or the arrow keys to select the desired menu item. Command choices appear on the left side of the screen. Communication status and COM port in use are shown on the bottom of the screen. In the upper right area of the screen the software revision will be displayed. Screen information can be printed on the computer printer by pressing the F2 key when the desired screen is being displayed. This is useful for obtaining a hardcopy of simulations for later reference.

The menus outlined below are used to establish communication with the relay, read/save setpoints to a computer file, configure computer settings and provide product information.

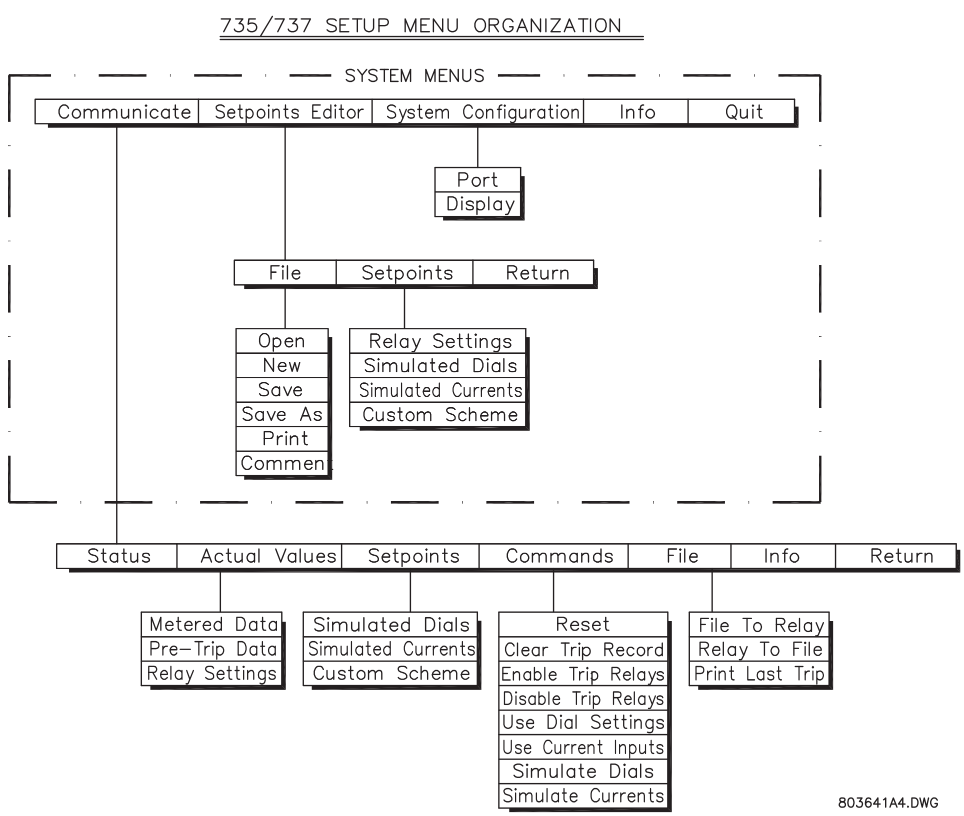

FIGURE 3–10: Setup Software System Menus

3.5.2 Communicate

Select Communicate to establish communication with the connected relay. Set the front panel COMMUNICATION switches to 9600 baud, address 1, test = ON, then apply power to the relay. When successful communications is established, a message will be displayed near the bottom of the screen. If the message indicates unsuccessful communications, check communication switch settings and wiring connections between the relay, computer and RS232/485 converter. Also ensure that the correct computer COM port is being used. When communications is established, the screen displays menus with Status selected.

3.5.3 Setpoints Editor

SETPOINTS EDITOR > FILE > OPEN:

Retrieve a setpoint file from the disk. All relay values, with the exception of actual dial settings, can be modified and saved back to disk either as the same file or as a new one. This is useful for creating different relay setups.

Starting from version D1.3, a File List Window will pop up to select a setpoint file. The File List window displays file names in the current directory, the parent directory, and all subdirectories. You can enter a file name explicitly or enter a file name with standard DOS wildcards (`*` and `?`) to filter the names appearing in the window. You can use arrows to select a file name, and then press Enter to open it. You can also double click your left mouse button to open any file displayed in the window.

SETPOINTS EDITOR > FILE > NEW:

Loads factory default settings into the computer memory. These can be used as a starting point for making new relay setups.

SETPOINTS EDITOR > FILE > SAVE:

Saves the settings in the computer memory to the file on the currently selected disk which was originally loaded. The original file is overwritten.

SETPOINTS EDITOR > FILE > SAVE AS:

Saves the settings in the computer memory to a new file. A File List window, identical to the one in `Setpoints > File > Open`, will pop up to enter a new file name to be saved to the disk.

SETPOINTS EDITOR > FILE > PRINT:

Print all the settings in the computer memory to obtain a hard copy. A File List window identical to the one in `Setpoints > File > Open` will pop up to select the file to print.

SETPOINTS EDITOR > FILE > COMMENT:

User comments typed with this menu selection will be added to the saved file and printed out on a hardcopy. This is useful for documenting relay types and comments for a specific application.

SETPOINTS EDITOR > SETPOINTS > SIMULATED DIALS:

To create a relay simulation setup using simulated protection settings from the computer instead of the relay dials themselves enter the required settings with this menu. After saving entered values different simulation setups can be recalled later with `Setpoints > File > Open` menu to save having to re-enter different test settings.

SEPOINTS EDITOR > SETPOINTS > SIMULATED CURRENTS:

Required currents for a specific test are entered using this menu. When used in conjunction with the simulated dials menu, a complete test setup can be created. Once the required setup has been entered in the computer memory, use `Setpoints > File > Save As` to save to a file for later recall and downloading to the relay being tested.

RETURN:

When using a mouse, click on this menu to move cursor up to the next higher menu level. This selection is the same as pressing the ESCAPE key.

3.5.4 System Configuration

SYSTEM CONFIGURATION > PORT:

Enter the computer COM port that is being used for communication to the relay. Usually this will be COM1:

SYSTEM CONFIGURATION > DISPLAY:

Color, monochrome, and black and white displays are supported by the `735SETUP` program. Select the display type that best matches the computer system used.

INFO:

Product features are displayed in this screen for reference. No operation is performed when this menu item is selected.

QUIT:

Exit the `735SETUP` program back to DOS

3.5.5 Status

Once communication with the relay is established menus are used for direct communication with the relay to read actual values, read settings and simulate relay operation. When screen values are changed, the modified data is sent immediately to the connected relay. These menu items are shown and described below.

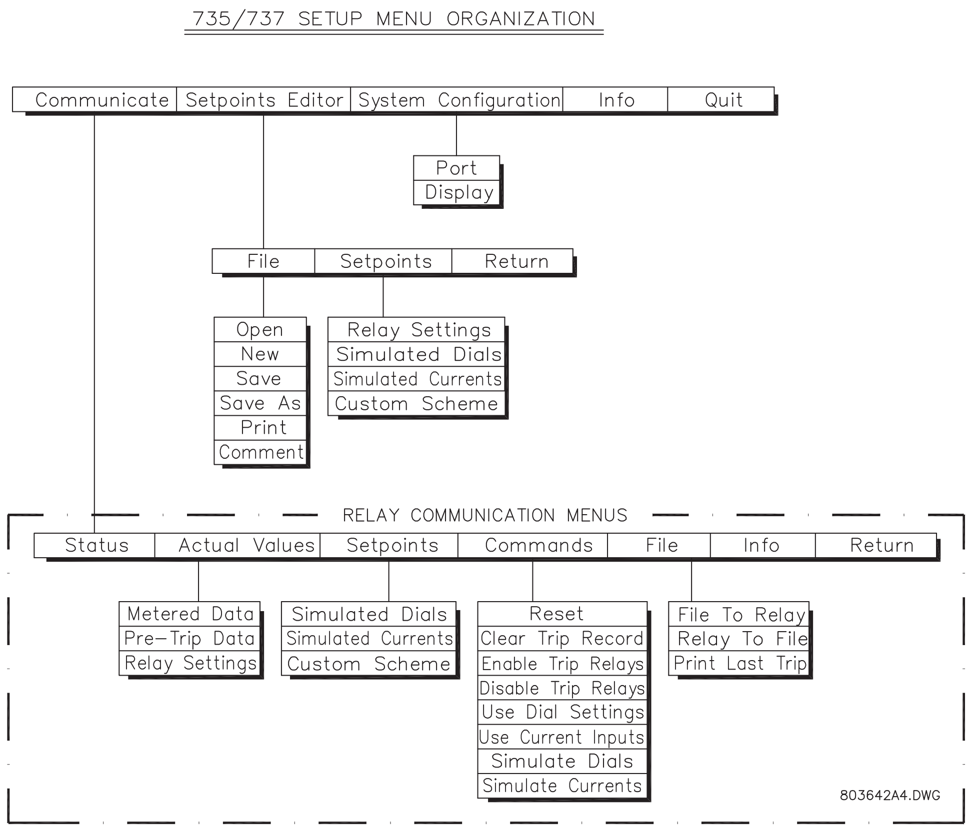

FIGURE 3–11: Setup Software Relay Communication Menus

The computer screen is a mimic of the relay front panel indicators. It shows status, pickup, cause of trip indicators and the current bargraph. The computer screen information is constantly updated to agree with the relay front panel indications.

3.5.6 Actual Values

ACTUAL VALUES > METERED DATA:

Actual phase A B C and ground current being measured by the relay are displayed. If the relay is in simulation mode, the displayed current will be the programmed simulation current.

ACTUAL VALUES > PRE-TRIP DATA:

After the relay trips, all currents and cause of trip are saved by the relay. This screen shows the information present at time of trip and the cause of trip. Normally this pre-trip information is used when the relay is connected in a communication network to diagnose the fault that caused the trip. When used with the `735SETUP` program it confirms how the relay will operate and appear under simulated fault conditions which is useful for training and product understanding.

ACTUAL VALUES > RELAY SETTINGS:

Actual dial and option switch settings on the relay are displayed on the screen. This is useful for verification prior to installation that intended settings have in fact been set correctly. Use the `File > Relay To File` menu selection to save these displayed settings to a file for future reference.

3.5.7 Setpoints

SETPOINTS > SIMULATED DIALS:

When doing simulations, protection settings can be either the actual relay dials on the front panel or simulated settings from the computer. If simulated settings are to be used, enter them using this menu selection.

SETPOINTS > /SIMULATED CURRENTS:

If a current injection set is available, actual currents can be injected into the relay via its rear terminals for testing. Fault simulations can also be simulated using only a computer by entering required currents with this menu.

SETPOINTS > CUSTOM SCHEME:

Custom scheme setpoints can be selected on the screen. This allows the relay to be configured using one of three curve types, Aux relay assignment and block instantaneous. Switch 8 on the side of the relay must be ON for the setpoints to be used.

3.5.8 Commands

COMMANDS > RESET:

Clear the trip target indicators on the front of the relay if any are set by executing this command. It has the same effect as pressing the CLEAR key on the front of the relay.

COMMANDS > CLEAR TRIP RECORD:

Clear the trip record stored in the pre-trip data page of the relay to none.

COMMANDS > ENABLE TRIP RELAYS:

Whenever the relay trips during testing the output trip relays will activate. This is the normal default when TEST switch 8 is first turned on. Use this mode for activating a test set timer to verify actual operation of the relay.

COMMANDS > /DISABLE TRIP RELAYS:

If testing is to be done in a situation where the trip relay outputs would shut down equipment, the trip relays can be disabled to prevent this. Select this mode of operation before injecting currents or issuing the "Simulate Currents" command. If the output relays are disabled, no protection is provided to the switchgear. Returning the TEST switch 8 to the off position after issuing this command re-enables all trip relays and full protection is restored.

COMMANDS > /USE DIAL SETTINGS:

Select this item if the desired protection settings for the simulation are to be from the relay front panel dials. The relay front panel TEST switch 8 must be on for simulation mode to work.

COMMANDS > /USE CURRENT INPUTS:

The relay will use actual currents from its rear terminal inputs for all readings. A current injection set would need to be connected to the relay during simulation to use this mode. The relay front panel TEST switch 8 must be on for simulation mode to work.

COMMANDS > SIMULATE DIALS:

Protection settings can be generated from the computer instead of the actual dials on the front of the relay. Use this menu to simulate dial settings from the computer and see the effect that changes make during simulation. Enter the desired settings with the `Setpoints > Simulated Dials` menu before executing this command. Relay front panel TEST switch 8 must be on for simulation mode to work.

COMMANDS > SIMULATE CURRENTS:

Once desired current values for a fault simulation have been entered into the computer using the `Setpoints > Simulated Currents` menu, make the relay see these currents by executing this menu selection. Protection timeout begins as soon as the relay receives the command over the serial communications link. After a trip, the relay will return to `Command > Use Current Inputs` mode and the `Command > Simulate Currents` command must be executed for each new trip simulation. The relay front panel TEST switch 8 must be on for simulation mode to work.

3.5.9 File

FILE > FILE TO RELAY:

Transfer all settings except the actual relay settings from a file on the disk in the default directory to the relay connected to the computer. Previously saved simulation setups can be automatically loaded this way.

FILE > RELAY TO FILE:

Transfer all settings in the relay connected to the computer to a file on the disk in the default drive. When used with the print command in `Setpoints Editor > File`, this is useful for making hardcopy records of relay settings prior to installation in the field.

FILE > PRINT LAST TRIP:

Print a hard copy of relay settings and pre-trip data to the printer. If the relay is in dial simulation mode, the simulation settings are printed, otherwise the real relay settings are printed. This feature is useful to keep a hard copy of the last fault simulation.

INFO

Product features are displayed in this screen for reference. No operation is performed when this menu item is selected.

RETURN

When using a mouse, click on this menu to move cursor up to the next higher menu level. This selection is the same as pressing the ESCAPE key.

3.6 Setup Example

3.6.1 Example Requirements and Settings

Refer to Section *3.2: Controls* for the corresponding dial settings.

CTs: 600:5

The primary CT current rating (600 A) affects phase and ground pickup and instantaneous dials since these are a percentage of CT sensor. Check label on side of drawout chassis to ensure the relay is configured for 5 A CTs.

Phase Time Overcurrent Pickup: 360 A

$$\frac{\text{Setting}}{\text{CT Primary}} = \frac{360}{600} = 60\%$$

Set the PHASE PICKUP dial to 60%. Note this is the LO band used in setting the PHASE CURRENT SHAPE dial.

Phase Current Shape: Normal Inverse

Set PHASE CURVE SHAPE to Normal Inverse-LO to match the PHASE PICKUP dial setting on LO band (60% of sensor)

Phase Time Multiplier: 1 second at 4 × PU

From system co-ordination curves, choose the closest matching curve by overlaying the required curve shape with the curve figures or reading off a trip time point for a given shape. Assuming an ANSI Normal Inverse curve with a trip time of 1 second at 4 × PU, this is curve multiplier 2. Set the PHASE TIME MULTIPLIER to 2. Set phase o/c curve shift to 1 (option switches 2=OFF 1=OFF).

Phase Instantaneous: 6000 A

$$\frac{\text{Setting}}{\text{CT Ratio}} = \frac{6000}{600} = 10 \times \text{CT}$$

Set the PHASE INSTANTANEOUS to 10 (× CT). This setting is independent of the PHASE PICKUP setting used for time overcurrent trips.

Ground Sensing: Residual

Wire the ground current input using the phase CTs connected for residual sensing. Use the phase CT primary as the ground CT value in setting pickup and instantaneous ground settings.

Ground Fault Trip Level: 240 A

Ground current sensing is by residual connection of the phase CTs. If a separate ground CT is used for ground fault detection, use the primary value for the CT in calculating the GROUND PICKUP dial setting.

$$\frac{\text{Pickup Setting}}{\text{Sensor CT}} = \frac{240}{600} = 40\% \text{ of CT}$$

The GROUND PICKUP dial is set to 40 (% of CT) which falls on the LO band. Consequently, the selected ground curve shape must be on the LO band setting.

Ground Time Multiplier: 200 ms delay definite time

A fixed delay of 200 ms after ground fault detection is required for co-ordination so set the curve shape to DEFINITE TIME-LO. From the definite time curves to get a 200 ms delay, curve 2 is required with a ground time o/c shift of 1. Set GROUND TIME MULTIPLIER to 2. Set ground time o/c shift option switches 4=OFF, 3=OFF.

Ground Instantaneous Trip: None

Only the 200 ms delayed pickup of 240 A is required so set the GROUND INSTANTANEOUS dial to OFF.

Slave address: 10
Baud rate: 9600

For a baud rate of 9600, 2=on, 1=off. Choose the combination of numbers that adds up to the required slave address: 10 = 2 (4=on) + 8 (6=on), (3=off, 5=off, 7=off). Disable communications test mode for normal operations (Test 8=off). The switch settings are:

Table 3–3:

SWITCH	POSITION	SETTING
1	OFF	9600 baud
2	ON	
3	OFF	Address 10
4	ON	
5	OFF	
6	ON	
7	OFF	
8	OFF	Test OFF

Digital Energy
Multilin

735/737 Feeder Protection Relay

Chapter 4: Modbus Communications

4.1 Overview

4.1.1 Description

Communication with an external computer/PLC/SCADA system is useful for continuous status monitoring and for testing. Two wire RS485 or four wire RS422 communication interfaces are available; RS485 being the preferred type, with RS422 available as an option.

The 735/737 implements a subset of the AEG Modicon Modbus serial communication standard. Modbus protocol is hardware independent. The 735/737 supports RS485 and RS422 hardware configurations. Modbus is a single master / multiple slave type of protocol suitable for a multi-drop configuration as provided by RS485 hardware. Using RS485, up to 32 slaves can be daisy-chained together on a single communication channel. Due to address limitations only 31 735/737s can be put on a single channel. However, another model of relay could be added, increasing the number to 32.

735/737 relays are always Modbus slaves. They can not be programmed as Modbus masters. Computers, PLCs or SCADA systems are commonly programmed as masters. Modbus protocol exists in two versions: Remote Terminal Unit (RTU, binary) and ASCII. Only the RTU version is supported by the 735/737. Both monitoring and control are possible using read and write register commands. Commands are supported to provide additional functions.

4.1.2 Electrical Interface

The 735/737 Modbus implementation employs two-wire RS485 hardware (4 wire RS422 is also available). Data flow is bidirectional, referred to as half duplex. That is, data is never transmitted and received at the same time. For RS485 electrical interface, receive and transmit data alternate over the same 2 wires.

RS485 lines should be connected in a daisy chain configuration with terminating resistors installed at each end of the link (that is, at the master end and at the slave farthest from the master). The value of the terminating resistors should be approximately equal to the characteristic impedance of the line. A recommended wire type is Belden #9841, 24 AWG stranded, shielded twisted pair. This wire has a characteristic impedance of 120 Ω, thus requiring 120 Ω terminating resistors. It is also recommended that a 1 nF / 50 V bidirectional capacitor be put in series with the terminating resistors thus ensuring that the I/O terminals are biased correctly. Shielded wire should always be used to minimize noise. Polarity is important in RS485 communications. The '+' terminals of every device must be connected together. See Section 2.2.4 *Communications* for further wiring details.

4.1.3 Data Frame Format and Rate

One data frame of an asynchronous transmission to or from a 735/737 consists of 1 start bit, 8 data bits, and 1 stop bit to produce a 10 bit data frame. This is important for transmission through modems at high bit rates (11 bit data frames are not supported by some modems at bit rates of greater than 300 bps). Although Modbus protocol can be implemented at any standard communication speed, the 735/737 supports operation at 1200, 2400, 9600 and 19200 baud by front panel switch selection.

4.1.4 Data Packet Format

A complete request/response sequence consists of the following bytes transmitted as separate data frames:

Master Request Transmission:

SLAVE ADDRESS: 1 byte
FUNCTION CODE: 1 byte
DATA: variable number of bytes depending on FUNCTION CODE
CRC: 2 bytes

Slave Response Transmission:

SLAVE ADDRESS: 1 byte
FUNCTION CODE: 1 byte
DATA: variable number of bytes depending on FUNCTION CODE
CRC: 2 bytes

Slave Address:

This is the first byte of every transmission. It is the user-assigned address of the slave device that is to receive the message sent by the master. Each slave device must be assigned a unique address using the front panel switches and only the addressed slave will respond to a transmission that starts with its address.

In a master request transmission the SLAVE ADDRESS represents the address of the slave to which the request is being sent. In a slave response transmission the SLAVE ADDRESS represents the address of the slave that is sending the response. A master transmission with a SLAVE ADDRESS of 0 indicates a broadcast command. All slaves on the communication link will take action based on the transmission but no response will be made.

Function Code

This is the second byte of every transmission. Modbus defines function codes of 1 to 127. The 735/737 implements some of these functions. See section 4.3 for details of the supported function codes. In a master request transmission the FUNCTION CODE tells the slave what action to perform. In a slave response transmission if the FUNCTION CODE sent from the slave is the same as the FUNCTION CODE sent from the master then the slave performed the function as requested. If the high order bit of the FUNCTION CODE sent from the slave is a 1 (that is, if the FUNCTION CODE > 127) then the slave did not perform the function as requested and is sending an error or exception response.

Data

This will be a variable number of bytes depending on the FUNCTION CODE. Data may be actual values, setpoints, or addresses sent by the master to the slave or by the slave to the master. See Section *4.2: Supported Modbus Functions* for a description of the supported functions and the data required for each.

CRC

This is a two byte error checking code (see the following section for additional details).

4.1.5 Timing

Data packet synchronization is maintained by timing constraints. The receiving device must measure the time between the reception of characters. If three and one half character times elapse without receiving a new character or completion of the message, then the communication link must be reset (that is, all slaves start listening for a new transmission from the master). Thus at 9600 baud a delay of greater than $3.5 \times 1 / 9600 \times 10 = 3.6$ ms will cause the communication link to be reset.

4.1.6 Error Checking

The RTU version of Modbus includes a two byte CRC-16 (16 bit cyclic redundancy check) with every transmission. The CRC-16 algorithm essentially treats the entire data stream (data bits only; start, stop and parity ignored) as one continuous binary number. This number is first shifted left 16 bits and then divided by a characteristic polynomial (11000000000000101B). The 16 bit remainder of the division is appended to the end of the transmission, most significant byte first. The resulting message including CRC, when divided by the same polynomial at the receiver will give a zero remainder if no transmission errors have occurred.

If a 735/737 Modbus slave device receives a transmission in which an error is indicated by the CRC-16 calculation, the slave device will not respond to the transmission. A CRC-16 error indicates than one or more bytes of the transmission were received incorrectly and thus the entire transmission should be ignored in order to avoid the slave device performing any incorrect operation. The CRC-16 calculation is an industry standard method used for error detection. An algorithm is included here to assist programmers in situations where no standard CRC-16 calculation routines are available.

CRC-16 Algorithm:

Once the algorithm is complete, the working register “A” will contain the CRC value to be transmitted. Note that this algorithm requires the characteristic polynomial to be reverse bit ordered. The most significant bit of the characteristic polynomial is dropped since it does not affect the value of the remainder. The following symbols are used in the algorithm:

-->	data transfer
A	16 bit working register
AL	low order byte of A
AH	high order byte of A
CRC	16 bit CRC-16 value
i, j	loop counters
(+)	logical exclusive or operator
Di	ith data byte (i = 0 to N-1)
G	16 bit characteristic polynomial = 1010000000000001 with the MSbit dropped and bit order reversed
shr(x)	shift right (the LSbit of the low order byte of x shifts into a carry flag, a '0' is shifted into the MSbit of the high order byte of x, all other bits shift right one location)

The algorithm is:

```
1. FFFF hex --> A

2. 0 --> i

3. 0 --> j

4. Di (+) AL --> AL

5. j+1 --> j

6. shr(A)

7. is there a carry?No: go to 8.
Yes: G (+) A --> A

8. is j = 8?No: go to 5.
Yes: go to 9.

9. i+1 --> i

10. is i = N? No: go to 3.
Yes: go to 11.

11. A --> CRC
```

4.2 Supported Modbus Functions

4.2.1 Description

The following functions are supported by the 735/737:

- 03: Read Setpoints
- 04:Read Actual Values
- 05: Execute Operation
- 06: Store Single Setpoint (test/simulation)
- 07: Read Device Status
- 16: Store Multiple Setpoints (test/simulation)

4.2.2 Function Code 03: Read Setpoints

Modbus implementation: Read Holding Registers
735/737 implementation: Read Setpoints

For the Modbus implementation, "holding registers" are equivalent to memory locations reflecting the user switch settings. Holding registers are 16-bit (two byte) values transmitted high order byte first. Thus all setpoints are sent as two bytes. This function code allows the master to read setpoints from a slave device.

The slave response is the slave address, function code, a count of the number of data bytes to follow, the data itself and the CRC. Each data item (setpoint) is sent as a two byte number with the high order byte sent first. Note that broadcast mode is not allowed with this function. The master transmission will be ignored by all slaves if broadcast mode is used with this function code.

Message Format and Example:

Request slave 11 to respond with 3 setpoints starting at address 0040. For this example the setpoint data is:

Table 4–1:

ADDRESS	DATA
0040	0003
0041	0000
0042	0009

Table 4–2:

MASTER TRANSMISSION:	BYTES	EXAMPLE / DESCRIPTION	
SLAVE ADDRESS	1	11	message for slave 11
FUNCTION CODE	1	03	read setpoints
START ADDRESS	2	00 40	data starts at 0040h
NUMBER OF SETPOINTS	2	00 06	3 setpoints = 6 bytes

Table 4–2:

CRC	2	?? ??	CRC calculated by the master

SLAVE RESPONSE:	BYTES	EXAMPLE / DESCRIPTION	
SLAVE ADDRESS	1	11	response message from slave 11
FUNCTION CODE	1	03	read setpoints
BYTE COUNT	1	06	3 setpoints = 6 bytes
DATA #1	2	00 03	setpoints data at 0040h
DATA #2	2	00 00	setpoints data at 0041h
DATA #3	2	00 09	setpoints data at 0042h
CRC	2	?? ??	CRC calculated by the slave

4.2.3 Function Code 04: Read Actual Values

Modbus Implementation: Read Input Registers
735/737 Implementation: Read Actual Values

For the Modbus implementation, "input registers" are equivalent to 735/737 actual values. Input registers are 16 bit (two byte) values transmitted high order byte first. Thus all 735/737 actual values are sent as two bytes. This command allows the master to read a group of actual values from a slave device. The maximum number of actual values that can be read in one transmission is 60 in the 735/737. The slave response to this function code is the slave address, function code, a count of the number of data bytes to follow, the data itself, and the CRC. Each data item (actual value) is sent as a two byte number with the high order byte sent first.

The broadcast mode is not allowed with this function code. The master transmission will be ignored by all slaves if broadcast mode is used with this function code.

Message Format and Example:

Request slave 11 to respond with 1 actual value starting at address 0008. For this example the actual value in this address (0008) is 01AE.

Table 4–3:

MASTER TRANSMISSION:	BYTES	EXAMPLE / DESCRIPTION	
SLAVE ADDRESS	1	11	message for slave 11
FUNCTION CODE	1	04	read actual values
DATA STARTING ADDRESS	2	00 08	data starts at 0008h
NUMBER OF ACTUAL VALUES	2	00 01	1 actual value = 2 bytes
CRC	2	?? ??	CRC calculated by the master

SLAVE RESPONSE:	BYTES	EXAMPLE / DESCRIPTION	
SLAVE ADDRESS	1	11	response message from slave 11
FUNCTION CODE	1	04	read actual values

Table 4–3:

BYTE COUNT	1	06	1 actual value = 2 bytes
DATA	2	01 A3	data at 0008h
CRC	2	?? ??	CRC calculated by the slave

4.2.4 Function Code 05: Execute Operation

Modbus Implementation: Force Single Coil
735/737 Implementation: Execute Operation

This function code allows the master to request the 735/737 to perform specific operations. The operations that can be performed by the 735/737 are as follows:

Table 4–4:

OPCODE	FUNCTION	DESCRIPTION	OPCODE	FUNCTION	DESCRIPTION
01	clear	clear trip indicators	08	disable watchdog	reset main processor
02	remote settings	simulation dials	09	enable service	activate service relay & indicator
03	normal settings	front panel dials	0A	disable service	deactivate service relay & indicator
04	simulation on	simulation currents			
05	simulation off	actual currents	0B	disable relays	disable output relays
06	test I/O on	setpoint control of I/O	0C	enable relays	enable output relays
07	test I/O off	normal control of I/O	0D	clear last trips	clear 5 causes of last trips

Simulation and I/O test commands are for production testing and training simulation. Commands 02 - 07 will be ignored unless communications “TEST” switch 8 is on. When a REMOTE SETTINGS command is received (TEST switch=on) the front panel switch settings are replaced by the dial settings loaded into setpoint memory. Send command NORMAL SETTINGS to restore selection of front panel dial settings. If command SIMULATION ON is sent the actual phase and ground current are replaced by the pre-loaded values in setpoint memory. The relay will respond as if these are the actual dial settings and measured current values. This mode continues until power is lost or until the command “SIMULATION OFF” is received or TEST switch 8 is set to off. Setpoints used in this mode are stored in RAM memory and are erased when control power is lost. The relay may behave erratically if invalid values are loaded into setpoint memory.

To turn on relays, LEDs and the bargraph under computer control for testing purposes, the appropriate I/O test patterns are first loaded as setpoints using STORE SETPOINTS function 06 or 16. Then command “TEST I/O ON” is issued. Normal relay control of this I/O hardware is suspended and the test patterns in setpoint memory are substituted. This continues until a “TEST I/O OFF” command is received or control power is removed or TEST switch 8=off.

During testing, normal protection is disabled. As a safeguard, all test and simulation commands are ignored unless switch 8 is in the TEST on=1 position.

Message Format and Example:

Request slave 11 to execute operation code 1 (clear trip indicators).

Table 4–5:

MASTER TRANSMISSION:	BYTES	EXAMPLE / DESCRIPTION	
SLAVE ADDRESS	1	11	message for slave 11
FUNCTION CODE	1	05	execute operation
OPERATION CODE	2	00 01	operation code 1 = clear trip indicators
CODE VALUE	2	FF 00	perform function
CRC	2	?? ??	CRC calculated by the master

SLAVE RESPONSE:	BYTES	EXAMPLE / DESCRIPTION	
SLAVE ADDRESS	1	11	response message from slave 11
FUNCTION CODE	1	05	execute operation
OPERATION CODE	2	00 01	operation code 1 = clear trip indicators
CODE VALUE	2	FF 00	perform function
CRC	2	?? ??	CRC calculated by the slave

4.2.5 Function Code 06: Store Single Setpoint

Modbus Implementation: Preset Single Register
735/737 Implementation: Store Single Setpoint

This command allows the master to store a single setpoint into the memory of a slave device. The slave device response to this function code is to echo the entire master transmission. Note that broadcast mode is not allowed with this function code. When a broadcast transmission is sent by the master (that is, SLAVE ADDRESS = 0) the message will be ignored.

Message Format and Example:

Request slave 11 to store the value 039E in setpoint address 0049. After the transmission in this example is complete, setpoints address 0049 will contain the value 039E

.

Table 4–6:

MASTER TRANSMISSION:	BYTES	EXAMPLE / DESCRIPTION	
SLAVE ADDRESS	1	11	message for slave 11
FUNCTION CODE	1	06	store single setpoint
DATA STARTING ADDRESS	2	00 49	setpoint address 0049h
DATA	2	03 9E	data for address 0049h
CRC	2	?? ??	CRC calculated by the master

Table 4–6:

SLAVE RESPONSE:	BYTES	EXAMPLE / DESCRIPTION	
SLAVE ADDRESS	1	11	response message from slave 11
FUNCTION CODE	1	06	store single setpoint
DATA STARTING ADDRESS	2	00 49	setpoint address 0049h
DATA	2	03 9E	data stored in 0049h
CRC	2	?? ??	CRC calculated by the slave

4.2.6 Function Code 07: Read Status

Modbus Implementation: Read Exception Status
735/737 Implementation: Read General Status

This is a function used to quickly read the status of a selected relay. A short message length allows for rapid reading of status. The status byte returned is the lower 8 bits of the relay status register defined in the memory map. Note that broadcast mode is not allowed with this function code. The master transmission will be ignored by all slaves if broadcast mode is used with this function code.

Message Format and Example:

Request status from slave 11. The status is stored in actual values memory map location 0014H. Assume the value is 01101101b.

Table 4–7:

MASTER TRANSMISSION:	BYTES	EXAMPLE / DESCRIPTION	
SLAVE ADDRESS	1	11	message for slave 11
FUNCTION CODE	1	07	read device status
CRC	2	?? ??	CRC calculated by the master

SLAVE RESPONSE:	BYTES	EXAMPLE / DESCRIPTION	
SLAVE ADDRESS	1	11	response message from slave 11
FUNCTION CODE	1	07	read device status
CODE VALUE	1	6D	status = 001101101 (binary)
CRC	2	?? ??	CRC calculated by the slave

4.2.7 Function Code 16: Store Multiple Setpoints

Modbus Implementation: Preset Multiple Registers
735/737 Implementation: Store Multiple Setpoints

This function code allows multiple setpoints to be stored into the 735/737 memory for test purposes only. Modbus “registers” are 16 bit (two byte) values transmitted high order byte first. Thus all 735/737 setpoints are sent as two bytes. The slave device response to this function code is to echo the slave address, function code, starting address, the number of setpoints loaded, and the CRC.

For production testing and training simulation without a current source, setpoint values can be loaded into RAM. These are lost at power down. Using the multiple setpoints store command, phase and ground dial setting setpoints are first stored in memory. Simulated values for phase and ground current can also be loaded.

To enter simulation mode, “TEST” switch #8 must be on. Function code 05 execute operation sends command “SIMULATION ON”. If test switch 8 is off, this command is ignored. On receipt of the “SIMULATION ON” command values for phase and ground current from setpoint memory replace the actual measured currents.

The relay responds as if these current were actually being measured. If execute operation command "REMOTE SETTINGS" is also sent, front panel dial settings will be replaced by the previously sent dial setpoints. These values continue to be used until control power is removed or commands "SIMULATION OFF" and "NORMAL SETTINGS" is received or TEST switch 8=off.

Setpoint test patterns can also be stored for forcing relays and LEDs and the bargraph to test outputs. Using this setpoint store command the test pattern is first stored. The Execute Operation function 05 command “TEST I/O ON” is issued. The LEDs, relays and bargraph are driven by the test patterns stored in setpoints instead of relay control until command “TEST I/O OFF” is received, control power is lost or TEST switch 8=off.

Message Format and Example:

To perform a simulation on relay slave address 11H, the following simulated dial settings and input currents are required:

Table 4–8:

DIAL	REQUIRED VALUE	LOAD (H)	ADDR (H)
phase pickup	60% of CT	0005	0060
phase curve shape	normal inverse (LO)	0005	0061
phase time multiplier	7	0007	0062
phase instantaneous	off	0001	0063
ground pickup	100% of CT	000A	0064
ground curve shape	very inverse (HI)	0008	0065
ground time multiplier	3	0003	0066
ground instantaneous	0.8 x CT	0005	0067
phase current	120% of CT	0078	0068
ground current	50% of CT	0032	0069

▷ Set the communications TEST switch ON.

▷ Load the dial settings and current values in setpoint memory using this function code

- ▷ Issue the Function Code 5: EXECUTE OPERATION op code 02: REMOTE SETTINGS to select the dial settings from memory just sent.
- ▷ Issue the Function Code 5: EXECUTE OPERATION op code 04: SIMULATION ON to enable the relay to see the phase and ground currents loaded into setpoint memory. The relay will begin timing out if an overcurrent condition occurs.
- ▷ Issue the Function Code 5: EXECUTE OPERATION op code 05: SIMULATION OFF to remove the simulated current.

The master transmission / slave response message format example for this function code is shown on the following page:

Table 4–9:

MASTER TRANSMISSION:	**BYTES**	**EXAMPLE / DESCRIPTION**	
SLAVE ADDRESS	1	11	message for slave 11
FUNCTION CODE	1	10	store setpoint block
DATA STARTING ADDRESS	2	00 60	first setpoint address 0060h
NUMBER OF SETPOINTS	2	00 0A	10 setpoints
DATA BYTE COUNT	1	14	20 bytes of setpoint data
DATA #1	2	00 06	phase pickup = position 6
DATA #2	2	00 05	phase shape = position 5
DATA #3	2	00 07	phase time multiplier = 7
DATA #4	2	00 01	phase instantaneous = off
DATA #5	2	00 0A	ground pickup = 10 (100% of CT)
DATA #6	2	00 08	ground curve shape = 8 (very inverse)
DATA #7	2	00 03	ground time multiplier = 3
DATA #8	2	00 05	ground instantaneous = 5 (0.8 × CT)
DATA #9	2	00 78	phase current = 78 (120%)
DATA #10	2	00 32	ground current = 32 (50%)
CRC	2	?? ??	CRC calculated by the master

SLAVE RESPONSE:	**BYTES**	**EXAMPLE / DESCRIPTION**	
SLAVE ADDRESS	1	11	response message from slave 11
FUNCTION CODE	1	10	store setpoint block
DATA STARTING ADDRESS	2	00 50	block start address
NUMBER OF SETPOINTS	2	00 0A	10 setpoints (2 bytes each)
CRC	2	?? ??	CRC calculated by the slave

NOTE

For 16 bit transfers hi byte is transmitted first. For example, 0050h is transmitted 00h then 50h

4.2.8 Error Responses

When a 735/737 detects an error other than a CRC error, a response will be sent to the master. The most significant bit of the FUNCTION CODE byte will be set to 1 (that is, the function code sent from the slave will be equal to the function code sent from the master plus 128). The byte which follows it will be an exception code indicating the type of error that occurred. Transmissions received from the master with CRC errors will be ignored by the 735/737.

The slave response to an error (other than CRC error) will be:

- SLAVE ADDRESS: 1 byte
- FUNCTION CODE: 1 byte (with MSbit set to 1)
- EXCEPTION CODE: 1 byte
- CRC: 2 bytes

The 735/737 implements the following exception response codes.

- **01: ILLEGAL FUNCTION**: The function code transmitted is not one of the functions supported by the 735/737.
- **02: ILLEGAL DATA ADDRESS**: The address referenced in the data field transmitted by the master is not an allowable address for the 735/737.
- **03: ILLEGAL DATA VALUE**: The value referenced in the data field transmitted by the master is not within range for the selected data address.
- **06: BUSY, REJECTED MESSAGE**: The transmission was received error-free but the request could not be performed.
- **08: MEMORY PARITY ERROR**: A hardware error has occurred in the 735/737. For example, a RAM failure has occurred and the data requested cannot be sent.

4.3 Memory Map

4.3.1 Modbus Memory Map

The data stored in the 735/737 is grouped as actual values and setpoints. Setpoints can be read and written by a master computer. Actual values can only be read. All setpoints and actual values are stored as two byte values. That is, each address listed in the memory map is the address of a two byte value. Addresses are listed in hexadecimal. Data values (setpoint ranges, increments, etc.) are listed in decimal. Consult the units, step and range as well as format tables following the memory map for interpretation of register values.

Table 4–10: 735/737 MODBUS MEMORY MAP (Sheet 1 of 4)

GROUP	ADDR	DESCRIPTION	RANGE	STEP	UNITS	FORMAT	FACTORY DEFAULT
PRODUCT ID	0000	GE product device code	25, 26	---	---	F1	25=735,26=737
	0001	GE product hardware revision code	1 to 26	---	---	F1	4=D
	0002	GE product firmware revision code	1 to 255	---	---	F3	01, 00 = 1.0
	0003	GE product modification file number	0 to 1000	---	---	F1	0 = no mod
	0004	Reserved	---	---	---	---	---
	↓	↓	↓	↓	↓	↓	↓
	000F	Reserved	---	---	---	---	---
MONITORED DATA	0010	Phase A current	0 to 2000	1	% CT	F1	---
	0011	Phase B current	0 to 2000	1	% CT	F1	---
	0012	Phase C current	0 to 2000	1	% CT	F1	---
	0013	Ground current	0 to 2000	1	% CT	F1	---
	0014	Relay Status Register	---	1	---	F101	---
	0015	Output relays	---	---	---	F103	---
	0016	Not used	---	---	---	---	---
	0017	LEDs	---	---	---	F105	---
	0018	Bargraph	---	---	---	F106	---
	0019	Not used	---	---	---	---	---
	↓	↓	↓	↓	↓	↓	↓
	001F	Not used	---	---	---	---	---

Table 4–10: 735/737 MODBUS MEMORY MAP (Sheet 2 of 4)

GROUP	ADDR	DESCRIPTION	RANGE	STEP	UNITS	FORMAT	FACTORY DEFAULT
PRE-TRIP DATA	0020	Phase A pre-trip current	0 to 2000	1	% CT	F1	---
	0021	Phase B pre-trip current	0 - 2000	1	% CT	F1	---
	0022	Phase C pre-trip current	0 to 2000	1	% CT	F1	---
	0023	Ground pre-trip current	0 to 2000	1	% CT	F1	---
	0024	Cause of last trip	Bits	---	---	F113	---
	0025	Last OC trip time	0 to 65000	1	ms	F115	---
	0026	Cause of second last trip	Bits	---	---	F113	---
	0027	Cause of third last trip	Bits	---	---	F113	---
	0028	Cause of fourth last trip	Bits	---	---	F113	---
	0029	Cause of fifth last trip	Bits	---	---	F113	---
SYSTEM CONFIG	002A	Phase Pickup dial setting	1 to 19	1	dial	F108	---
	002B	Phase Curve Shape dial setting	1 to 10	1	dial	F107	---
	002C	Phase Time Multiplier dial setting	1 to 10	1	dial	F112	---
	002D	Phase Instantaneous dial setting	1 to 10	1	dial	F109	---
	002E	Ground Pickup dial setting	1 to 19	1	dial	F110	---
	002F	Ground Curve Shape dial setting	1 to 10	1	dial	F107	---
	0030	Ground Time Multiplier dial setting	1 to 10	1	dial	F112	---
	0031	Ground Instantaneous dial setting	1 to 10	1	dial	F111	---
	0032	Comm DIP switch setting	---	---	---	F102	---
	0033	Curve shift switch setting	---	---	---	F114	---
	0034	Reset switch status	0-1	1	1=on	F1	---
	0035	Not used	---	---	---	---	---
	↓	↓	↓	↓	↓	↓	↓
	004F	Not used	---	---	---	---	---
SETPOINTS DIAL SETTINGS FOR SIMULATION AND TEST I/O	0050	Phase Pickup dial (Remote)	1 to 19	1	dial	F108	0
	0051	Phase Curve Shape dial (Remote)	1 to 5	1	dial	F104	0
	0052	Phase Time Multiplier dial (Remote)	1 to 10	1	dial	F112	0
	0053	Phase Instantaneous dial (Remote)	1 to 10	1	dial	F109	0
	0054	Ground Pickup dial (Remote)	1 to 19	1	dial	F110	0
	0055	Ground Curve Shape dial (Remote)	1 to 5	1	dial	F104	0
	0056	Ground Time Multiplier dial (Remote)	1 to 10	1	dial	F112	0
	0057	Ground Instantaneous dial (Remote)	1 to 10	1	dial	F111	0
	0058	Phase A current (Simulation)	0 to 2000	1	% CT	F1	0
	0059	Phase B current (Simulation)	0 to 2000	1	% CT	F1	0
	005A	Phase C current (Simulation)	0 to 2000	1	% CT	F1	0

Table 4–10: 735/737 MODBUS MEMORY MAP (Sheet 3 of 4)

GROUP	ADDR	DESCRIPTION	RANGE	STEP	UNITS	FORMAT	FACTORY DEFAULT
	005B	Ground current (Simulation)	0 to 2000	1	% CT	F1	0
	005C	Output relays (Test - I/O)	Bits	---	---	F103	0
	005D	LED (Test - I/O)	Bits	---	---	F105	0
	005E	Bargraph (Test - I/O)	Bits	---	---	F106	0
	005F	Curve shift switch	Bits	---	---	F114	0
CUSTOM SCHEME	0060	Curve Shape	0 to 2	1	---	F116	0
	0061	Block Instantaneous	0 to 180	1	0=OFF	F117	OFF
	0062	Aux Trip Relay	0 to 2	1	---	F118	0

Table 4–10: 735/737 MODBUS MEMORY MAP (Sheet 4 of 4)

GROUP	ADDR	DESCRIPTION	RANGE	STEP	UNITS	FORMAT	FACTORY DEFAULT
COMMANDS	0063	Reset	0 to 1	1	1=reset	F1	0
	0064	Clear Last Trips	0 to 1	1	1=clear	F1	0
	0065	Not used	---	---	---	---	---
	↓	↓	↓	↓	↓	↓	↓
	006F	Not used	---	---	---	---	---

4.3.2 Memory Map Data Formats

Table 4–11: 735/737 MEMORY MAP DATA FORMATS (Sheet 1 of 6)

FORMAT	TYPE	DESCRIPTION
F1	UNSIGNED INTEGER	0 to 65535
F2	UNSIGNED INTEGER 1 DECIMAL PLACE	0 to 6553.5
F3	2 UNSIGNED CHARACTERS	0 to 255, 0 to 255
F4	SIGNED INTEGER	–32768 to 32767
F101	STATUS BYTE	XXXX XXXX XXXX XXX1 = Phase A pickup
		XXXX XXXX XXXX XX1X = Phase B pickup
		XXXX XXXX XXXX X1XX = Phase C pickup
		XXXX XXXX XXXX 1XXX = Ground pickup
		XXXX XXXX XXX1 XXXX = Relay in service
		XXXX XXXX XX1X XXXX = Service required
		XXXX XXXX X1XX XXXX = Test mode
		XXXX XXXX 1XXX XXXX = Relay tripped
		XXXX XXX1 XXXX XXXX = not used
		XXXX XX1X XXXX XXXX = not used
		XXXX X1XX XXXX XXXX = not used
		XXXX 1XXX XXXX XXXX = not used
		XXX1 XXXX XXXX XXXX = not used
		XX1X XXXX XXXX XXXX = trip relays disabled = 1
		X1XX XXXX XXXX XXXX = simulated dials = 1
		1XXX XXXX XXXX XXXX = simulated current = 1

Table 4–11: 735/737 MEMORY MAP DATA FORMATS (Sheet 2 of 6)

FORMAT	TYPE	DESCRIPTION
F102	DIP Switches	XXXX XXXX XXXX XXX1 = Switch 1 on=1
		XXXX XXXX XXXX XX1X = Switch 2 on = 1
		XXXX XXXX XXXX X1XX = Switch 3 on = 1
		XXXX XXXX XXXX 1XXX = Switch 4 on = 1
		XXXX XXXX XXX1 XXXX = Switch 5 on = 1
		XXXX XXXX XX1X XXXX = Switch 6 on = 1
		XXXX XXXX X1XX XXXX = Switch 7 on = 1
		XXXX XXXX 1XXX XXXX = Switch 8 on = 1
F103	MAIN OUTPUT RELAYS (READ ONLY)	XXXX XXXX XXXX XXX1 = Trip relay on = 1
		XXXX XXXX XXXX XX1X = Aux trip relay on =1
		XXXX XXXX XXXX X1XX = Service relay on = 1
		XXXX XXXX XXXX 1XXX = not used
		XXXX XXXX XXX1 XXXX = not used
		XXXX XXXX XX1X XXXX = not used
		XXXX XXXX X1XX XXXX = not used
		XXXX XXXX 1XXX XXXX = not used
F103 ctd.	737 OUTPUT RELAYS	XXXX XXX1 XXXX XXXX = Phase A time OC pickup/trip (51P-A)
		XXXX XX1X XXXX XXXX = Phase B time OC pickup/trip (51P-B)
		XXXX X1XX XXXX XXXX = Phase C time OC pickup/trip (51P-C)
		XXXX 1XXX XXXX XXXX = Ground time OC pickup/trip (51G)
		XXX1 XXXX XXXX XXXX = Phase A nest pickup/trip (50P-A)
		XX1X XXXX XXXX XXXX = Phase B nest pickup/trip (50P-B)
		X1XX XXXX XXXX XXXX = Phase C nest pickup/trip (50P-C)
		1XXX XXXX XXXX XXXX = Ground nest pickup/trip (50G)
F104	CURVE SHAPE SETPOINT	Definite time = 1
		Moderately Inverse = 2
		Normal Inverse = 3
		Very Inverse = 4
		Extremely Inverse = 5

Table 4–11: 735/737 MEMORY MAP DATA FORMATS (Sheet 3 of 6)

FORMAT	TYPE	DESCRIPTION
F105	LEDs (READ ONLY)	XXXX XXXX XXXX XXX1 = Phase A overcurrent LED on = 1
		XXXX XXXX XXXX XX1X = Phase B overcurrent LED on = 1
		XXXX XXXX XXXX X1XX = Phase C overcurrent LED on = 1
		XXXX XXXX XXXX 1XXX = Ground overcurrent LED on = 1
		XXXX XXXX XXX1 XXXX = Phase A instantaneous LED on = 1
		XXXX XXXX XX1X XXXX = Phase B instantaneous LED on = 1
		XXXX XXXX X1XX XXXX = Phase C instantaneous LED on = 1
		XXXX XXXX 1XXX XXXX = Ground instantaneous LED on = 1
		XXXX XXX1 XXXX XXXX = Phase pickup LED on = 1
		XXXX XX1X XXXX XXXX = Ground pickup LED on = 1
		XXXX X1XX XXXX XXXX = Relay in service LED on = 1
		XXXX 1XXX XXXX XXXX = Service required LED on = 1
F106	BARGRAPH (ACTUAL VALUE)	XXXX XXXX XXXX XXX1 = 100% indicator on = 1
		XXXX XXXX XXXX XX1X = 90% indicator on = 1
		XXXX XXXX XXXX X1XX = 80% indicator on = 1
		XXXX XXXX XXXX 1XXX = 70% indicator on = 1
		XXXX XXXX XXX1 XXXX = 60% indicator on = 1
		XXXX XXXX XX1X XXXX = 50% indicator on = 1
		XXXX XXXX X1XX XXXX = 40% indicator on = 1
		XXXX XXXX 1XXX XXXX = 30% indicator on = 1
		XXXX XXX1 XXXX XXXX = 20% indicator on = 1
		XXXX XX1X XXXX XXXX = 10% indicator on = 1
F107	CURVE SHAPE SWITCH	Definite time (low) = 1
		Definite time (high) = 2
		Moderately Inverse (low) = 3
		Moderately Inverse (high) = 4
		Normal Inverse (low) = 5
		Normal Inverse (high) = 6
		Very Inverse (low) = 7
		Very Inverse (high) = 8
		Extremely Inverse (low) = 9
		Extremely Inverse (high) = 10

Table 4–11: 735/737 MEMORY MAP DATA FORMATS (Sheet 4 of 6)

FORMAT	TYPE	DESCRIPTION
F108	PHASE PICKUP SWITCH	OFF = 1
		20 = 2
		30 = 3
		40 = 4
		50 = 5
		60 = 6
		70 = 7
		80 = 8
		90 = 9
		100 = 10
		110 = 11
		120 = 12
		130 = 13
		140 = 14
		150 = 15
		160 = 16
		180 = 17
		200 = 18
		220 = 19
F109	PHASE INSTANTANEOUS DIAL	OFF = 1
		4 = 2
		5 = 3
		6 = 4
		8 = 5
		10 = 6
		12 = 7
		14 = 8
		16 = 9
		20 = 10
F110	Ground fault pickup	OFF = 1
		15 = 2
		20 = 3
		25 = 4
		30 = 5
		35 = 6
		40 = 7
		45 = 8
		50 = 9
		55 = 10

Table 4–11: 735/737 MEMORY MAP DATA FORMATS (Sheet 5 of 6)

FORMAT	TYPE	DESCRIPTION
F110 ctd.		60 = 11
		65 = 12
		70 = 13
		75 = 14
		80 = 15
		85 = 16
		90 = 17
		95 = 18
		100 = 19
F111	GROUND INST DIAL	OFF = 1
		0.1 = 2
		0.2 = 3
		0.4 = 4
		0.8 = 5
		1 = 6
		2 = 7
		4 = 8
		8 = 9
		16 = 10
F112	TIME MULTIPLIER DIAL	1 = 1
		2 = 2
		3 = 3
		4 = 4
		5 = 5
		6 = 6

Table 4–11: 735/737 MEMORY MAP DATA FORMATS (Sheet 6 of 6)

FORMAT	TYPE	DESCRIPTION
		7 = 7
		8 = 8
		9 = 9
		10 = 10
F113	CAUSE OF TRIP	XXXX XXXX XXXX XXX1 = Phase A time OC trip
		XXXX XXXX XXXX XX1X = Phase B time OC trip
		XXXX XXXX XXXX X1XX = Phase C time OC trip
		XXXX XXXX XXXX 1XXX = Ground time OC trip
		XXXX XXXX XXX1 XXXX = Phase A inst trip
		XXXX XXXX XX1X XXXX = Phase B inst trip
		XXXX XXXX X1XX XXXX = Phase C inst trip
		XXXX XXXX 1XXX XXXX = Ground inst trip
F114	CURVE SHIFT SETPOINT	XXXX XXXX XXXX XXX1 = Switch 8 on = 1
		XXXX XXXX XXXX XX1X = Switch 7 on = 1
		XXXX XXXX XXXX X1XX = Switch 6 on = 1
		XXXX XXXX XXXX 1XXX = Switch 5 on = 1
		XXXX XXXX XXX1 XXXX = Switch 4 on = 1
		XXXX XXXX XX1X XXXX = Switch 3 on = 1
		XXXX XXXX X1XX XXXX = Switch 2 on = 1
		XXXX XXXX 1XXX XXXX = Switch 1 on = 1
F115	LAST OC TRIP TIME	0 to 65000 = Actual Trip Time
		65001 = Trip time > 65 seconds
		65535 = Time not available
F116	CURVE SHAPE	0 = ANSI
		1 = IAC
		2 = IEC/BS142
F117	BLOCK INSTANTANEOUS	0 = DISABLED
		1 to 180 seconds
F118	AUX TRIP RELAY	0 = Main Trip
		1 = 86 Lockout
		2 = Ground Trip

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Chapter 5: Overcurrent Curves

5.1 Overview

5.1.1 Description

This chapter lists the 3 possible curve types, and their corresponding curve shapes. They are listed as follows:

ANSI CURVES

- Moderately Inverse
- Normal Inverse
- Very Inverse
- Extremely Inverse
- Definite Time

IAC CURVES

- IAC Short Time
- IAC Inverse
- IAC Very Inverse
- IAC Extremely Inverse
- Definite Time

IEC/BS142 CURVES

- IEC Short Time
- IEC A (Normal Inverse)
- IEC B (Very Inverse)
- IEC C (Extremely Inverse)
- Definite Time

For the graphs shown in this chapter, the per unit value (on the x-axis) is given as:

$$\text{Per Unit } \frac{I}{I_0} = \frac{I}{(I_{pu} / 100) \times \text{CT}}$$

where: I = current input to relay
I_{pu} = pickup current setpoint
CT = CT secondary, that is1 or 5 A

5.2 ANSI Curves

5.2.1 ANSI Moderately Inverse Curves

The trip time is given by:

$$T = S \times M \times \left(A + \frac{B}{(I/I_{pu}) - C} + \frac{D}{((I/I_{pu}) - C)^2} + \frac{E}{((I/I_{pu}) - C)^3} \right)$$

where:
T = trip time (in seconds)
S = curve shift multiplier
M = 735/737 curve multiplier setpoint
I = input current (in amps)
Ipu = pickup current setpoint

A = 0.1735 (curve shape constant)
B = 0.6791 (curve shape constant)
C = 0.8000 (curve shape constant)
D = –0.0800 (curve shape constant)
E = 0.1271 (curve shape constant)

Table 5–1:

SHIFT S	CURVE M	CURRENT (per unit I/I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	9.744	1.351	0.757	0.478	0.382	0.332	0.302	0.281	0.267	0.255	0.247	0.221	0.209
	2	19.489	2.702	1.515	0.955	0.764	0.665	0.604	0.563	0.533	0.511	0.493	0.442	0.417
	3	29.233	4.053	2.272	1.433	1.145	0.997	0.906	0.844	0.800	0.766	0.740	0.663	0.626
	4	38.977	5.404	3.030	1.910	1.527	1.329	1.208	1.126	1.066	1.021	0.986	0.884	0.835
	5	48.722	6.755	3.787	2.388	1.909	1.662	1.510	1.407	1.333	1.277	1.233	1.105	1.043
	6	58.466	8.106	4.544	2.866	2.291	1.994	1.812	1.689	1.600	1.532	1.479	1.326	1.252
	7	68.210	9.457	5.302	3.343	2.672	2.327	2.114	1.970	1.866	1.788	1.726	1.547	1.461
	8	77.954	10.807	6.059	3.821	3.054	2.659	2.416	2.252	2.133	2.043	1.972	1.768	1.669
	9	87.699	12.158	6.817	4.298	3.436	2.991	2.718	2.533	2.400	2.298	2.219	1.989	1.878
	10	97.443	13.509	7.574	4.776	3.818	3.324	3.020	2.815	2.666	2.554	2.465	2.210	2.087
0.5	1	4.872	0.675	0.379	0.239	0.191	0.166	0.151	0.141	0.133	0.128	0.123	0.110	0.104
	2	9.744	1.351	0.757	0.478	0.382	0.332	0.302	0.281	0.267	0.255	0.247	0.221	0.209
	3	14.616	2.026	1.136	0.716	0.573	0.499	0.453	0.422	0.400	0.383	0.370	0.331	0.313
	4	19.489	2.702	1.515	0.955	0.764	0.665	0.604	0.563	0.533	0.511	0.493	0.442	0.417
	5	24.361	3.377	1.894	1.194	0.954	0.831	0.755	0.704	0.667	0.638	0.616	0.552	0.522
	6	29.233	4.053	2.272	1.433	1.145	0.997	0.906	0.844	0.800	0.766	0.740	0.663	0.626
	7	34.105	4.728	2.651	1.672	1.336	1.163	1.057	0.985	0.933	0.894	0.863	0.773	0.730
	8	38.977	5.404	3.030	1.910	1.527	1.329	1.208	1.126	1.066	1.021	0.986	0.884	0.835
	9	43.849	6.079	3.408	2.149	1.718	1.496	1.359	1.267	1.200	1.149	1.109	0.994	0.939
	10	48.722	6.755	3.787	2.388	1.909	1.662	1.510	1.407	1.333	1.277	1.233	1.105	1.043

Table 5–1:

SHIFT S	CURVE M	CURRENT (per unit I/I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	7.795	1.081	0.606	0.382	0.305	0.266	0.242	0.225	0.213	0.204	0.197	0.177	0.167
	2	15.591	2.161	1.212	0.764	0.611	0.532	0.483	0.450	0.427	0.409	0.394	0.354	0.334
	3	23.386	3.242	1.818	1.146	0.916	0.798	0.725	0.676	0.640	0.613	0.592	0.530	0.501
	4	31.182	4.323	2.424	1.528	1.222	1.064	0.967	0.901	0.853	0.817	0.789	0.707	0.668
	5	38.977	5.404	3.030	1.910	1.527	1.329	1.208	1.126	1.066	1.021	0.986	0.884	0.835
	6	46.773	6.484	3.636	2.292	1.833	1.595	1.450	1.351	1.280	1.226	1.183	1.061	1.002
	7	54.568	7.565	4.242	2.675	2.138	1.861	1.691	1.576	1.493	1.430	1.381	1.237	1.169
	8	62.364	8.646	4.847	3.057	2.443	2.127	1.933	1.802	1.706	1.634	1.578	1.414	1.335
	9	70.159	9.727	5.453	3.439	2.749	2.393	2.175	2.027	1.920	1.839	1.775	1.591	1.502
	10	77.954	10.807	6.059	3.821	3.054	2.659	2.416	2.252	2.133	2.043	1.972	1.768	1.669
1.1	1	10.719	1.486	0.833	0.525	0.420	0.366	0.332	0.310	0.293	0.281	0.271	0.243	0.230
	2	21.437	2.972	1.666	1.051	0.840	0.731	0.664	0.619	0.587	0.562	0.542	0.486	0.459
	3	32.156	4.458	2.499	1.576	1.260	1.097	0.997	0.929	0.880	0.843	0.814	0.729	0.689
	4	42.875	5.944	3.333	2.101	1.680	1.462	1.329	1.239	1.173	1.124	1.085	0.972	0.918
	5	53.594	7.430	4.166	2.627	2.100	1.828	1.661	1.548	1.466	1.404	1.356	1.215	1.148
	6	64.312	8.916	4.999	3.152	2.520	2.194	1.993	1.858	1.760	1.685	1.627	1.458	1.377
	7	75.031	10.402	5.832	3.677	2.940	2.559	2.326	2.167	2.053	1.966	1.898	1.701	1.607
	8	85.750	11.888	6.665	4.203	3.360	2.925	2.658	2.477	2.346	2.247	2.169	1.945	1.836
	9	96.469	13.374	7.498	4.728	3.780	3.290	2.990	2.787	2.640	2.528	2.441	2.188	2.066
	10	107.187	14.860	8.332	5.253	4.200	3.656	3.322	3.096	2.933	2.809	2.712	2.431	2.295

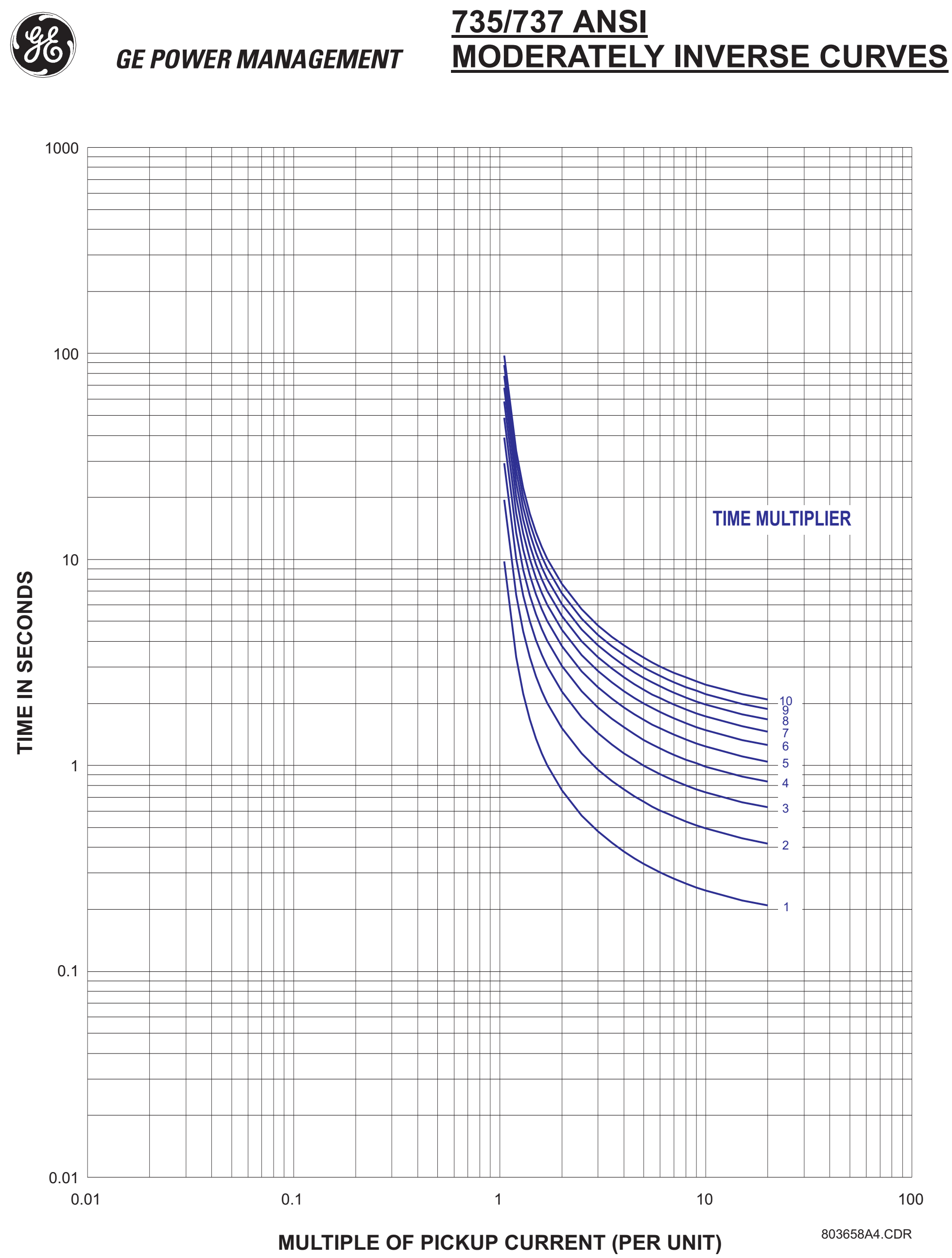

FIGURE 5–1: ANSI Moderately Inverse Curves

5.2.2 ANSI Normal Inverse Curves

The trip time is given by:

$$T = S \times M \times \left(A + \frac{B}{(I/I_{pu}) - C} + \frac{D}{((I/I_{pu}) - C)^2} + \frac{E}{((I/I_{pu}) - C)^3} \right)$$

where:
T = trip time (in seconds)
S = curve shift multiplier
M = 735/737 curve multiplier setpoint
I = input current (in amps)
Ipu = pickup current setpoint
A = 0.0274 (curve shape constant)
B = 2.2614 (curve shape constant)
C = 0.3000 (curve shape constant)
D = –4.1899 (curve shape constant)
E = 9.1272 (curve shape constant)

Table 5–2:

SHIFT S	CURVE M	CURRENT (per unit I /I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	17.229	4.284	1.766	0.754	0.513	0.407	0.344	0.302	0.270	0.246	0.226	0.165	0.133
	2	34.457	8.568	3.531	1.508	1.025	0.813	0.689	0.604	0.541	0.492	0.452	0.329	0.265
	3	51.686	12.852	5.297	2.262	1.538	1.220	1.033	0.906	0.811	0.737	0.678	0.494	0.398
	4	68.915	17.137	7.062	3.016	2.051	1.627	1.378	1.208	1.082	0.983	0.904	0.659	0.530
	5	86.143	21.421	8.828	3.769	2.563	2.034	1.722	1.509	1.352	1.229	1.130	0.823	0.663
	6	103.372	25.705	10.593	4.523	3.076	2.440	2.067	1.811	1.622	1.475	1.356	0.988	0.795
	7	120.600	29.989	12.359	5.277	3.589	2.847	2.411	2.113	1.893	1.721	1.582	1.153	0.928
	8	137.829	34.273	14.124	6.031	4.101	3.254	2.755	2.415	2.163	1.966	1.808	1.317	1.060
	9	155.058	38.557	15.890	6.785	4.614	3.661	3.100	2.717	2.433	2.212	2.034	1.482	1.193
	10	172.286	42.841	17.656	7.539	5.127	4.067	3.444	3.019	2.704	2.458	2.260	1.647	1.326
0.5	1	8.614	2.142	0.883	0.377	0.256	0.203	0.172	0.151	0.135	0.123	0.113	0.082	0.066
	2	17.229	4.284	1.766	0.754	0.513	0.407	0.344	0.302	0.270	0.246	0.226	0.165	0.133
	3	25.843	6.426	2.648	1.131	0.769	0.610	0.517	0.453	0.406	0.369	0.339	0.247	0.199
	4	34.457	8.568	3.531	1.508	1.025	0.813	0.689	0.604	0.541	0.492	0.452	0.329	0.265
	5	43.072	10.710	4.414	1.885	1.282	1.017	0.861	0.755	0.676	0.614	0.565	0.412	0.331
	6	51.686	12.852	5.297	2.262	1.538	1.220	1.033	0.906	0.811	0.737	0.678	0.494	0.398
	7	60.300	14.994	6.179	2.639	1.794	1.424	1.205	1.057	0.946	0.860	0.791	0.576	0.464
	8	68.915	17.137	7.062	3.016	2.051	1.627	1.378	1.208	1.082	0.983	0.904	0.659	0.530
	9	77.529	19.279	7.945	3.392	2.307	1.830	1.550	1.359	1.217	1.106	1.017	0.741	0.596
	10	86.143	21.421	8.828	3.769	2.563	2.034	1.722	1.509	1.352	1.229	1.130	0.823	0.663

Table 5–2:

SHIFTS	CURVEM	CURRENT (per unit I/I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	13.783	3.427	1.412	0.603	0.410	0.325	0.276	0.242	0.216	0.197	0.181	0.132	0.106
	2	27.566	6.855	2.825	1.206	0.820	0.651	0.551	0.483	0.433	0.393	0.362	0.263	0.212
	3	41.349	10.282	4.237	1.809	1.230	0.976	0.827	0.725	0.649	0.590	0.542	0.395	0.318
	4	55.132	13.709	5.650	2.412	1.641	1.302	1.102	0.966	0.865	0.787	0.723	0.527	0.424
	5	68.915	17.137	7.062	3.016	2.051	1.627	1.378	1.208	1.082	0.983	0.904	0.659	0.530
	6	82.697	20.564	8.475	3.619	2.461	1.952	1.653	1.449	1.298	1.180	1.085	0.790	0.636
	7	96.480	23.991	9.887	4.222	2.871	2.278	1.929	1.691	1.514	1.376	1.265	0.922	0.742
	8	110.263	27.418	11.300	4.825	3.281	2.603	2.204	1.932	1.730	1.573	1.446	1.054	0.848
	9	124.046	30.846	12.712	5.428	3.691	2.929	2.480	2.174	1.947	1.770	1.627	1.186	0.954
	10	137.829	34.273	14.124	6.031	4.101	3.254	2.755	2.415	2.163	1.966	1.808	1.317	1.060
1.1	1	18.952	4.713	1.942	0.829	0.564	0.447	0.379	0.332	0.297	0.270	0.249	0.181	0.146
	2	37.903	9.425	3.884	1.659	1.128	0.895	0.758	0.664	0.595	0.541	0.497	0.362	0.292
	3	56.855	14.138	5.826	2.488	1.692	1.342	1.137	0.996	0.892	0.811	0.746	0.543	0.437
	4	75.806	18.850	7.768	3.317	2.256	1.790	1.515	1.328	1.190	1.082	0.994	0.725	0.583
	5	94.758	23.563	9.711	4.146	2.820	2.237	1.894	1.660	1.487	1.352	1.243	0.906	0.729
	6	113.709	28.275	11.653	4.976	3.384	2.685	2.273	1.993	1.784	1.622	1.491	1.087	0.875
	7	132.661	32.988	13.595	5.805	3.948	3.132	2.652	2.325	2.082	1.893	1.740	1.268	1.021
	8	151.612	37.700	15.537	6.634	4.512	3.579	3.031	2.657	2.379	2.163	1.989	1.449	1.166
	9	170.564	42.413	17.479	7.463	5.076	4.027	3.410	2.989	2.677	2.433	2.237	1.630	1.312
	10	189.515	47.125	19.421	8.293	5.640	4.474	3.789	3.321	2.974	2.704	2.486	1.812	1.458

GE POWER MANAGEMENT

735/737 ANSI NORMAL INVERSE CURVE

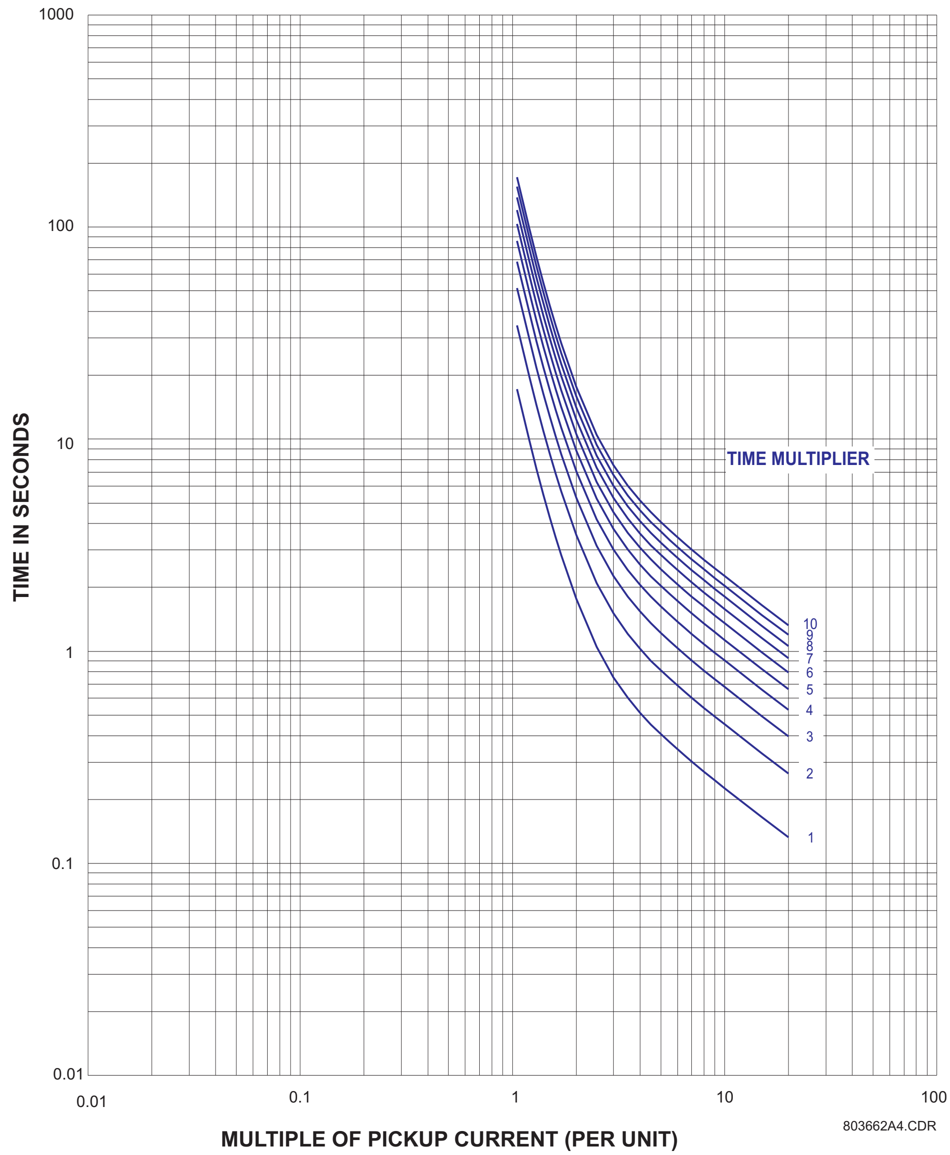

FIGURE 5–2: ANSI Normal Inverse Curves

5.2.3 ANSI Very Inverse Curves

The trip time is given by:

$$T = S \times M \times \left(A + \frac{B}{(I/I_{pu}) - C} + \frac{D}{((I/I_{pu}) - C)^2} + \frac{E}{((I/I_{pu}) - C)^3}\right)$$

where: T = trip time (in seconds)
S = curve shift multiplier
M = 735/737 curve multiplier setpoint
I = input current (in amps)
Ipu = pickup current setpoint

A = 0.0615 (curve shape constant)
B = 0.7989 (curve shape constant)
C = 0.3400 (curve shape constant)
D = –0.2840 (curve shape constant)
E = 4.0505 (curve shape constant)

Table 5–3:

SHIFT S	CURVE M	CURRENT (per unit I / I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	11.940	3.134	1.325	0.537	0.341	0.260	0.216	0.189	0.170	0.156	0.146	0.116	0.102
	2	23.881	6.268	2.650	1.074	0.682	0.520	0.432	0.378	0.340	0.312	0.291	0.232	0.204
	3	35.821	9.402	3.976	1.611	1.024	0.780	0.648	0.566	0.510	0.469	0.437	0.348	0.306
	4	47.762	12.537	5.301	2.148	1.365	1.040	0.864	0.755	0.680	0.625	0.583	0.464	0.408
	5	59.702	15.671	6.626	2.685	1.706	1.299	1.081	0.944	0.850	0.781	0.728	0.580	0.510
	6	71.642	18.805	7.951	3.221	2.047	1.559	1.297	1.133	1.020	0.937	0.874	0.696	0.612
	7	83.583	21.939	9.276	3.758	2.388	1.819	1.513	1.321	1.190	1.093	1.020	0.812	0.714
	8	95.523	25.073	10.602	4.295	2.730	2.079	1.729	1.510	1.360	1.250	1.165	0.928	0.815
	9	107.464	28.207	11.927	4.832	3.071	2.339	1.945	1.699	1.530	1.406	1.311	1.044	0.917
	10	119.404	31.341	13.252	5.369	3.412	2.599	2.161	1.888	1.700	1.562	1.457	1.160	1.019
0.5	1	5.970	1.567	0.663	0.268	0.171	0.130	0.108	0.094	0.085	0.078	0.073	0.058	0.051
	2	11.940	3.134	1.325	0.537	0.341	0.260	0.216	0.189	0.170	0.156	0.146	0.116	0.102
	3	17.911	4.701	1.988	0.805	0.512	0.390	0.324	0.283	0.255	0.234	0.218	0.174	0.153
	4	23.881	6.268	2.650	1.074	0.682	0.520	0.432	0.378	0.340	0.312	0.291	0.232	0.204
	5	29.851	7.835	3.313	1.342	0.853	0.650	0.540	0.472	0.425	0.391	0.364	0.290	0.255
	6	35.821	9.402	3.976	1.611	1.024	0.780	0.648	0.566	0.510	0.469	0.437	0.348	0.306
	7	41.791	10.969	4.638	1.879	1.194	0.910	0.756	0.661	0.595	0.547	0.510	0.406	0.357
	8	47.762	12.537	5.301	2.148	1.365	1.040	0.864	0.755	0.680	0.625	0.583	0.464	0.408
	9	53.732	14.104	5.963	2.416	1.535	1.169	0.973	0.849	0.765	0.703	0.655	0.522	0.459
	10	59.702	15.671	6.626	2.685	1.706	1.299	1.081	0.944	0.850	0.781	0.728	0.580	0.510

Table 5–3:

SHIFTS	CURVE M	CURRENT (per unit I /I_0)												
		1.05	**1.50**	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**7.00**	**8.00**	**9.00**	**10.00**	**15.00**	**20.00**
0.8	1	9.552	2.507	1.060	0.430	0.273	0.208	0.173	0.151	0.136	0.125	0.117	0.093	0.082
	2	19.105	5.015	2.120	0.859	0.546	0.416	0.346	0.302	0.272	0.250	0.233	0.186	0.163
	3	28.657	7.522	3.180	1.289	0.819	0.624	0.519	0.453	0.408	0.375	0.350	0.278	0.245
	4	38.209	10.029	4.241	1.718	1.092	0.832	0.692	0.604	0.544	0.500	0.466	0.371	0.326
	5	47.762	12.537	5.301	2.148	1.365	1.040	0.864	0.755	0.680	0.625	0.583	0.464	0.408
	6	57.314	15.044	6.361	2.577	1.638	1.247	1.037	0.906	0.816	0.750	0.699	0.557	0.489
	7	66.866	17.551	7.421	3.007	1.911	1.455	1.210	1.057	0.952	0.875	0.816	0.649	0.571
	8	76.418	20.058	8.481	3.436	2.184	1.663	1.383	1.208	1.088	1.000	0.932	0.742	0.652
	9	85.971	22.566	9.541	3.866	2.457	1.871	1.556	1.359	1.224	1.125	1.049	0.835	0.734
	10	95.523	25.073	10.602	4.295	2.730	2.079	1.729	1.510	1.360	1.250	1.165	0.928	0.815
1.1	1	13.134	3.448	1.458	0.591	0.375	0.286	0.238	0.208	0.187	0.172	0.160	0.128	0.112
	2	26.269	6.895	2.915	1.181	0.751	0.572	0.475	0.415	0.374	0.344	0.320	0.255	0.224
	3	39.403	10.343	4.373	1.772	1.126	0.858	0.713	0.623	0.561	0.515	0.481	0.383	0.336
	4	52.538	13.790	5.831	2.362	1.501	1.144	0.951	0.831	0.748	0.687	0.641	0.510	0.449
	5	65.672	17.238	7.289	2.953	1.877	1.429	1.189	1.038	0.935	0.859	0.801	0.638	0.561
	6	78.807	20.685	8.746	3.544	2.252	1.715	1.426	1.246	1.122	1.031	0.961	0.765	0.673
	7	91.941	24.133	10.204	4.134	2.627	2.001	1.664	1.453	1.309	1.203	1.122	0.893	0.785
	8	105.075	27.580	11.662	4.725	3.003	2.287	1.902	1.661	1.496	1.375	1.282	1.020	0.897
	9	118.210	31.028	13.119	5.315	3.378	2.573	2.140	1.869	1.683	1.546	1.442	1.148	1.009
	10	131.344	34.475	14.577	5.906	3.753	2.859	2.377	2.076	1.870	1.718	1.602	1.276	1.121

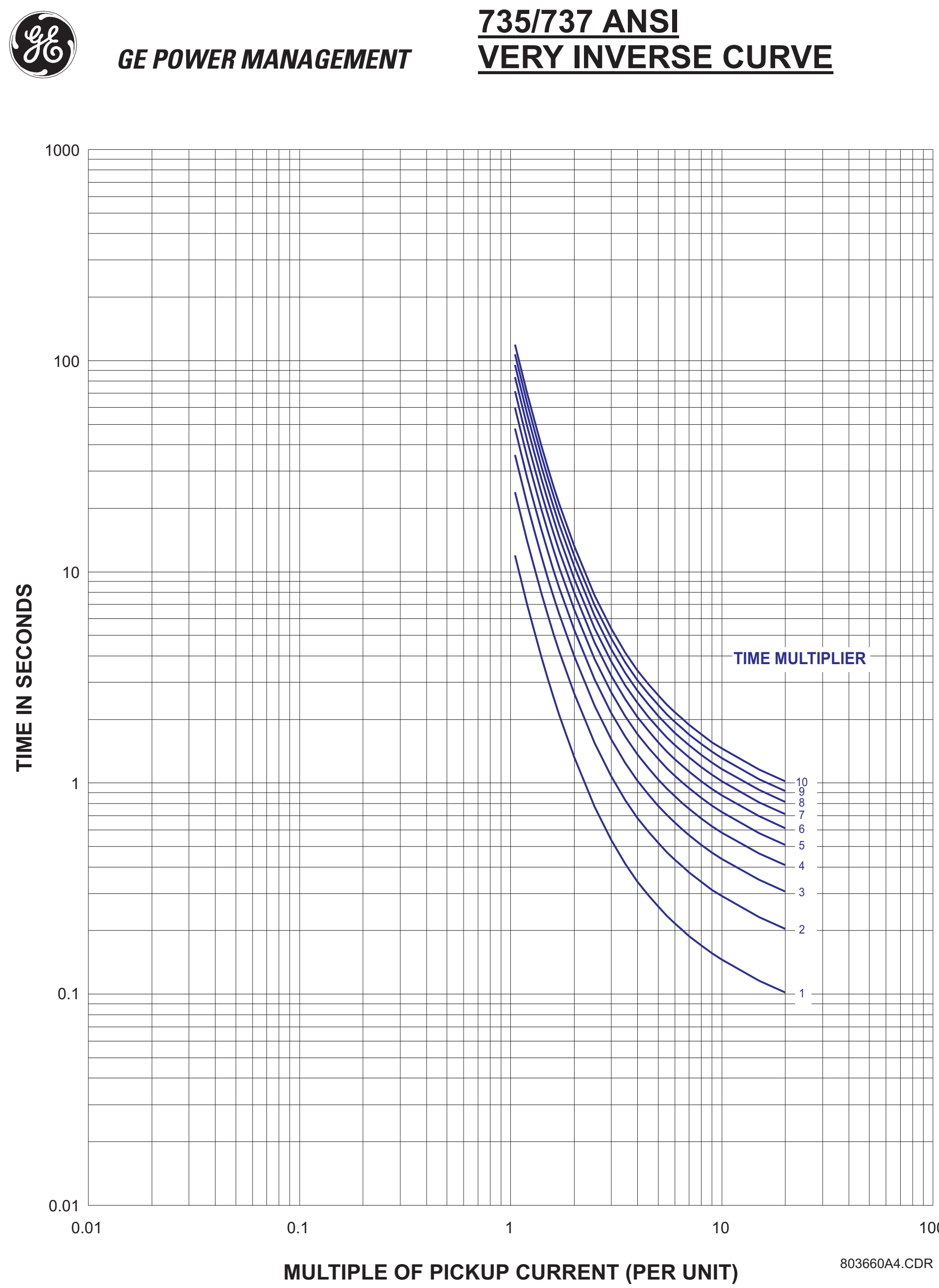

FIGURE 5–3: ANSI Very Inverse Curves

5.2.4 ANSI Extremely Inverse Curves

The trip time is given by:

$$T = S \times M \times \left(A + \frac{B}{(I/I_{pu}) - C} + \frac{D}{((I/I_{pu}) - C)^2} + \frac{E}{((I/I_{pu}) - C)^3} \right)$$

where: T = trip time (in seconds)
S = curve shift multiplier
M = 735/737 curve multiplier setpoint
I = input current (in amps)
Ipu = pickup current setpoint

A = 0.0399 (curve shape constant)
B = 0.2294 (curve shape constant)
C = 0.5000 (curve shape constant)
D = 3.0094 (curve shape constant)
E = 0.7222 (curve shape constant)

Table 5–4:

SHIFT S	CURVE M	CURRENT (per unit I /I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	14.746	4.001	1.744	0.659	0.368	0.247	0.185	0.149	0.126	0.110	0.098	0.070	0.060
	2	29.492	8.002	3.489	1.319	0.736	0.495	0.371	0.298	0.251	0.219	0.196	0.141	0.119
	3	44.239	12.003	5.233	1.978	1.104	0.742	0.556	0.447	0.377	0.329	0.295	0.211	0.179
	4	58.985	16.004	6.977	2.638	1.472	0.990	0.742	0.596	0.503	0.439	0.393	0.281	0.239
	5	73.731	20.005	8.722	3.297	1.840	1.237	0.927	0.745	0.628	0.549	0.491	0.351	0.298
	6	88.477	24.005	10.466	3.956	2.208	1.484	1.113	0.894	0.754	0.658	0.589	0.422	0.358
	7	103.224	28.006	12.210	4.616	2.576	1.732	1.298	1.043	0.880	0.768	0.688	0.492	0.418
	8	117.970	32.007	13.955	5.275	2.944	1.979	1.483	1.192	1.006	0.878	0.786	0.562	0.477
	9	132.716	36.008	15.699	5.934	3.312	2.227	1.669	1.341	1.131	0.987	0.884	0.632	0.537
	10	147.462	40.009	17.443	6.594	3.680	2.474	1.854	1.491	1.257	1.097	0.982	0.703	0.597
0.5	1	7.373	2.000	0.872	0.330	0.184	0.124	0.093	0.075	0.063	0.055	0.049	0.035	0.030
	2	14.746	4.001	1.744	0.659	0.368	0.247	0.185	0.149	0.126	0.110	0.098	0.070	0.060
	3	22.119	6.001	2.616	0.989	0.552	0.371	0.278	0.224	0.189	0.165	0.147	0.105	0.090
	4	29.492	8.002	3.489	1.319	0.736	0.495	0.371	0.298	0.251	0.219	0.196	0.141	0.119
	5	36.866	10.002	4.361	1.648	0.920	0.619	0.464	0.373	0.314	0.274	0.246	0.176	0.149
	6	44.239	12.003	5.233	1.978	1.104	0.742	0.556	0.447	0.377	0.329	0.295	0.211	0.179
	7	51.612	14.003	6.105	2.308	1.288	0.866	0.649	0.522	0.440	0.384	0.344	0.246	0.209
	8	58.985	16.004	6.977	2.638	1.472	0.990	0.742	0.596	0.503	0.439	0.393	0.281	0.239
	9	66.358	18.004	7.849	2.967	1.656	1.113	0.834	0.671	0.566	0.494	0.442	0.316	0.269
	10	73.731	20.005	8.722	3.297	1.840	1.237	0.927	0.745	0.628	0.549	0.491	0.351	0.298

Table 5–4:

SHIFTS	CURVE M	CURRENT (per unit I /I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	11.797	3.201	1.395	0.528	0.294	0.198	0.148	0.119	0.101	0.088	0.079	0.056	0.048
	2	23.594	6.401	2.791	1.055	0.589	0.396	0.297	0.238	0.201	0.176	0.157	0.112	0.095
	3	35.391	9.602	4.186	1.583	0.883	0.594	0.445	0.358	0.302	0.263	0.236	0.169	0.143
	4	47.188	12.803	5.582	2.110	1.177	0.792	0.593	0.477	0.402	0.351	0.314	0.225	0.191
	5	58.985	16.004	6.977	2.638	1.472	0.990	0.742	0.596	0.503	0.439	0.393	0.281	0.239
	6	70.782	19.204	8.373	3.165	1.766	1.188	0.890	0.715	0.603	0.527	0.472	0.337	0.286
	7	82.579	22.405	9.768	3.693	2.061	1.386	1.038	0.835	0.704	0.614	0.550	0.394	0.334
	8	94.376	25.606	11.164	4.220	2.355	1.583	1.187	0.954	0.804	0.702	0.629	0.450	0.382
	9	106.173	28.806	12.559	4.748	2.649	1.781	1.335	1.073	0.905	0.790	0.707	0.506	0.430
	10	117.970	32.007	13.955	5.275	2.944	1.979	1.483	1.192	1.006	0.878	0.786	0.562	0.477
1.1	1	16.221	4.401	1.919	0.725	0.405	0.272	0.204	0.164	0.138	0.121	0.108	0.077	0.066
	2	32.442	8.802	3.838	1.451	0.809	0.544	0.408	0.328	0.277	0.241	0.216	0.155	0.131
	3	48.663	13.203	5.756	2.176	1.214	0.816	0.612	0.492	0.415	0.362	0.324	0.232	0.197
	4	64.883	17.604	7.675	2.901	1.619	1.089	0.816	0.656	0.553	0.483	0.432	0.309	0.263
	5	81.104	22.005	9.594	3.627	2.024	1.361	1.020	0.820	0.691	0.603	0.540	0.386	0.328
	6	97.325	26.406	11.513	4.352	2.428	1.633	1.224	0.984	0.830	0.724	0.648	0.464	0.394
	7	113.546	30.807	13.431	5.077	2.833	1.905	1.428	1.148	0.968	0.845	0.756	0.541	0.460
	8	129.767	35.208	15.350	5.803	3.238	2.177	1.632	1.312	1.106	0.966	0.864	0.618	0.525
	9	145.988	39.609	17.269	6.528	3.643	2.449	1.836	1.476	1.244	1.086	0.973	0.696	0.591
	10	162.208	44.010	19.188	7.253	4.047	2.722	2.040	1.640	1.383	1.207	1.081	0.773	0.656

GE POWER MANAGEMENT

735/737 ANSI EXTREMELY INVERSE CURVE

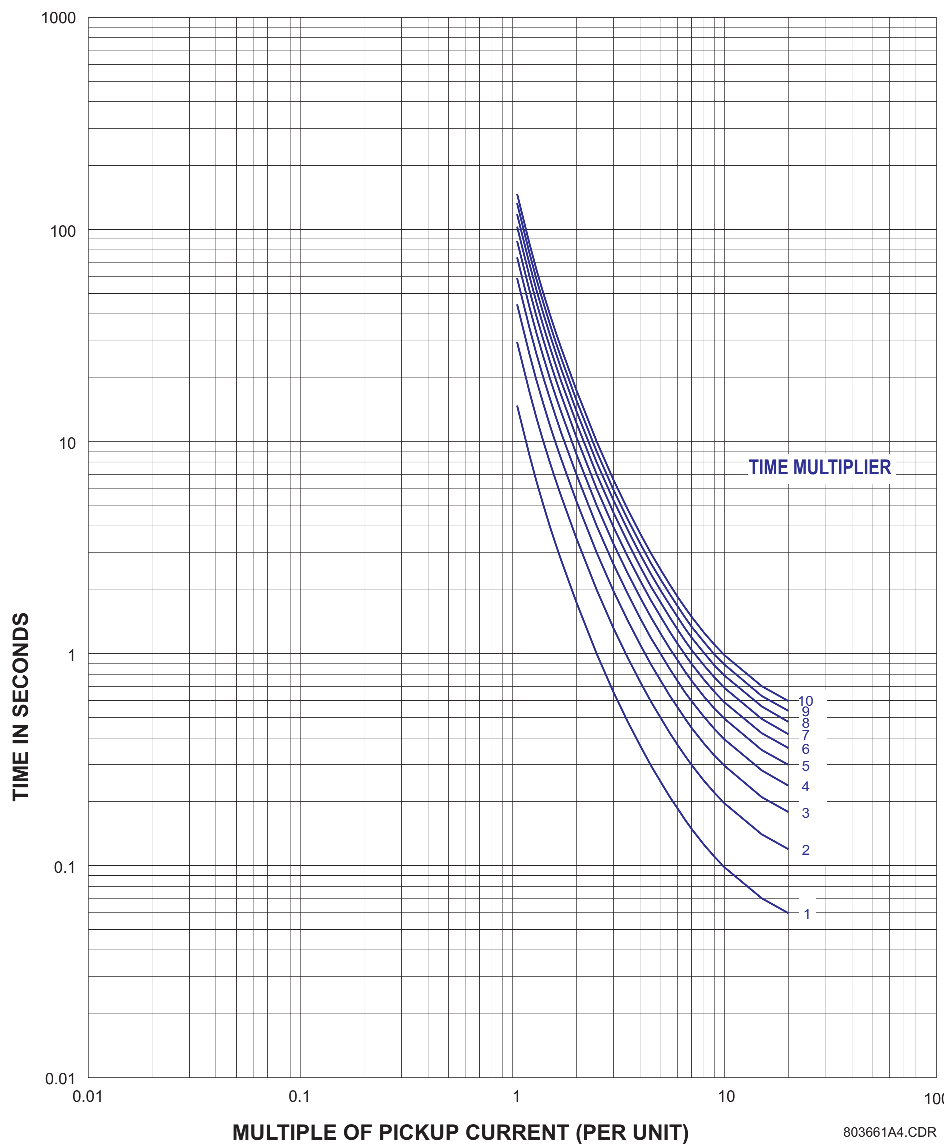

FIGURE 5–4: Ansi Extremely Inverse Curves

5.3 Definite Time Curves

5.3.1 Description

The trip time is given by: $T = S \times M \times 0.1$

where: T = trip time (in seconds)
S = curve shift multiplier
M = 735/737 curve multiplier setpoint
I = input current (in amps)
Ipu = pickup current setpoint

Table 5–5:

SHIFT S	CURVE M	CURRENT (per unit I / I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
	2	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
	3	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
	4	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
	5	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
	6	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
	7	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700
	8	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800
	9	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
	10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.5	1	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
	2	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
	3	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
	4	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
	5	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250
	6	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
	7	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350
	8	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
	9	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	10	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500

Table 5–5:

SHIFTS	CURVE M	CURRENT (per unit I /I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
	2	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160
	3	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240
	4	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320
	5	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
	6	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480
	7	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560
	8	0.640	0.640	0.640	0.640	0.640	0.640	0.640	0.640	0.640	0.640	0.640	0.640	0.640
	9	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
	10	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800
1.1	1	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110
	2	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220
	3	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330
	4	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440
	5	0.550	0.550	0.550	0.550	0.550	0.550	0.550	0.550	0.550	0.550	0.550	0.550	0.550
	6	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660
	7	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.770
	8	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880
	9	0.990	0.990	0.990	0.990	0.990	0.990	0.990	0.990	0.990	0.990	0.990	0.990	0.990
	10	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100

GE POWER MANAGEMENT

735/737 DEFINITE TIME CURVES

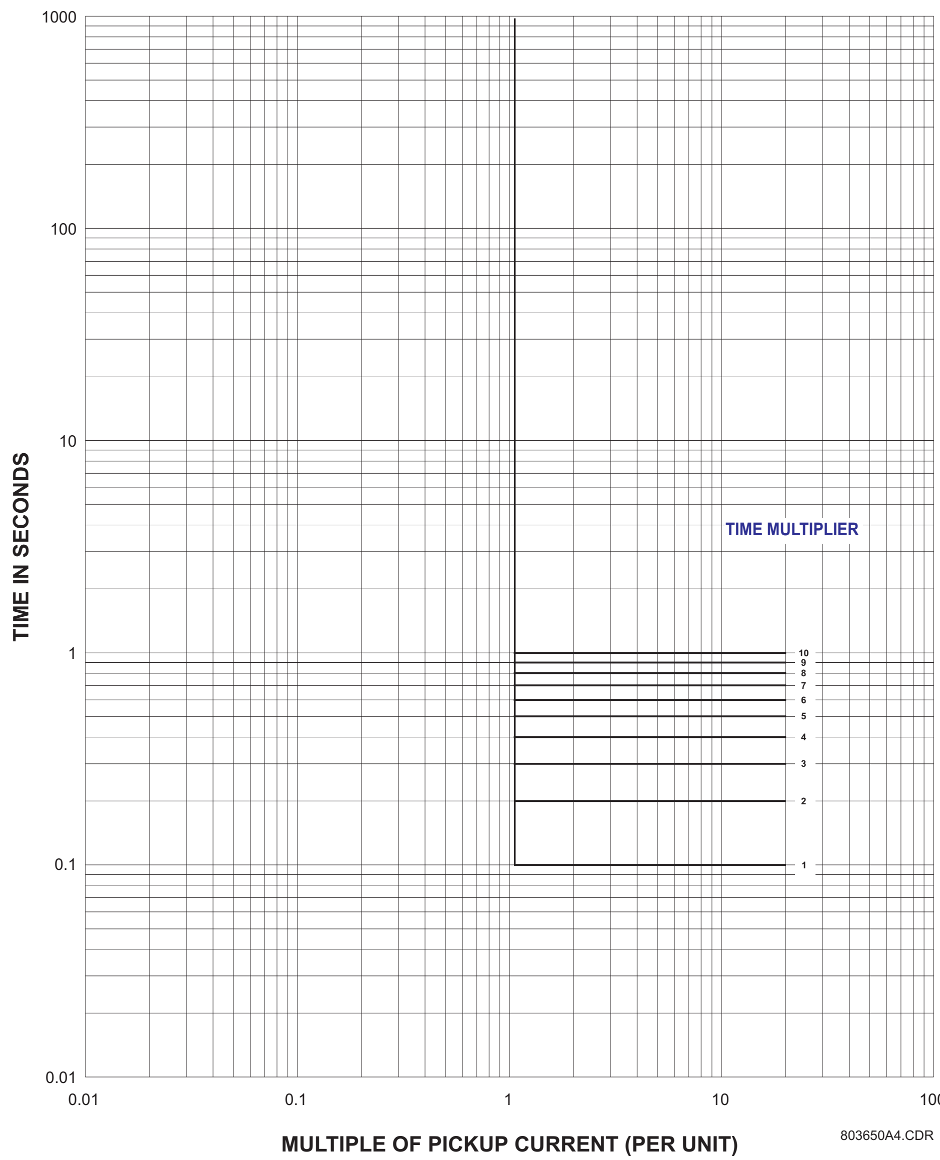

FIGURE 5–5: Definite Time Curves

5.4 IAC Curves

5.4.1 IAC Short Inverse Curves

The trip time is given by:

$$T = S \times M \times \left(A + \frac{B}{(I/I_{pu}) - C} + \frac{D}{((I/I_{pu}) - C)^2} + \frac{E}{((I/I_{pu}) - C)^3} \right)$$

where: T = trip time (in seconds)
S = curve shift multiplier
M = 735/737 curve multiplier setpoint
I = input current (in amps)
Ipu = pickup current setpoint

A = 0.043 (curve shape constant)
B = 0.061 (curve shape constant)
C = 0.620 (curve shape constant)
D = –0.001 (curve shape constant)
E = 0.022 (curve shape constant)

Table 5–6:

SHIFTS	CURVE M	CURRENT (per unit I/I_0)												
		1.05	**1.50**	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**7.00**	**8.00**	**9.00**	**10.00**	**15.00**	**20.00**
1	1	0.457	0.143	0.095	0.070	0.061	0.057	0.054	0.052	0.051	0.050	0.049	0.047	0.046
	2	0.914	0.286	0.190	0.140	0.123	0.114	0.108	0.105	0.102	0.100	0.099	0.094	0.092
	3	1.371	0.429	0.284	0.210	0.184	0.171	0.163	0.157	0.153	0.150	0.148	0.141	0.138
	4	1.828	0.573	0.379	0.279	0.245	0.228	0.217	0.210	0.204	0.200	0.197	0.188	0.184
	5	2.285	0.716	0.474	0.349	0.307	0.285	0.271	0.262	0.255	0.250	0.247	0.235	0.230
	6	2.742	0.859	0.569	0.419	0.368	0.341	0.325	0.314	0.307	0.301	0.296	0.282	0.276
	7	3.199	1.002	0.664	0.489	0.429	0.398	0.380	0.367	0.358	0.351	0.345	0.329	0.322
	8	3.656	1.145	0.759	0.559	0.490	0.455	0.434	0.419	0.409	0.401	0.394	0.376	0.368
	9	4.113	1.288	0.853	0.629	0.552	0.512	0.488	0.472	0.460	0.451	0.444	0.423	0.413
	10	4.570	1.431	0.948	0.699	0.613	0.569	0.542	0.524	0.511	0.501	0.493	0.470	0.459
0.5	1	0.228	0.072	0.047	0.035	0.031	0.028	0.027	0.026	0.026	0.025	0.025	0.024	0.023
	2	0.457	0.143	0.095	0.070	0.061	0.057	0.054	0.052	0.051	0.050	0.049	0.047	0.046
	3	0.685	0.215	0.142	0.105	0.092	0.085	0.081	0.079	0.077	0.075	0.074	0.071	0.069
	4	0.914	0.286	0.190	0.140	0.123	0.114	0.108	0.105	0.102	0.100	0.099	0.094	0.092
	5	1.142	0.358	0.237	0.175	0.153	0.142	0.136	0.131	0.128	0.125	0.123	0.118	0.115
	6	1.371	0.429	0.284	0.210	0.184	0.171	0.163	0.157	0.153	0.150	0.148	0.141	0.138
	7	1.599	0.501	0.332	0.244	0.215	0.199	0.190	0.183	0.179	0.175	0.173	0.165	0.161
	8	1.828	0.573	0.379	0.279	0.245	0.228	0.217	0.210	0.204	0.200	0.197	0.188	0.184
	9	2.056	0.644	0.427	0.314	0.276	0.256	0.244	0.236	0.230	0.225	0.222	0.212	0.207
	10	2.285	0.716	0.474	0.349	0.307	0.285	0.271	0.262	0.255	0.250	0.247	0.235	0.230

Table 5–6:

SHIFTS	CURVE M	CURRENT (per unit I /I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	0.366	0.115	0.076	0.056	0.049	0.046	0.043	0.042	0.041	0.040	0.039	0.038	0.037
	2	0.731	0.229	0.152	0.112	0.098	0.091	0.087	0.084	0.082	0.080	0.079	0.075	0.074
	3	1.097	0.344	0.228	0.168	0.147	0.137	0.130	0.126	0.123	0.120	0.118	0.113	0.110
	4	1.462	0.458	0.303	0.224	0.196	0.182	0.174	0.168	0.163	0.160	0.158	0.151	0.147
	5	1.828	0.573	0.379	0.279	0.245	0.228	0.217	0.210	0.204	0.200	0.197	0.188	0.184
	6	2.194	0.687	0.455	0.335	0.294	0.273	0.260	0.252	0.245	0.240	0.237	0.226	0.221
	7	2.559	0.802	0.531	0.391	0.343	0.319	0.304	0.293	0.286	0.281	0.276	0.263	0.257
	8	2.925	0.916	0.607	0.447	0.392	0.364	0.347	0.335	0.327	0.321	0.316	0.301	0.294
	9	3.290	1.031	0.683	0.503	0.441	0.410	0.390	0.377	0.368	0.361	0.355	0.339	0.331
	10	3.656	1.145	0.759	0.559	0.490	0.455	0.434	0.419	0.409	0.401	0.394	0.376	0.368
1.1	1	0.503	0.157	0.104	0.077	0.067	0.063	0.060	0.058	0.056	0.055	0.054	0.052	0.051
	2	1.005	0.315	0.209	0.154	0.135	0.125	0.119	0.115	0.112	0.110	0.108	0.103	0.101
	3	1.508	0.472	0.313	0.231	0.202	0.188	0.179	0.173	0.169	0.165	0.163	0.155	0.152
	4	2.011	0.630	0.417	0.307	0.270	0.250	0.239	0.231	0.225	0.220	0.217	0.207	0.202
	5	2.513	0.787	0.521	0.384	0.337	0.313	0.298	0.288	0.281	0.275	0.271	0.259	0.253
	6	3.016	0.945	0.626	0.461	0.405	0.376	0.358	0.346	0.337	0.331	0.325	0.310	0.303
	7	3.519	1.102	0.730	0.538	0.472	0.438	0.418	0.404	0.393	0.386	0.380	0.362	0.354
	8	4.021	1.260	0.834	0.615	0.539	0.501	0.477	0.461	0.450	0.441	0.434	0.414	0.404
	9	4.524	1.417	0.939	0.692	0.607	0.563	0.537	0.519	0.506	0.496	0.488	0.466	0.455
	10	5.027	1.575	1.043	0.768	0.674	0.626	0.596	0.576	0.562	0.551	0.542	0.517	0.505

GE POWER MANAGEMENT

735/737 IAC SHORT INVERSE CURVE

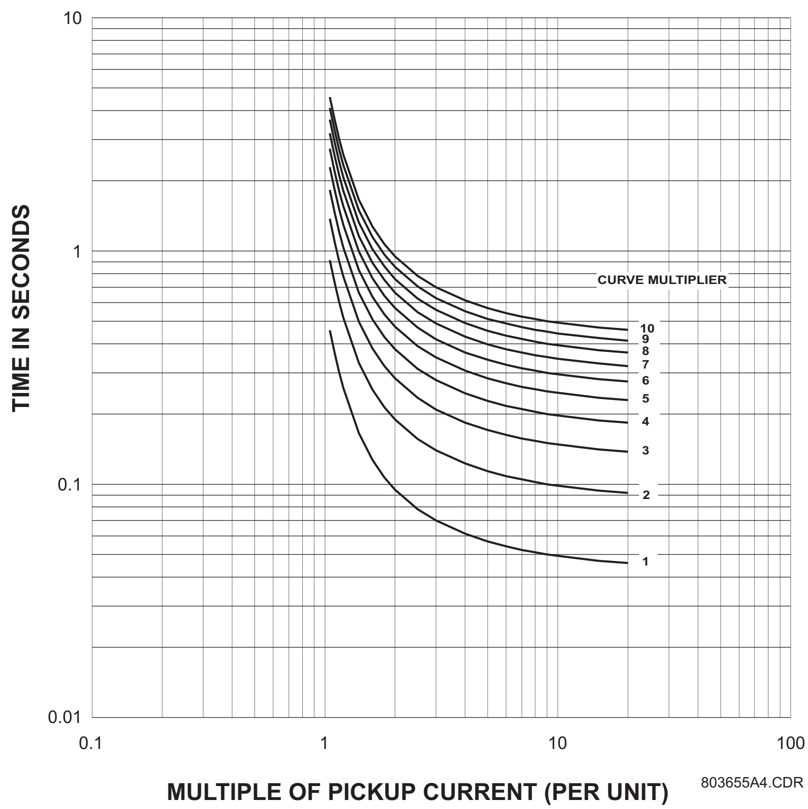

FIGURE 5–6: IAC Short Inverse Curves

5.4.2 IAC Inverse Curves

The trip time is given by:

$$T = S \times M \times \left(A + \frac{B}{(I/I_{pu}) - C} + \frac{D}{((I/I_{pu}) - C)^2} + \frac{E}{((I/I_{pu}) - C)^3} \right)$$

where:

T = trip time (in seconds)	A = 0.2078 (curve shape constant)
S = curve shift multiplier	B = 0.8630 (curve shape constant)
M = 735/737 curve multiplier setpoint	C = 0.8000 (curve shape constant)
I = input current (in amps)	D = –0.4180 (curve shape constant)
Ipu = pickup current setpoint	E = 0.1947 (curve shape constant)

Table 5–7:

SHIFT S	CURVE M	CURRENT (per unit I/I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	9.433	1.155	0.749	0.532	0.443	0.392	0.360	0.337	0.320	0.307	0.297	0.267	0.252
	2	18.865	2.310	1.499	1.064	0.885	0.784	0.719	0.674	0.640	0.614	0.594	0.533	0.503
	3	28.298	3.466	2.248	1.596	1.328	1.177	1.079	1.011	0.960	0.922	0.891	0.800	0.755
	4	37.730	4.621	2.997	2.128	1.770	1.569	1.439	1.348	1.280	1.229	1.188	1.066	1.007
	5	47.163	5.776	3.747	2.660	2.213	1.961	1.798	1.685	1.601	1.536	1.485	1.333	1.258
	6	56.596	6.931	4.496	3.192	2.656	2.353	2.158	2.022	1.921	1.843	1.781	1.599	1.510
	7	66.028	8.087	5.246	3.724	3.098	2.745	2.518	2.359	2.241	2.150	2.078	1.866	1.761
	8	75.461	9.242	5.995	4.256	3.541	3.138	2.878	2.695	2.561	2.457	2.375	2.133	2.013
	9	84.893	10.397	6.744	4.788	3.983	3.530	3.237	3.032	2.881	2.765	2.672	2.399	2.265
	10	94.326	11.552	7.494	5.320	4.426	3.922	3.597	3.369	3.201	3.072	2.969	2.666	2.516
0.5	1	4.716	0.578	0.375	0.266	0.221	0.196	0.180	0.168	0.160	0.154	0.148	0.133	0.126
	2	9.433	1.155	0.749	0.532	0.443	0.392	0.360	0.337	0.320	0.307	0.297	0.267	0.252
	3	14.149	1.733	1.124	0.798	0.664	0.588	0.540	0.505	0.480	0.461	0.445	0.400	0.377
	4	18.865	2.310	1.499	1.064	0.885	0.784	0.719	0.674	0.640	0.614	0.594	0.533	0.503
	5	23.582	2.888	1.873	1.330	1.107	0.981	0.899	0.842	0.800	0.768	0.742	0.666	0.629
	6	28.298	3.466	2.248	1.596	1.328	1.177	1.079	1.011	0.960	0.922	0.891	0.800	0.755
	7	33.014	4.043	2.623	1.862	1.549	1.373	1.259	1.179	1.120	1.075	1.039	0.933	0.881
	8	37.730	4.621	2.997	2.128	1.770	1.569	1.439	1.348	1.280	1.229	1.188	1.066	1.007
	9	42.447	5.199	3.372	2.394	1.992	1.765	1.619	1.516	1.441	1.382	1.336	1.200	1.132
	10	47.163	5.776	3.747	2.660	2.213	1.961	1.798	1.685	1.601	1.536	1.485	1.333	1.258

Table 5–7:

SHIFTS	CURVE M	CURRENT (per unit I /I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	7.546	0.924	0.599	0.426	0.354	0.314	0.288	0.270	0.256	0.246	0.238	0.213	0.201
	2	15.092	1.848	1.199	0.851	0.708	0.628	0.576	0.539	0.512	0.491	0.475	0.427	0.403
	3	22.638	2.773	1.798	1.277	1.062	0.941	0.863	0.809	0.768	0.737	0.713	0.640	0.604
	4	30.184	3.697	2.398	1.702	1.416	1.255	1.151	1.078	1.024	0.983	0.950	0.853	0.805
	5	37.730	4.621	2.997	2.128	1.770	1.569	1.439	1.348	1.280	1.229	1.188	1.066	1.007
	6	45.276	5.545	3.597	2.554	2.125	1.883	1.727	1.617	1.537	1.474	1.425	1.280	1.208
	7	52.823	6.469	4.196	2.979	2.479	2.196	2.014	1.887	1.793	1.720	1.663	1.493	1.409
	8	60.369	7.394	4.796	3.405	2.833	2.510	2.302	2.156	2.049	1.966	1.900	1.706	1.611
	9	67.915	8.318	5.395	3.830	3.187	2.824	2.590	2.426	2.305	2.212	2.138	1.919	1.812
	10	75.461	9.242	5.995	4.256	3.541	3.138	2.878	2.695	2.561	2.457	2.375	2.133	2.013
1.1	1	10.376	1.271	0.824	0.585	0.487	0.431	0.396	0.371	0.352	0.338	0.327	0.293	0.277
	2	20.752	2.542	1.649	1.170	0.974	0.863	0.791	0.741	0.704	0.676	0.653	0.586	0.554
	3	31.128	3.812	2.473	1.756	1.461	1.294	1.187	1.112	1.056	1.014	0.980	0.880	0.830
	4	41.503	5.083	3.297	2.341	1.947	1.726	1.583	1.483	1.409	1.352	1.306	1.173	1.107
	5	51.879	6.354	4.121	2.926	2.434	2.157	1.978	1.853	1.761	1.689	1.633	1.466	1.384
	6	62.255	7.625	4.946	3.511	2.921	2.589	2.374	2.224	2.113	2.027	1.960	1.759	1.661
	7	72.631	8.895	5.770	4.096	3.408	3.020	2.770	2.594	2.465	2.365	2.286	2.053	1.938
	8	83.007	10.166	6.594	4.682	3.895	3.451	3.165	2.965	2.817	2.703	2.613	2.346	2.214
	9	93.383	11.437	7.419	5.267	4.382	3.883	3.561	3.336	3.169	3.041	2.939	2.639	2.491
	10	103.759	12.708	8.243	5.852	4.869	4.314	3.957	3.706	3.521	3.379	3.266	2.932	2.768

GE POWER MANAGEMENT

735/737 IAC INVERSE CURVE

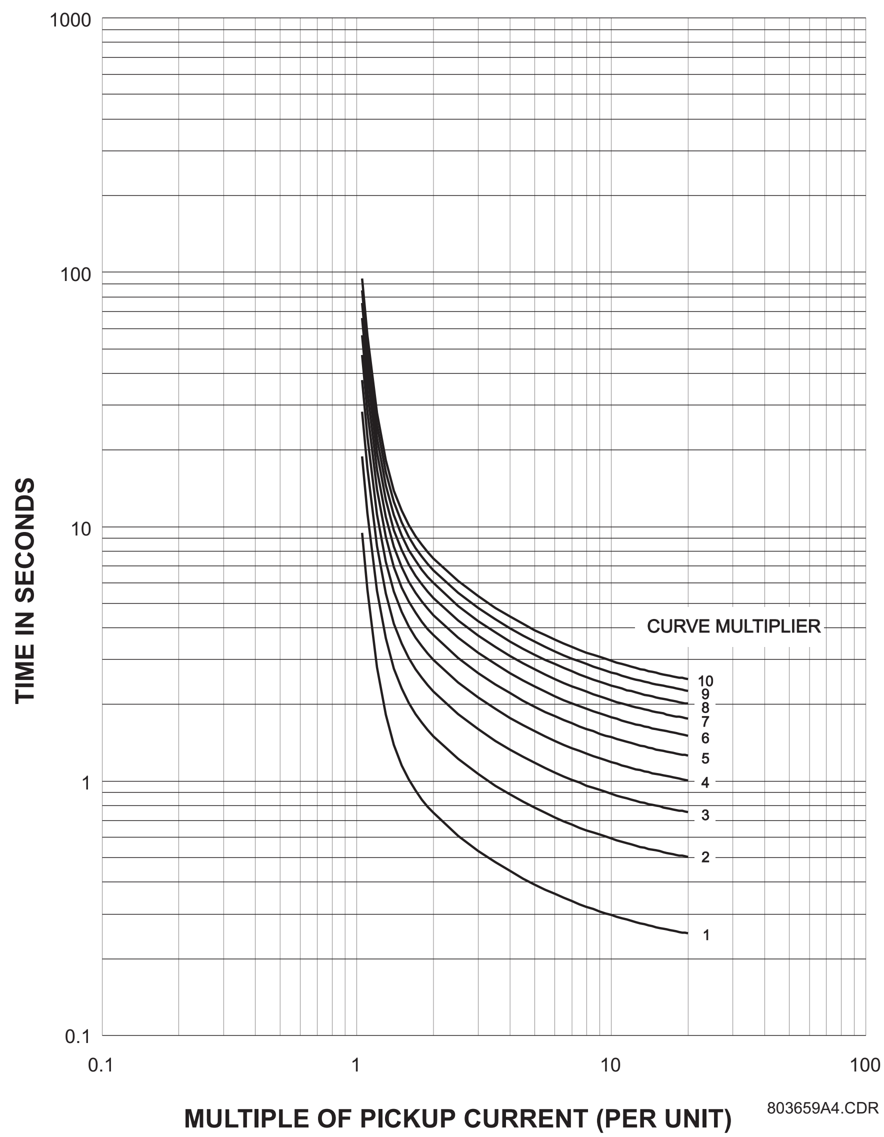

FIGURE 5–7: IAC Inverse Curves

5.4.3 IAC Very Inverse Curves

The trip time is given by:

$$T = S \times M \times \left(A + \frac{B}{(I/I_{pu}) - C} + \frac{D}{((I/I_{pu}) - C)^2} + \frac{E}{((I/I_{pu}) - C)^3} \right)$$

where:
- T = trip time (in seconds)
- S = curve shift multiplier
- M = 735/737 curve multiplier setpoint
- I = input current (in amps)
- Ipu = pickup current setpoint
- A = 0.090 (curve shape constant)
- B = 0.796 (curve shape constant)
- C = 0.100 (curve shape constant)
- D = –1.289 (curve shape constant)
- E = 7.959 (curve shape constant)

Table 5–8:

SHIFT S	CURVE M	CURRENT (per unit I/I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	8.782	2.901	1.312	0.537	0.343	0.266	0.227	0.202	0.186	0.174	0.165	0.140	0.128
	2	17.564	5.802	2.624	1.075	0.687	0.533	0.453	0.405	0.372	0.349	0.331	0.280	0.255
	3	26.347	8.704	3.936	1.612	1.030	0.799	0.680	0.607	0.559	0.523	0.496	0.420	0.383
	4	35.129	11.605	5.248	2.150	1.374	1.065	0.906	0.810	0.745	0.698	0.662	0.560	0.511
	5	43.911	14.506	6.560	2.687	1.717	1.332	1.133	1.012	0.931	0.872	0.827	0.700	0.639
	6	52.693	17.407	7.872	3.225	2.061	1.598	1.359	1.215	1.117	1.046	0.992	0.840	0.766
	7	61.475	20.308	9.185	3.762	2.404	1.864	1.586	1.417	1.303	1.221	1.158	0.980	0.894
	8	70.257	23.209	10.497	4.299	2.747	2.131	1.813	1.620	1.490	1.395	1.323	1.120	1.022
	9	79.040	26.111	11.809	4.837	3.091	2.397	2.039	1.822	1.676	1.570	1.489	1.260	1.150
	10	87.822	29.012	13.121	5.374	3.434	2.663	2.266	2.025	1.862	1.744	1.654	1.400	1.277
0.5	1	4.391	1.451	0.656	0.269	0.172	0.133	0.113	0.101	0.093	0.087	0.083	0.070	0.064
	2	8.782	2.901	1.312	0.537	0.343	0.266	0.227	0.202	0.186	0.174	0.165	0.140	0.128
	3	13.173	4.352	1.968	0.806	0.515	0.399	0.340	0.304	0.279	0.262	0.248	0.210	0.192
	4	17.564	5.802	2.624	1.075	0.687	0.533	0.453	0.405	0.372	0.349	0.331	0.280	0.255
	5	21.955	7.253	3.280	1.344	0.859	0.666	0.566	0.506	0.465	0.436	0.414	0.350	0.319
	6	26.347	8.704	3.936	1.612	1.030	0.799	0.680	0.607	0.559	0.523	0.496	0.420	0.383
	7	30.738	10.154	4.592	1.881	1.202	0.932	0.793	0.709	0.652	0.610	0.579	0.490	0.447
	8	35.129	11.605	5.248	2.150	1.374	1.065	0.906	0.810	0.745	0.698	0.662	0.560	0.511
	9	39.520	13.055	5.904	2.418	1.545	1.198	1.020	0.911	0.838	0.785	0.744	0.630	0.575
	10	43.911	14.506	6.560	2.687	1.717	1.332	1.133	1.012	0.931	0.872	0.827	0.700	0.639

Table 5–8:

SHIFT S	CURVE M	CURRENT (per unit I /I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	7.026	2.321	1.050	0.430	0.275	0.213	0.181	0.162	0.149	0.140	0.132	0.112	0.102
	2	14.051	4.642	2.099	0.860	0.549	0.426	0.363	0.324	0.298	0.279	0.265	0.224	0.204
	3	21.077	6.963	3.149	1.290	0.824	0.639	0.544	0.486	0.447	0.419	0.397	0.336	0.307
	4	28.103	9.284	4.199	1.720	1.099	0.852	0.725	0.648	0.596	0.558	0.529	0.448	0.409
	5	35.129	11.605	5.248	2.150	1.374	1.065	0.906	0.810	0.745	0.698	0.662	0.560	0.511
	6	42.154	13.926	6.298	2.580	1.648	1.278	1.088	0.972	0.894	0.837	0.794	0.672	0.613
	7	49.180	16.247	7.348	3.010	1.923	1.491	1.269	1.134	1.043	0.977	0.926	0.784	0.715
	8	56.206	18.568	8.397	3.439	2.198	1.705	1.450	1.296	1.192	1.116	1.059	0.896	0.817
	9	63.232	20.889	9.447	3.869	2.473	1.918	1.631	1.458	1.341	1.256	1.191	1.008	0.920
	10	70.257	23.209	10.497	4.299	2.747	2.131	1.813	1.620	1.490	1.395	1.323	1.120	1.022
1.1	1	9.660	3.191	1.443	0.591	0.378	0.293	0.249	0.223	0.205	0.192	0.182	0.154	0.141
	2	19.321	6.383	2.887	1.182	0.756	0.586	0.498	0.445	0.410	0.384	0.364	0.308	0.281
	3	28.981	9.574	4.330	1.773	1.133	0.879	0.748	0.668	0.614	0.576	0.546	0.462	0.422
	4	38.642	12.765	5.773	2.365	1.511	1.172	0.997	0.891	0.819	0.767	0.728	0.616	0.562
	5	48.302	15.956	7.216	2.956	1.889	1.465	1.246	1.113	1.024	0.959	0.910	0.770	0.703
	6	57.962	19.148	8.660	3.547	2.267	1.758	1.495	1.336	1.229	1.151	1.092	0.924	0.843
	7	67.623	22.339	10.103	4.138	2.644	2.051	1.745	1.559	1.434	1.343	1.274	1.078	0.984
	8	77.283	25.530	11.546	4.729	3.022	2.344	1.994	1.782	1.638	1.535	1.456	1.232	1.124
	9	86.944	28.722	12.990	5.320	3.400	2.637	2.243	2.004	1.843	1.727	1.638	1.386	1.265
	10	96.604	31.913	14.433	5.912	3.778	2.930	2.492	2.227	2.048	1.918	1.820	1.540	1.405

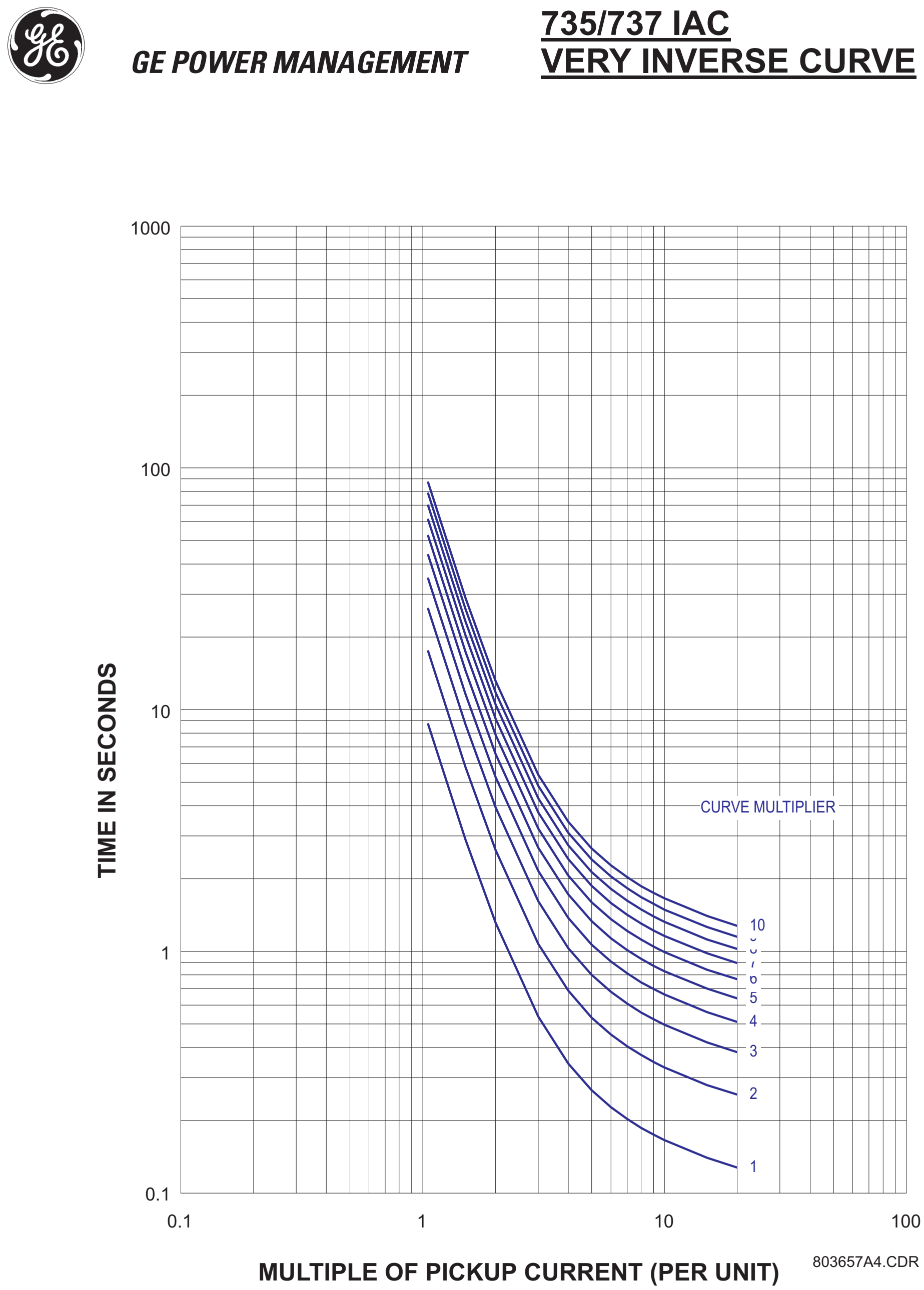

FIGURE 5–8: IAC Very Inverse Curves

5.4.4 IAC Extremely Inverse Curves

The trip time is given by:

$$T = S \times M \times \left(A + \frac{B}{(I/I_{pu}) - C} + \frac{D}{((I/I_{pu}) - C)^2} + \frac{E}{((I/I_{pu}) - C)^3} \right)$$

where:
T = trip time (in seconds)
S = curve shift multiplier
M = 735/737 curve multiplier setpoint
I = input current (in amps)
Ipu = pickup current setpoint

A = 0.004 (curve shape constant)
B = 0.638 (curve shape constant)
C = 0.620 (curve shape constant)
D = 1.787 (curve shape constant)
E = 0.246 (curve shape constant)

Table 5–9:

SHIFT S	CURVE M	CURRENT (per unit I/I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	14.249	3.398	1.498	0.606	0.356	0.246	0.186	0.149	0.124	0.106	0.093	0.057	0.042
	2	28.497	6.796	2.997	1.212	0.711	0.491	0.372	0.298	0.248	0.212	0.185	0.114	0.083
	3	42.746	10.194	4.495	1.817	1.067	0.737	0.558	0.447	0.372	0.318	0.278	0.171	0.125
	4	56.994	13.591	5.993	2.423	1.422	0.983	0.744	0.595	0.495	0.424	0.370	0.228	0.167
	5	71.243	16.989	7.492	3.029	1.778	1.229	0.929	0.744	0.619	0.530	0.463	0.285	0.209
	6	85.491	20.387	8.990	3.635	2.133	1.474	1.115	0.893	0.743	0.636	0.556	0.343	0.250
	7	99.740	23.785	10.488	4.241	2.489	1.720	1.301	1.042	0.867	0.742	0.648	0.400	0.292
	8	113.989	27.183	11.987	4.846	2.844	1.966	1.487	1.191	0.991	0.848	0.741	0.457	0.334
	9	128.237	30.581	13.485	5.452	3.200	2.212	1.673	1.340	1.115	0.954	0.834	0.514	0.375
	10	142.486	33.979	14.983	6.058	3.555	2.457	1.859	1.488	1.239	1.060	0.926	0.571	0.417
0.5	1	7.124	1.699	0.749	0.303	0.178	0.123	0.093	0.074	0.062	0.053	0.046	0.029	0.021
	2	14.249	3.398	1.498	0.606	0.356	0.246	0.186	0.149	0.124	0.106	0.093	0.057	0.042
	3	21.373	5.097	2.248	0.909	0.533	0.369	0.279	0.223	0.186	0.159	0.139	0.086	0.063
	4	28.497	6.796	2.997	1.212	0.711	0.491	0.372	0.298	0.248	0.212	0.185	0.114	0.083
	5	35.621	8.495	3.746	1.514	0.889	0.614	0.465	0.372	0.310	0.265	0.232	0.143	0.104
	6	42.746	10.194	4.495	1.817	1.067	0.737	0.558	0.447	0.372	0.318	0.278	0.171	0.125
	7	49.870	11.893	5.244	2.120	1.244	0.860	0.651	0.521	0.434	0.371	0.324	0.200	0.146
	8	56.994	13.591	5.993	2.423	1.422	0.983	0.744	0.595	0.495	0.424	0.370	0.228	0.167
	9	64.119	15.290	6.743	2.726	1.600	1.106	0.837	0.670	0.557	0.477	0.417	0.257	0.188
	10	71.243	16.989	7.492	3.029	1.778	1.229	0.929	0.744	0.619	0.530	0.463	0.285	0.209

Table 5–9:

SHIFTS	CURVE M	CURRENT (per unit I /I_0)												
		1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	11.399	2.718	1.199	0.485	0.284	0.197	0.149	0.119	0.099	0.085	0.074	0.046	0.033
	2	22.798	5.437	2.397	0.969	0.569	0.393	0.297	0.238	0.198	0.170	0.148	0.091	0.067
	3	34.197	8.155	3.596	1.454	0.853	0.590	0.446	0.357	0.297	0.254	0.222	0.137	0.100
	4	45.595	10.873	4.795	1.939	1.138	0.786	0.595	0.476	0.396	0.339	0.296	0.183	0.133
	5	56.994	13.591	5.993	2.423	1.422	0.983	0.744	0.595	0.495	0.424	0.370	0.228	0.167
	6	68.393	16.310	7.192	2.908	1.707	1.179	0.892	0.714	0.595	0.509	0.445	0.274	0.200
	7	79.792	19.028	8.391	3.392	1.991	1.376	1.041	0.833	0.694	0.594	0.519	0.320	0.234
	8	91.191	21.746	9.589	3.877	2.275	1.573	1.190	0.953	0.793	0.678	0.593	0.365	0.267
	9	102.590	24.465	10.788	4.362	2.560	1.769	1.338	1.072	0.892	0.763	0.667	0.411	0.300
	10	113.989	27.183	11.987	4.846	2.844	1.966	1.487	1.191	0.991	0.848	0.741	0.457	0.334
1.1	1	15.673	3.738	1.648	0.666	0.391	0.270	0.204	0.164	0.136	0.117	0.102	0.063	0.046
	2	31.347	7.475	3.296	1.333	0.782	0.541	0.409	0.327	0.272	0.233	0.204	0.126	0.092
	3	47.020	11.213	4.945	1.999	1.173	0.811	0.613	0.491	0.409	0.350	0.306	0.188	0.138
	4	62.694	14.951	6.593	2.665	1.564	1.081	0.818	0.655	0.545	0.466	0.408	0.251	0.184
	5	78.367	18.688	8.241	3.332	1.955	1.351	1.022	0.819	0.681	0.583	0.509	0.314	0.229
	6	94.041	22.426	9.889	3.998	2.347	1.622	1.227	0.982	0.817	0.700	0.611	0.377	0.275
	7	109.714	26.164	11.537	4.665	2.738	1.892	1.431	1.146	0.954	0.816	0.713	0.440	0.321
	8	125.387	29.901	13.185	5.331	3.129	2.162	1.636	1.310	1.090	0.933	0.815	0.502	0.367
	9	141.061	33.639	14.834	5.997	3.520	2.433	1.840	1.474	1.226	1.049	0.917	0.565	0.413
	10	156.734	37.377	16.482	6.664	3.911	2.703	2.045	1.637	1.362	1.166	1.019	0.628	0.459

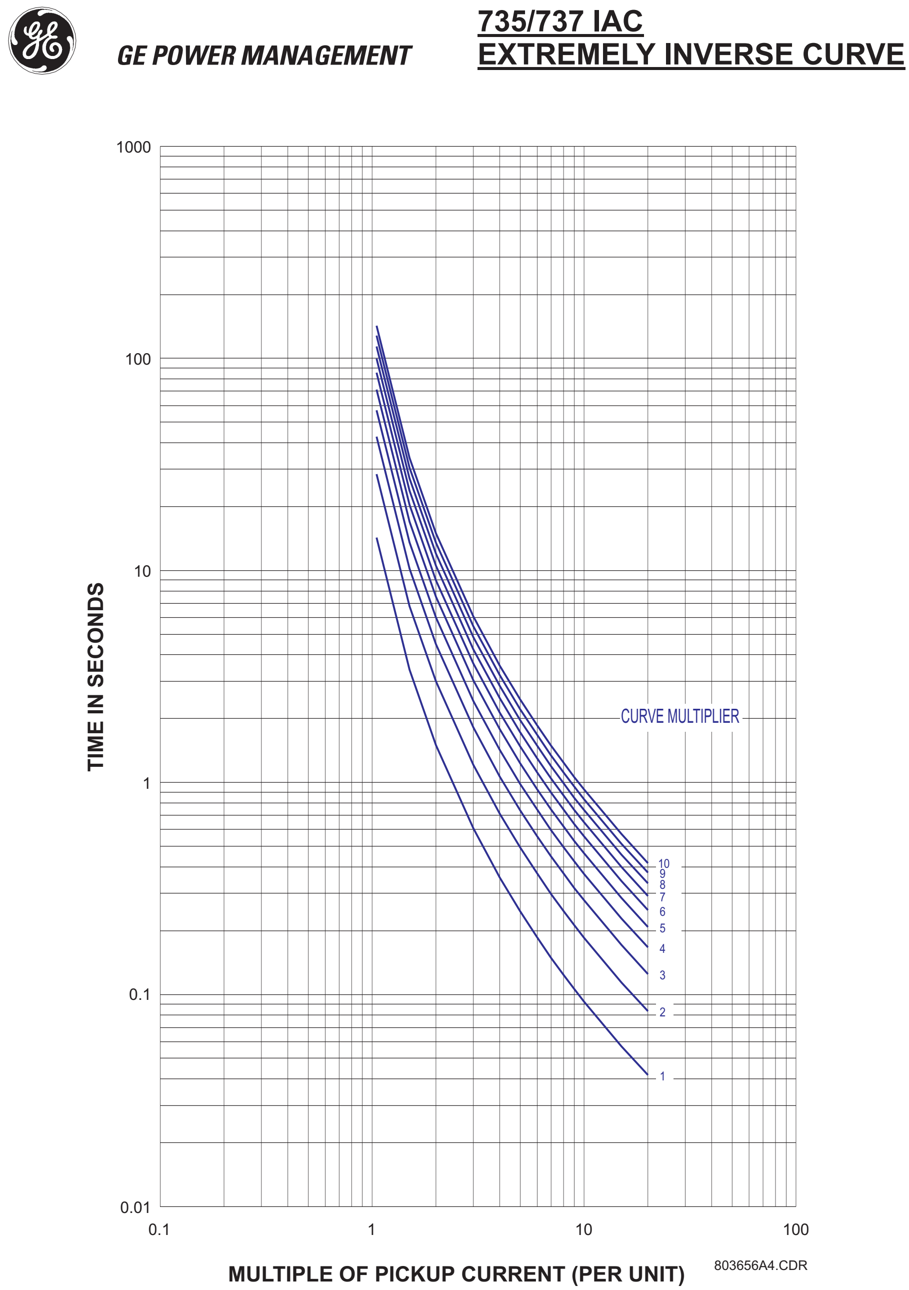

FIGURE 5–9: IAC Extremely Inverse Curves

5.5 IEC Curves

5.5.1 IEC Short Time Curves

The trip time is given by: $T = S \times M \times \left(\frac{K}{(I / I_{pu})^{E} - 1} \right)$

where: T = trip time (in seconds)
S = curve shift multiplier
M = 735/737 curve multiplier setpoint
I = input current (in amps)
Ipu = pickup current setpoint
K = 0.050 (curve shape constant)
E = 0.040 (curve shape constant)

Table 5–10:

S	MULT		CURRENT (per unit I /I_0) – values below calculated using the IEC M value												
	735	IEC	1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	0.1	2.560	0.306	0.178	0.112	0.088	0.075	0.067	0.062	0.057	0.054	0.052	0.044	0.040
	2	0.2	5.121	0.611	0.356	0.223	0.176	0.151	0.134	0.123	0.115	0.108	0.103	0.087	0.080
	3	0.3	7.681	0.917	0.534	0.335	0.264	0.226	0.202	0.185	0.172	0.162	0.155	0.131	0.119
	4	0.4	10.242	1.223	0.712	0.447	0.352	0.301	0.269	0.246	0.230	0.217	0.206	0.175	0.159
	5	0.5	12.802	1.528	0.890	0.559	0.440	0.377	0.336	0.308	0.287	0.271	0.258	0.219	0.199
	6	0.6	15.363	1.834	1.068	0.670	0.528	0.452	0.403	0.369	0.344	0.325	0.309	0.262	0.239
	7	0.7	17.923	2.140	1.246	0.782	0.616	0.527	0.471	0.431	0.402	0.379	0.361	0.306	0.278
	8	0.8	20.484	2.445	1.424	0.894	0.704	0.602	0.538	0.493	0.459	0.433	0.412	0.350	0.318
	9	0.9	23.044	2.751	1.602	1.005	0.792	0.678	0.605	0.554	0.516	0.487	0.464	0.393	0.358
	10	1.0	25.604	3.057	1.780	1.117	0.880	0.753	0.672	0.616	0.574	0.541	0.515	0.437	0.398
0.5	1	0.1	1.280	0.153	0.089	0.056	0.044	0.038	0.034	0.031	0.029	0.027	0.026	0.022	0.020
	2	0.2	2.560	0.306	0.178	0.112	0.088	0.075	0.067	0.062	0.057	0.054	0.052	0.044	0.040
	3	0.3	3.841	0.459	0.267	0.168	0.132	0.113	0.101	0.092	0.086	0.081	0.077	0.066	0.060
	4	0.4	5.121	0.611	0.356	0.223	0.176	0.151	0.134	0.123	0.115	0.108	0.103	0.087	0.080
	5	0.5	6.401	0.764	0.445	0.279	0.220	0.188	0.168	0.154	0.143	0.135	0.129	0.109	0.099
	6	0.6	7.681	0.917	0.534	0.335	0.264	0.226	0.202	0.185	0.172	0.162	0.155	0.131	0.119
	7	0.7	8.962	1.070	0.623	0.391	0.308	0.264	0.235	0.216	0.201	0.189	0.180	0.153	0.139
	8	0.8	10.242	1.223	0.712	0.447	0.352	0.301	0.269	0.246	0.230	0.217	0.206	0.175	0.159
	9	0.9	11.522	1.376	0.801	0.503	0.396	0.339	0.303	0.277	0.258	0.244	0.232	0.197	0.179
	10	1.0	12.802	1.528	0.890	0.559	0.440	0.377	0.336	0.308	0.287	0.271	0.258	0.219	0.199

Table 5–10:

S	MULT		CURRENT (per unit I / I_0) – values below calculated using the IEC M value												
	735	IEC	1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	0.1	2.048	0.245	0.142	0.089	0.070	0.060	0.054	0.049	0.046	0.043	0.041	0.035	0.032
	2	0.2	4.097	0.489	0.285	0.179	0.141	0.120	0.108	0.099	0.092	0.087	0.082	0.070	0.064
	3	0.3	6.145	0.734	0.427	0.268	0.211	0.181	0.161	0.148	0.138	0.130	0.124	0.105	0.095
	4	0.4	8.193	0.978	0.569	0.357	0.282	0.241	0.215	0.197	0.184	0.173	0.165	0.140	0.127
	5	0.5	10.242	1.223	0.712	0.447	0.352	0.301	0.269	0.246	0.230	0.217	0.206	0.175	0.159
	6	0.6	12.290	1.467	0.854	0.536	0.422	0.361	0.323	0.296	0.275	0.260	0.247	0.210	0.191
	7	0.7	14.338	1.712	0.997	0.626	0.493	0.422	0.376	0.345	0.321	0.303	0.289	0.245	0.223
	8	0.8	16.387	1.956	1.139	0.715	0.563	0.482	0.430	0.394	0.367	0.346	0.330	0.280	0.254
	9	0.9	18.435	2.201	1.281	0.804	0.634	0.542	0.484	0.443	0.413	0.390	0.371	0.315	0.286
	10	1.0	20.484	2.445	1.424	0.894	0.704	0.602	0.538	0.493	0.459	0.433	0.412	0.350	0.318
1.1	1	0.1	2.816	0.336	0.196	0.123	0.097	0.083	0.074	0.068	0.063	0.060	0.057	0.048	0.044
	2	0.2	5.633	0.672	0.392	0.246	0.194	0.166	0.148	0.135	0.126	0.119	0.113	0.096	0.087
	3	0.3	8.449	1.009	0.587	0.369	0.290	0.248	0.222	0.203	0.189	0.179	0.170	0.144	0.131
	4	0.4	11.266	1.345	0.783	0.492	0.387	0.331	0.296	0.271	0.252	0.238	0.227	0.192	0.175
	5	0.5	14.082	1.681	0.979	0.614	0.484	0.414	0.370	0.339	0.316	0.298	0.283	0.240	0.219
	6	0.6	16.899	2.017	1.175	0.737	0.581	0.497	0.444	0.406	0.379	0.357	0.340	0.289	0.262
	7	0.7	19.715	2.354	1.370	0.860	0.678	0.580	0.518	0.474	0.442	0.417	0.397	0.337	0.306
	8	0.8	22.532	2.690	1.566	0.983	0.774	0.663	0.592	0.542	0.505	0.476	0.454	0.385	0.350
	9	0.9	25.348	3.026	1.762	1.106	0.871	0.745	0.666	0.610	0.568	0.536	0.510	0.433	0.394
	10	1.0	28.165	3.362	1.958	1.229	0.968	0.828	0.739	0.677	0.631	0.595	0.567	0.481	0.437

GE POWER MANAGEMENT

735/737 IEC SHORT TIME CURVE

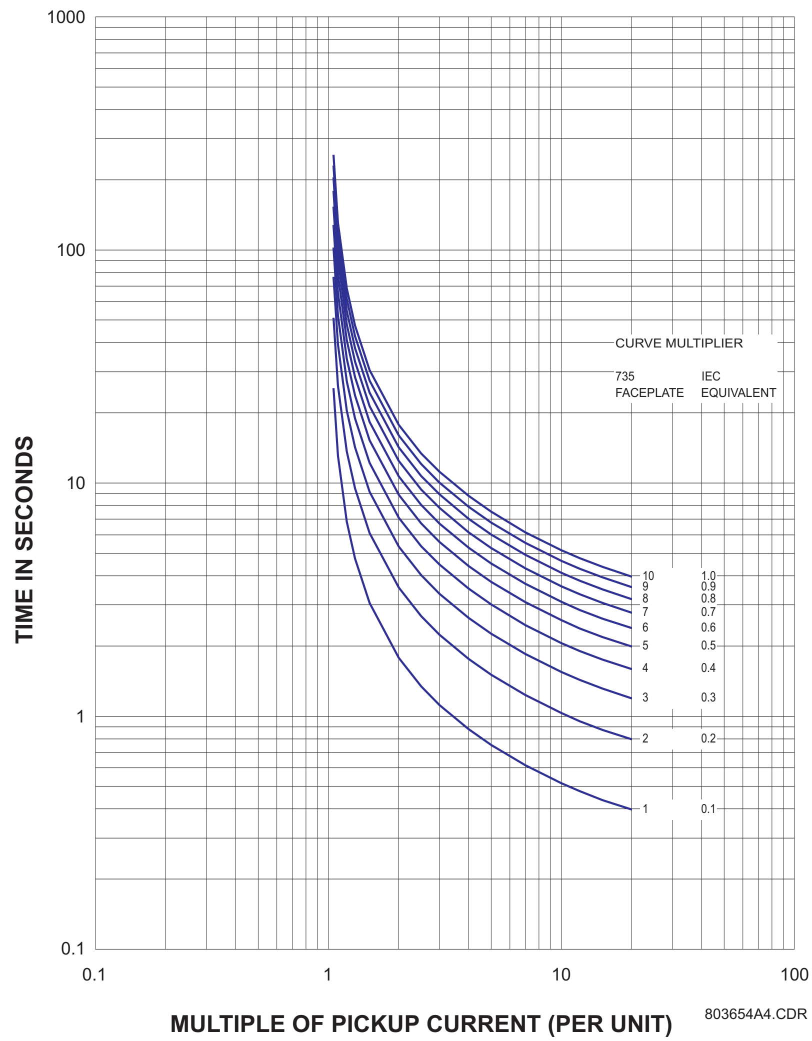

FIGURE 5–10: IEC Short Time Curves

5.5.2 IEC A Curves

The trip time is given by: $T = S \times M \times \left(\frac{K}{(I/I_{pu})^E - 1} \right)$

where: T = trip time (in seconds)
S = curve shift multiplier
M = 735/737 curve multiplier setpoint
I = input current (in amps)
Ipu = pickup current setpoint

K = 0.140 (curve shape constant)
E = 0.020 (curve shape constant)

Table 5–11:

S	MULT		CURRENT (per unit I /I_0)– values below calculated using the IEC M value												
	735	IEC	1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	0.1	14.340	1.718	1.002	0.632	0.499	0.428	0.383	0.351	0.328	0.309	0.295	0.251	0.228
	2	0.2	28.680	3.435	2.004	1.263	0.998	0.856	0.765	0.702	0.655	0.619	0.589	0.501	0.457
	3	0.3	43.020	5.153	3.007	1.895	1.497	1.284	1.148	1.053	0.983	0.928	0.884	0.752	0.685
	4	0.4	57.360	6.870	4.009	2.526	1.996	1.712	1.531	1.404	1.310	1.237	1.179	1.003	0.914
	5	0.5	71.700	8.588	5.011	3.158	2.495	2.139	1.913	1.755	1.638	1.546	1.473	1.253	1.142
	6	0.6	86.040	10.305	6.013	3.789	2.993	2.567	2.296	2.106	1.965	1.856	1.768	1.504	1.371
	7	0.7	100.380	12.023	7.016	4.421	3.492	2.995	2.679	2.457	2.293	2.165	2.063	1.755	1.599
	8	0.8	114.720	13.740	8.018	5.052	3.991	3.423	3.061	2.808	2.620	2.474	2.357	2.005	1.828
	9	0.9	129.060	15.458	9.020	5.684	4.490	3.851	3.444	3.159	2.948	2.783	2.652	2.256	2.056
	10	1.0	143.400	17.175	10.022	6.315	4.989	4.279	3.827	3.510	3.275	3.093	2.947	2.507	2.284
0.5	1	0.1	7.170	0.859	0.501	0.316	0.249	0.214	0.191	0.176	0.164	0.155	0.147	0.125	0.114
	2	0.2	14.340	1.718	1.002	0.632	0.499	0.428	0.383	0.351	0.328	0.309	0.295	0.251	0.228
	3	0.3	21.510	2.576	1.503	0.947	0.748	0.642	0.574	0.527	0.491	0.464	0.442	0.376	0.343
	4	0.4	28.680	3.435	2.004	1.263	0.998	0.856	0.765	0.702	0.655	0.619	0.589	0.501	0.457
	5	0.5	35.850	4.294	2.506	1.579	1.247	1.070	0.957	0.878	0.819	0.773	0.737	0.627	0.571
	6	0.6	43.020	5.153	3.007	1.895	1.497	1.284	1.148	1.053	0.983	0.928	0.884	0.752	0.685
	7	0.7	50.190	6.011	3.508	2.210	1.746	1.498	1.339	1.229	1.146	1.082	1.031	0.877	0.800
	8	0.8	57.360	6.870	4.009	2.526	1.996	1.712	1.531	1.404	1.310	1.237	1.179	1.003	0.914
	9	0.9	64.530	7.729	4.510	2.842	2.245	1.925	1.722	1.580	1.474	1.392	1.326	1.128	1.028
	10	1.0	71.700	8.588	5.011	3.158	2.495	2.139	1.913	1.755	1.638	1.546	1.473	1.253	1.142

Table 5–11:

S	MULT		CURRENT (per unit I / I_0)– values below calculated using the IEC M value												
	735	IEC	1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	0.1	11.472	1.374	0.802	0.505	0.399	0.342	0.306	0.281	0.262	0.247	0.236	0.201	0.183
	2	0.2	22.944	2.748	1.604	1.010	0.798	0.685	0.612	0.562	0.524	0.495	0.471	0.401	0.366
	3	0.3	34.416	4.122	2.405	1.516	1.197	1.027	0.918	0.842	0.786	0.742	0.707	0.602	0.548
	4	0.4	45.888	5.496	3.207	2.021	1.597	1.369	1.225	1.123	1.048	0.990	0.943	0.802	0.731
	5	0.5	57.360	6.870	4.009	2.526	1.996	1.712	1.531	1.404	1.310	1.237	1.179	1.003	0.914
	6	0.6	68.832	8.244	4.811	3.031	2.395	2.054	1.837	1.685	1.572	1.484	1.414	1.203	1.097
	7	0.7	80.304	9.618	5.612	3.536	2.794	2.396	2.143	1.966	1.834	1.732	1.650	1.404	1.279
	8	0.8	91.776	10.992	6.414	4.042	3.193	2.738	2.449	2.247	2.096	1.979	1.886	1.604	1.462
	9	0.9	103.248	12.366	7.216	4.547	3.592	3.081	2.755	2.527	2.358	2.227	2.122	1.805	1.645
	10	1.0	114.720	13.740	8.018	5.052	3.991	3.423	3.061	2.808	2.620	2.474	2.357	2.005	1.828
1.1	1	0.1	15.774	1.889	1.102	0.695	0.549	0.471	0.421	0.386	0.360	0.340	0.324	0.276	0.251
	2	0.2	31.548	3.779	2.205	1.389	1.098	0.941	0.842	0.772	0.721	0.680	0.648	0.552	0.503
	3	0.3	47.322	5.668	3.307	2.084	1.646	1.412	1.263	1.158	1.081	1.021	0.972	0.827	0.754
	4	0.4	63.096	7.557	4.410	2.779	2.195	1.883	1.684	1.545	1.441	1.361	1.297	1.103	1.005
	5	0.5	78.870	9.446	5.512	3.473	2.744	2.353	2.105	1.931	1.801	1.701	1.621	1.379	1.256
	6	0.6	94.644	11.336	6.615	4.168	3.293	2.824	2.526	2.317	2.162	2.041	1.945	1.655	1.508
	7	0.7	110.418	13.225	7.717	4.863	3.842	3.295	2.947	2.703	2.522	2.381	2.269	1.930	1.759
	8	0.8	126.192	15.114	8.820	5.557	4.390	3.765	3.368	3.089	2.882	2.721	2.593	2.206	2.010
	9	0.9	141.966	17.004	9.922	6.252	4.939	4.236	3.789	3.475	3.242	3.062	2.917	2.482	2.262
	10	1.0	157.740	18.893	11.024	6.947	5.488	4.707	4.209	3.861	3.603	3.402	3.241	2.758	2.513

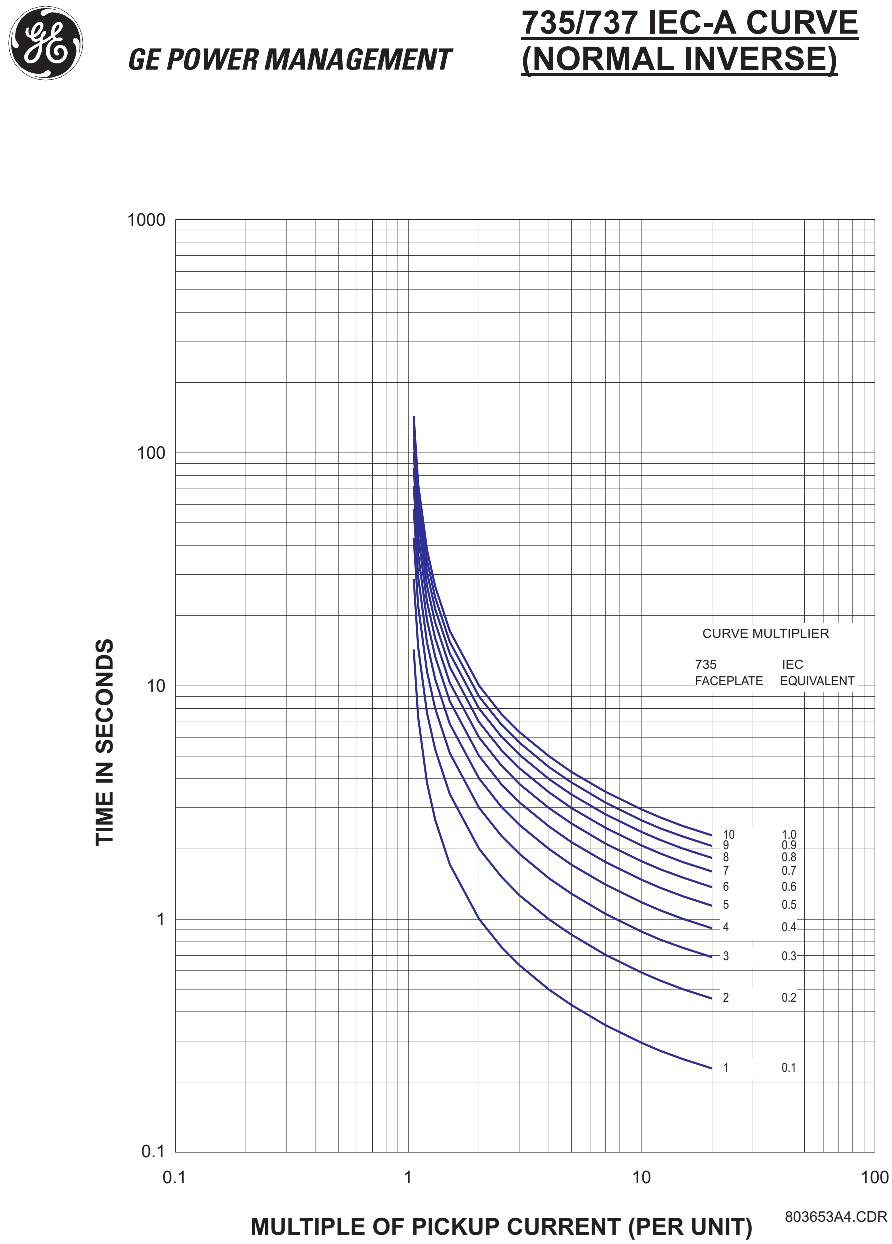

FIGURE 5–11: IEC A Curves

5.5.3 IEC B Curves

The trip time is given by: $T = S \times M \times \left(\frac{K}{(I/I_{pu})^{E} - 1} \right)$

where: T = trip time (in seconds)
S = curve shift multiplier
M = 735/737 curve multiplier setpoint
I = input current (in amps)
Ipu = pickup current setpoint

K = 13.500 (curve shape constant)
E = 1.000 (curve shape constant)

Table 5–12:

S	MULT		CURRENT (per unit I/I_0)– values below calculated using the IEC M value												
	735	IEC	1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	0.1	27.001	2.700	1.350	0.675	0.449	0.337	0.269	0.225	0.192	0.168	0.150	0.096	0.071
	2	0.2	54.002	5.401	2.701	1.349	0.899	0.674	0.539	0.449	0.385	0.337	0.299	0.193	0.143
	3	0.3	81.002	8.101	4.051	2.024	1.348	1.011	0.808	0.674	0.577	0.505	0.449	0.289	0.214
	4	0.4	108.004	10.801	5.401	2.699	1.798	1.348	1.078	0.898	0.770	0.674	0.599	0.386	0.285
	5	0.5	135.005	13.502	6.751	3.374	2.247	1.685	1.347	1.123	0.962	0.842	0.749	0.482	0.356
	6	0.6	162.006	16.202	8.102	4.048	2.697	2.022	1.617	1.347	1.155	1.010	0.898	0.579	0.428
	7	0.7	189.007	18.903	9.452	4.723	3.146	2.359	1.886	1.572	1.347	1.179	1.048	0.675	0.499
	8	0.8	216.008	21.603	10.802	5.398	3.596	2.696	2.156	1.796	1.540	1.347	1.198	0.772	0.570
	9	0.9	243.009	24.303	12.152	6.073	4.045	3.032	2.425	2.021	1.732	1.516	1.348	0.868	0.641
	10	1.0	270.010	27.004	13.503	6.747	4.495	3.369	2.695	2.245	1.924	1.684	1.497	0.964	0.713
0.5	1	0.1	13.500	1.350	0.675	0.337	0.225	0.168	0.135	0.112	0.096	0.084	0.075	0.048	0.036
	2	0.2	27.001	2.700	1.350	0.675	0.449	0.337	0.269	0.225	0.192	0.168	0.150	0.096	0.071
	3	0.3	40.501	4.051	2.025	1.012	0.674	0.505	0.404	0.337	0.289	0.253	0.225	0.145	0.107
	4	0.4	54.002	5.401	2.701	1.349	0.899	0.674	0.539	0.449	0.385	0.337	0.299	0.193	0.143
	5	0.5	67.502	6.751	3.376	1.687	1.124	0.842	0.674	0.561	0.481	0.421	0.374	0.241	0.178
	6	0.6	81.002	8.101	4.051	2.024	1.348	1.011	0.808	0.674	0.577	0.505	0.449	0.289	0.214
	7	0.7	94.503	9.451	4.726	2.362	1.573	1.179	0.943	0.786	0.674	0.589	0.524	0.338	0.249
	8	0.8	108.000	10.801	5.401	2.699	1.798	1.348	1.078	0.898	0.770	0.674	0.599	0.386	0.285
	9	0.9	121.500	12.152	6.076	3.036	2.023	1.516	1.213	1.010	0.866	0.758	0.674	0.434	0.321
	10	1.0	135.000	13.502	6.751	3.374	2.247	1.685	1.347	1.123	0.962	0.842	0.749	0.482	0.356

Table 5–12:

S	MULT		CURRENT (per unit I /I_0)– values below calculated using the IEC M value												
	735	IEC	1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	0.1	21.601	2.160	1.080	0.540	0.360	0.270	0.216	0.180	0.154	0.135	0.120	0.077	0.057
	2	0.2	43.201	4.321	2.160	1.080	0.719	0.539	0.431	0.359	0.308	0.269	0.240	0.154	0.114
	3	0.3	64.802	6.481	3.241	1.619	1.079	0.809	0.647	0.539	0.462	0.404	0.359	0.231	0.171
	4	0.4	86.403	8.641	4.321	2.159	1.438	1.078	0.862	0.718	0.616	0.539	0.479	0.309	0.228
	5	0.5	108.005	10.801	5.401	2.699	1.798	1.348	1.078	0.898	0.770	0.674	0.599	0.386	0.285
	6	0.6	129.606	12.962	6.481	3.239	2.158	1.617	1.293	1.078	0.924	0.808	0.719	0.463	0.342
	7	0.7	151.207	15.122	7.561	3.778	2.517	1.887	1.509	1.257	1.078	0.943	0.839	0.540	0.399
	8	0.8	172.808	17.282	8.642	4.318	2.877	2.156	1.725	1.437	1.232	1.078	0.958	0.617	0.456
	9	0.9	194.409	19.443	9.722	4.858	3.236	2.426	1.940	1.617	1.386	1.213	1.078	0.694	0.513
	10	1.0	216.010	21.603	10.802	5.398	3.596	2.696	2.156	1.796	1.540	1.347	1.198	0.772	0.570
1.1	1	0.1	29.701	2.970	1.485	0.742	0.494	0.371	0.296	0.247	0.212	0.185	0.165	0.106	0.078
	2	0.2	59.402	5.941	2.971	1.484	0.989	0.741	0.593	0.494	0.423	0.371	0.329	0.212	0.157
	3	0.3	89.103	8.911	4.456	2.227	1.483	1.112	0.889	0.741	0.635	0.556	0.494	0.318	0.235
	4	0.4	118.804	11.882	5.941	2.969	1.978	1.483	1.186	0.988	0.847	0.741	0.659	0.424	0.314
	5	0.5	148.505	14.852	7.426	3.711	2.472	1.853	1.482	1.235	1.058	0.926	0.824	0.530	0.392
	6	0.6	178.206	17.822	8.912	4.453	2.967	2.224	1.778	1.482	1.270	1.112	0.988	0.637	0.470
	7	0.7	207.907	20.793	10.397	5.195	3.461	2.594	2.075	1.729	1.482	1.297	1.153	0.743	0.549
	8	0.8	237.608	23.763	11.882	5.938	3.956	2.965	2.371	1.976	1.694	1.482	1.318	0.849	0.627
	9	0.9	267.309	26.734	13.368	6.680	4.450	3.336	2.668	2.223	1.905	1.667	1.482	0.955	0.705
	10	1.0	297.010	29.704	14.853	7.422	4.944	3.706	2.964	2.470	2.117	1.853	1.647	1.061	0.784

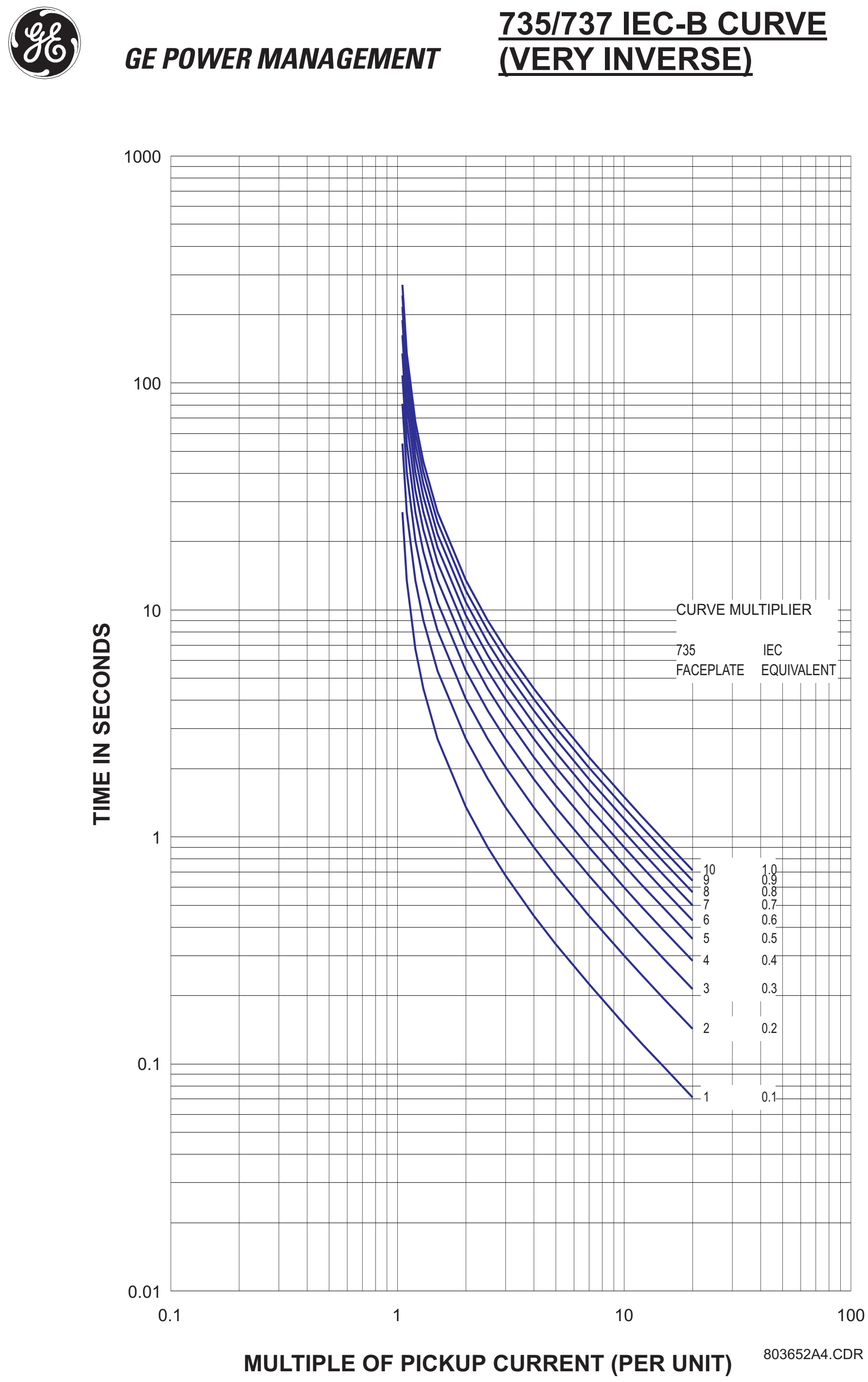

FIGURE 5–12: IEC B Curves

5.5.4 IEC C Curves

The trip time is given by: $T = S \times M \times \left(\frac{K}{(I/I_{pu})^E - 1} \right)$

where: T = trip time (in seconds)
S = curve shift multiplier
M = 735/737 curve multiplier setpoint
I = input current (in amps)
Ipu = pickup current setpoint

K = 80.000 (curve shape constant)
E = 2.000 (curve shape constant)

Table 5–13:

S	MULT		CURRENT (per unit I/I_0)– values below calculated using the IEC M value												
	735	IEC	1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
1	1	0.1	78.049	6.400	2.667	1.000	0.533	0.333	0.228	0.167	0.127	0.100	0.081	0.036	0.020
	2	0.2	156.098	12.800	5.334	2.000	1.066	0.666	0.457	0.333	0.254	0.200	0.162	0.072	0.041
	3	0.3	234.147	19.201	8.001	3.000	1.599	0.999	0.685	0.500	0.381	0.300	0.242	0.108	0.061
	4	0.4	312.192	25.601	10.668	4.000	2.132	1.332	0.913	0.666	0.508	0.400	0.323	0.144	0.082
	5	0.5	390.245	32.001	13.335	5.000	2.666	1.665	1.142	0.833	0.634	0.500	0.404	0.180	0.102
	6	0.6	468.294	38.401	16.001	6.000	3.199	1.999	1.370	0.999	0.761	0.600	0.485	0.216	0.123
	7	0.7	546.343	44.802	18.668	7.000	3.732	2.332	1.599	1.166	0.888	0.700	0.566	0.252	0.143
	8	0.8	624.392	51.202	21.335	7.999	4.265	2.665	1.827	1.332	1.015	0.800	0.647	0.288	0.164
	9	0.9	702.441	57.602	24.002	8.999	4.798	2.998	2.055	1.499	1.142	0.900	0.727	0.324	0.184
	10	1.0	780.490	64.002	26.669	9.999	5.331	3.331	2.284	1.665	1.269	1.000	0.808	0.360	0.204
0.5	1	0.1	39.024	3.200	1.333	0.500	0.267	0.167	0.114	0.083	0.063	0.050	0.040	0.018	0.010
	2	0.2	78.049	6.400	2.667	1.000	0.533	0.333	0.228	0.167	0.127	0.100	0.081	0.036	0.020
	3	0.3	117.072	9.600	4.000	1.500	0.800	0.500	0.343	0.250	0.190	0.150	0.121	0.054	0.031
	4	0.4	156.096	12.800	5.334	2.000	1.066	0.666	0.457	0.333	0.254	0.200	0.162	0.072	0.041
	5	0.5	195.120	16.001	6.667	2.500	1.333	0.833	0.571	0.416	0.317	0.250	0.202	0.090	0.051
	6	0.6	234.144	19.201	8.001	3.000	1.599	0.999	0.685	0.500	0.381	0.300	0.242	0.108	0.061
	7	0.7	273.168	22.401	9.334	3.500	1.866	1.166	0.799	0.583	0.444	0.350	0.283	0.126	0.072
	8	0.8	312.192	25.601	10.668	4.000	2.132	1.332	0.913	0.666	0.508	0.400	0.323	0.144	0.082
	9	0.9	351.216	28.801	12.001	4.500	2.399	1.499	1.028	0.749	0.571	0.450	0.364	0.162	0.092
	10	1.0	390.240	32.001	13.335	5.000	2.666	1.665	1.142	0.833	0.634	0.500	0.404	0.180	0.102

Table 5–13:

S	MULT		CURRENT (per unit I /I_0)– values below calculated using the IEC M value												
	735	IEC	1.05	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00
0.8	1	0.1	62.439	5.120	2.134	0.800	0.426	0.266	0.183	0.133	0.102	0.080	0.065	0.029	0.016
	2	0.2	124.878	10.240	4.267	1.600	0.853	0.533	0.365	0.266	0.203	0.160	0.129	0.058	0.033
	3	0.3	187.317	15.361	6.401	2.400	1.279	0.799	0.548	0.400	0.305	0.240	0.194	0.086	0.049
	4	0.4	249.756	20.481	8.534	3.200	1.706	1.066	0.731	0.533	0.406	0.320	0.259	0.115	0.065
	5	0.5	312.195	25.601	10.668	4.000	2.132	1.332	0.913	0.666	0.508	0.400	0.323	0.144	0.082
	6	0.6	374.634	30.721	12.801	4.800	2.559	1.599	1.096	0.799	0.609	0.480	0.388	0.173	0.098
	7	0.7	437.073	35.841	14.935	5.600	2.985	1.865	1.279	0.932	0.711	0.560	0.453	0.201	0.114
	8	0.8	499.512	40.961	17.068	6.400	3.412	2.132	1.462	1.066	0.812	0.640	0.517	0.230	0.131
	9	0.9	561.951	46.082	19.202	7.200	3.838	2.398	1.644	1.199	0.914	0.720	0.582	0.259	0.147
	10	1.0	624.390	51.202	21.335	7.999	4.265	2.665	1.827	1.332	1.015	0.800	0.647	0.288	0.164
1.1	1	0.1	85.854	7.040	2.934	1.100	0.586	0.366	0.251	0.183	0.140	0.110	0.089	0.040	0.022
	2	0.2	171.708	14.080	5.867	2.200	1.173	0.733	0.502	0.366	0.279	0.220	0.178	0.079	0.045
	3	0.3	257.562	21.121	8.801	3.300	1.759	1.099	0.754	0.549	0.419	0.330	0.267	0.119	0.067
	4	0.4	343.416	28.161	11.734	4.400	2.346	1.466	1.005	0.733	0.558	0.440	0.356	0.158	0.090
	5	0.5	429.270	35.201	14.668	5.500	2.932	1.832	1.256	0.916	0.698	0.550	0.445	0.198	0.112
	6	0.6	515.124	42.241	17.602	6.600	3.519	2.198	1.507	1.099	0.837	0.660	0.533	0.237	0.135
	7	0.7	600.978	49.282	20.535	7.699	4.105	2.565	1.758	1.282	0.977	0.770	0.622	0.277	0.157
	8	0.8	686.832	56.322	23.469	8.799	4.691	2.931	2.010	1.465	1.117	0.880	0.711	0.316	0.180
	9	0.9	772.686	63.362	26.402	9.899	5.278	3.298	2.261	1.648	1.256	0.990	0.800	0.356	0.202
	10	1.0	858.540	70.402	29.336	10.999	5.864	3.664	2.512	1.832	1.396	1.100	0.889	0.396	0.225

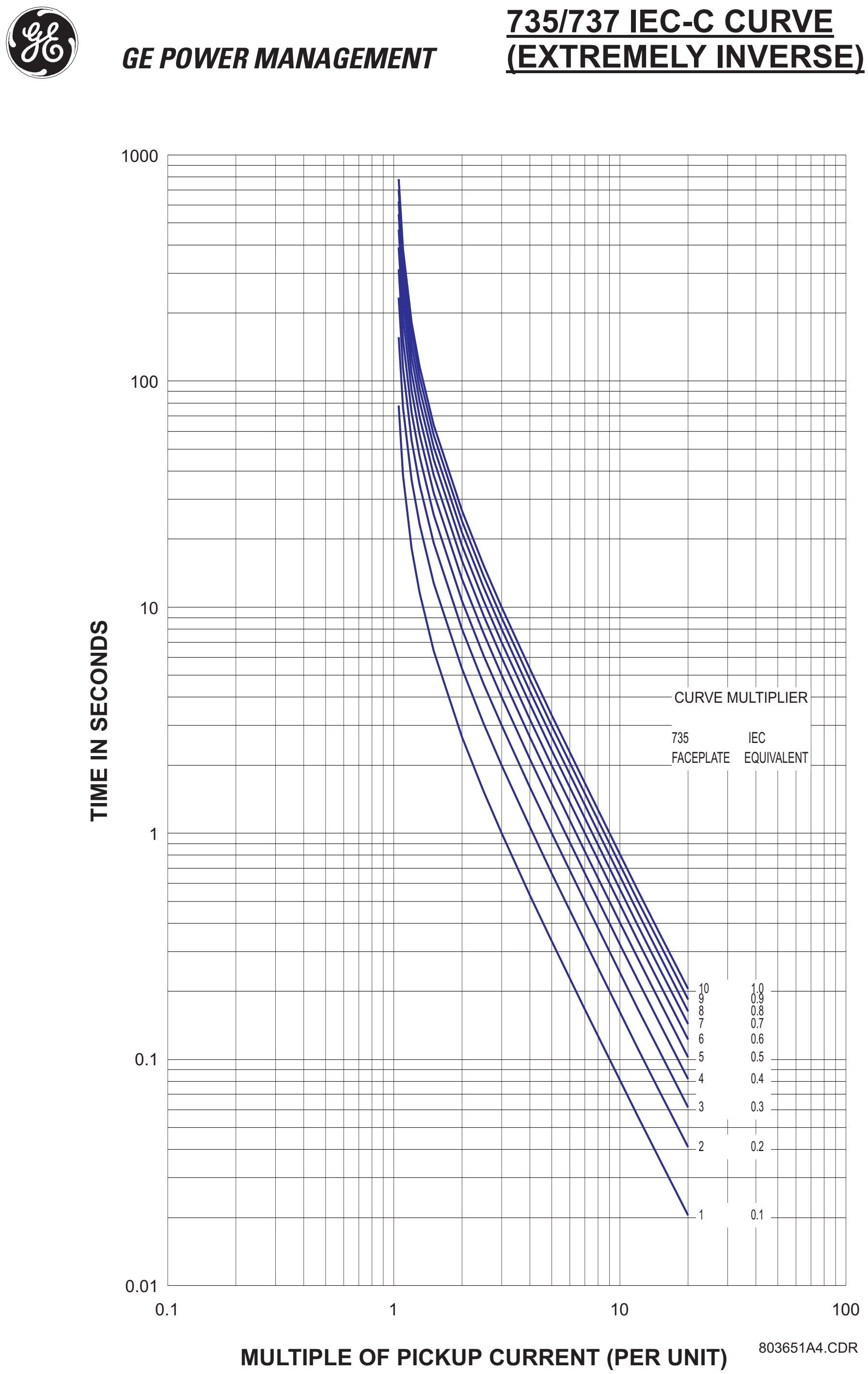

FIGURE 5–13: IEC C Curves

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735/737 Feeder Protection Relay

Chapter 6: Testing

6.1 Procedures

6.1.1 Primary Injection Testing

This is the preferred method of testing as complete system operation can be checked by injecting current through the phase and ground CTs. To do this a primary (high current) test set is required. The operation of the entire system including CTs and wiring can then be checked. If this equipment is not available, secondary injection tests can be performed to check everything except the CTs. This procedure is described in the following sections.

6.1.2 Secondary Injection Testing

Single phase secondary injection testing can be performed using a test setup similar to that FIGURE 6–1: *Test Setup* on page 6–3. Tests can be performed with the user programmed relay settings or with any others the tester requires. The relay settings should be recorded on the relay setting sheet (see Section 6.2 *Test Records*) so they can be reset when the relay is again put into service.

WARNING

NEVER OPEN THE SECONDARY CIRCUIT OF A LIVE CT. THE HIGH VOLTAGE PRODUCED MAY RESULT IN A SITUATION DANGEROUS TO BOTH PERSONNEL AND EQUIPMENT!

6.1.3 Communications Test

A PC equipped with an RS232/RS485 convertor and the Setup program can be used to establish communications with the 735 or 737. See Sections 2.2.4 *Communications* and 3.5 *Setup Program*. With the use of the setup program or Relaycom, custom scheme setpoints can be set and tested and the actual values screens can be used to monitor metered data and pre-trip data. Relay operation can also be simulated for training or testing purposes to understand how the relay operates.

6.1.4 Phase Current Reading Accuracy Test

The 735/737 relay must read the phase current signals input from the CTs correctly to provide the instantaneous and timed overcurrent protection. To determine if the relay is reading correctly set the phase pickup dial to 100% of the CT primary. Use the 3 Phase Test Set to set the phase current injected into the phases. Usually a mid value and a high value are tested (i.e. 40 and 400% of CT). Remember the current value injected will be dependent on whether 5A or 1A CTs are used in the relay.

6.1.5 Ground Current Reading Accuracy Test

This test is done in a similar manner to that for the phases. However lower or different values of injected current may be desired to test.

6.1.6 Instantaneous Phase Overcurrent Pickup Level Test

Set the phase pickup dial to OFF. Set the phase instantaneous dial to the desired level. Usually a low and a high value are tested (i.e. 4 × CT and 14 × CT). Using the 3-phase Test Set slowly increase the phase current injected until the trip or auxiliary relay (if assigned) is activated and the corresponding LED illuminated. Verify that the injected current at the time of trip corresponds to the instantaneous trip level setting ±3%.

6.1.7 Instantaneous Ground Fault Overcurrent Pickup Level Test

Set the ground pickup dial to OFF. Set the ground instantaneous dial to the desired level. Usually a low and a high value are tested (i.e. 0.1 × CT and 8 × CT). Using the 3-phase Test Set slowly increase the current injected into the ground CT input until the trip or auxiliary relay (depending upon how assigned) is activated and the corresponding LED illuminated. Verify that the injected current at the time of trip corresponds to the instantaneous trip level setting ±3%.

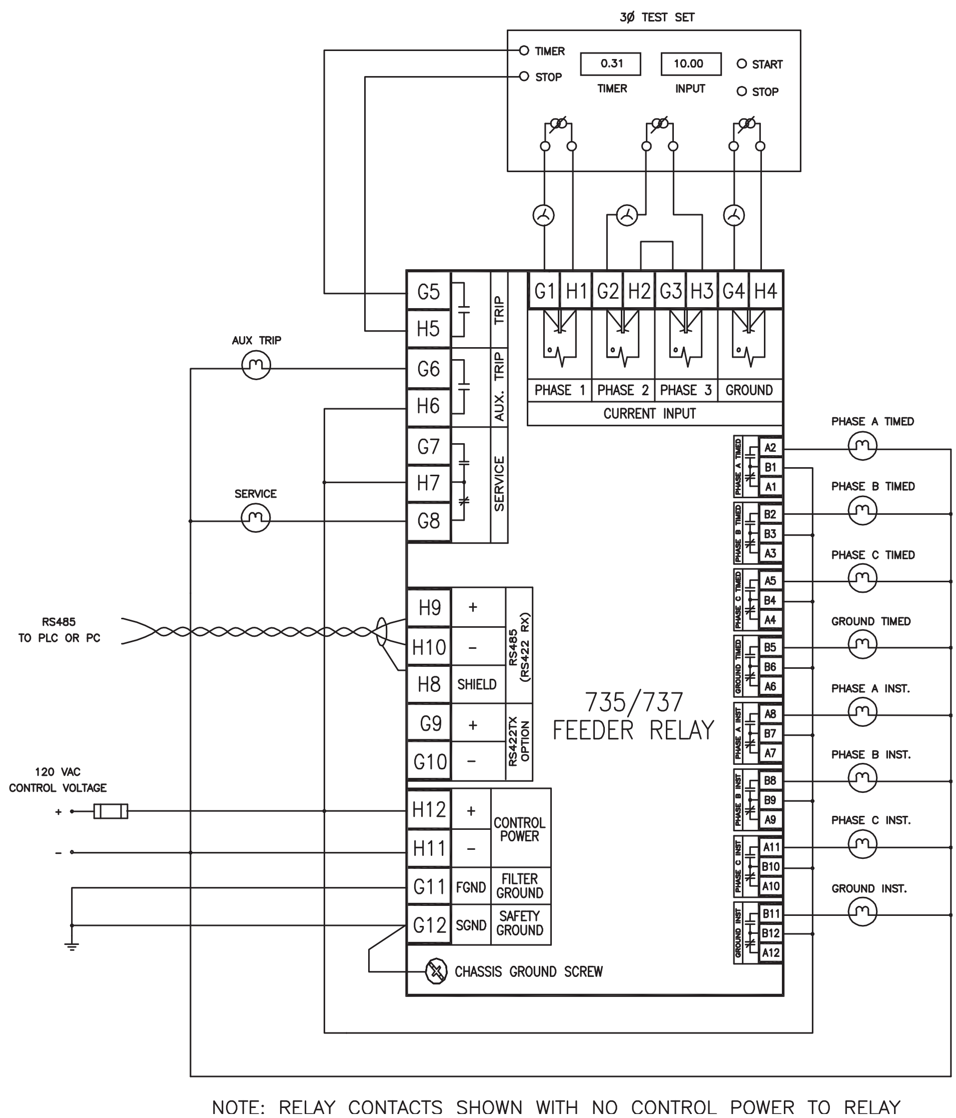

FIGURE 6–1: Test Setup

6.1.8 Instantaneous Phase Overcurrent Timing Test

Set the phase pickup dial to OFF. Set the phase instantaneous dial to the desired level. Using the 3-phase Test Set inject current equal to or above the instantaneous level setting. The timer on the 3-phase Test Set should be setup to start when current is injected and stop when the trip or auxiliary (if assigned) relay activates. Verify that the INST 50 phase A, B, or C (whichever phase tested) LED has been activated and latched.

6.1.9 Instantaneous Ground Fault Overcurrent Timing Test

Set the ground pickup dial to OFF. Set the ground instantaneous dial to the desired level. Using the 3-phase Test Set inject current equal to or above the instantaneous level setting. The timer on the 3-phase Test Set should be setup to start when current is injected and stop when the trip and/or auxiliary relay (depending upon how assigned) activates. Verify that the INST 50 N LED has been activated and latched.

6.1.10 Phase Overcurrent Curve Verification

Using the switches on the faceplate select the desired settings to test. i.e. pickup, curve shape and time multiplier. Set instantaneous switch to OFF. From the option dip switches located on the side of the relay select the phase time multiplier shift. If the curve type needs to be changed or checked this can be done through the setup program-setpoints-custom scheme. If a curve type other than ANSI is selected remember to enable switch 8 of the option dip switches. Using the 3-phase test set adjust the phase current to the desired trip level. Reset any current trips on the relay and press the test start button to activate the timer and inject the current. The timer on the 3-phase Test Set should be setup to start when current is injected and stop when the trip or auxiliary (if assigned) relay activates. Verify that the TIME 51 phase A, B, or C (whichever phase tested) LED has been activated and latched. Check the trip time with the times and curves located in Chapter 5. The accuracy of the timing is 3% or ±20 ms at > 150% of pickup.

NOTE

The more inverse the curve the more accurate the current source required to yield accurate time measurements. A small error in injected current will create a larger error in time to trip due to the extreme slope of the curve.

6.1.11 Ground Fault Overcurrent Curve Verification

This test is done in a similar manner to that for the phases. However different settings and current levels may be desired to test. Verify that the TIME 51 N LED has been activated and latched after a trip.

6.1.12 Power Loss/recover Test

A variac can be used to vary the supply voltage applied to the relay. First cause a trip on the relay and make note of the LED illuminated. The service relay H7 and G8 contacts should be open. Lower the voltage applied to the relay. The relay should not power off and the service relay change state until below the specified range for the power supply used. See Section *1.3: Specifications*. After the relay powers off the service relay should change state and the LEDs turn off. Now power up the relay. The relay should turn on and the service relay change state at or before the specified power supply range. The trip LED should again be illuminated.

6.1.13 Hi Potential Test

All terminals except filter ground and communications (H8, H9, H10, G9, G10) can be hi-pot tested. All remaining terminals except safety ground (G12) should be connected together and the test performed with respect to safety ground. Make sure to disconnect the filter ground (G11) before performing this test. Refer to Section *2.2.7: Hi-pot Testing* for more information.

6.2 Test Records

6.2.1 735/737 Test Record

Table 6–1:

MODEL NUMBER:	
FIRMWARE NUMBER:	
SERIAL NUMBER:	
STATION:	
CIRCUIT	

DATE	
TESTED BY	

6.2.2 Communications Test

Table 6–2:

TYPE OF COMMUNICATIONS ESTABLISHED	STATUS

6.2.3 Phase Current Reading Accuracy Test

Table 6–3:

PHASE AND LEVEL	INPUT CURRENT (%CT)	MEASURED CURRENT (%CT)	STATUS
PHASE 1 CURRENT LOW END			
PHASE 1 CURRENT HIGH END			
PHASE 2 CURRENT LOW END			
PHASE 2 CURRENT HIGH END			
PHASE 3 CURRENT LOW END			
PHASE 3 CURRENT HIGH END			

6.2.4 Ground Current Reading Accuracy Test

Table 6–4:

GROUND LEVEL	INPUT CURRENT (%CT)	MEASURED CURRENT (%CT)	STATUS
GROUND CURRENT LOW END			
GROUND CURRENT MID RANGE			
GROUND CURRENT HIGH END			

6.2.5 Instantaneous Phase Overcurrent Pickup Test

Table 6–5:

PHASE AND LEVEL	DIAL SETTING (xCT)	INPUT CURRENT ( )	STATUS
PHASE 1 / LOW END			
PHASE 1 / HIGH END			
PHASE 2 / LOW END			
PHASE 2 /HIGH END			
PHASE 3 / LOW END			
PHASE 3 / HIGH END			

6.2.6 Instantaneous Ground Overcurrent Pickup Test

Table 6–6:

PHASE AND LEVEL	DIAL SETTING (xCT)	INPUT CURRENT ( )	STATUS
GROUND / LOW END			
GROUND / HIGH END			

6.2.7 Instantaneous Phase Overcurrent Timing Test

Table 6–7:

PHASE AND LEVEL	DIAL SETTING (xCT)	INPUT CURRENT ( )	EXPECTED TIME (ms)	MEASURED TIME (ms)	STATUS
PHASE 1 / LOW END			≤ 35		
PHASE 1 / HIGH END			≤ 35		
PHASE 2 / LOW END			≤ 35		
PHASE 2 /HIGH END			≤ 35		
PHASE 3 / LOW END			≤ 35		
PHASE 3 / HIGH END			≤ 35		

6.2.8 Instantaneous Ground Fault Overcurrent Timing Test

Table 6–8:

GROUND LEVEL	DIAL SETTING (xCT)	INPUT CURRENT ( )	EXPECTED TIME (ms)	MEASURED TIME (ms)	STATUS
GROUND / LOW END			≤ 35		
GROUND / HIGH END			≤ 35		

6.2.9 Phase Overcurrent Curve Verification

Table 6–9:

PICKUP LEVEL	CURVE SHAPE	TIME MULT	TIME SHIFT	INPUT CURRENT ( )	EXPECTED TIME	MEASURED TIME	STATUS

6.2.10 Ground Fault Overcurrent Curve Verification

Table 6–10:

PICKUP LEVEL	CURVE SHAPE	TIME MULT	TIME SHIFT	INPUT CURRENT ( )	EXPECTED TIME	MEASURED TIME	STATUS

6.2.11 Power Fail/recover Test

Table 6–11:

POWER FAIL/RECOVERY LEVEL (V)	MEASURED LEVEL (V)	STATUS
FAIL @		
RECOVER @		

6.2.12 Hi Potential Test

Note the Filter Ground (terminal G11) must be left floating for this test. See Section *2.2.7: Hi-pot Testing* for details.

Table 6–12:

HIPOT LEVEL (kV)	DURATION ( )	STATUS

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735/737 Feeder Protection Relay

Chapter 7: Commissioning

7.1 Settings Table

7.1.1 Installation Information

STATION NAME	
EQUIPMENT DESIGNATION	
VOLTAGE	
DEVICE NUMBER	
CT RATIO	
ISSUE DATE	
APPLIED DATE	
735/737 SERIAL NUMBER	

7.1.2 Relay Settings

PHASE DIAL SETTINGS	
Phase Pickup Dial (LO: 20 to 100% of CT; HI: 110 to 220% of CT; OFF)	
Curve Shape Dial (MI, NI, VI, EI, Definite Time – HI/LO)	
Phase Time Multiplier Dial (1 to 10)	
Phase Instantaneous Dial (OFF, 4, 5, 6, 8, 10, 12, 14, 16, 20 x CT)	
GROUND DIAL SETTINGS	
Ground Pickup Dial (LO: 15 to 55% of CT; HI: 60 to 100% of CT; OFF)	

Ground Shape Dial (MI, NI, VI, EI, Definite Time – HI/LO)	
Ground Time Multiplier Dial (1 to 10)	
Ground Instantaneous Dial (OFF, 0.1, 0.2, 0.4, 0.8, 1, 2, 4, 8, 16 × CT)	
OPTION SWITCH SETTINGS	
Phase O/C Shift Multiplier (0.5, 0.8, 1.0, 1.1)	
Ground Time O/C Shift Multiplier (0.5, 0.8, 1.0, 1.1)	
Frequency (50 Hz, 60 Hz)	
Output Relays (Pulsed, Latched, Pickup, Pickup and Latched) – 737 only	
Custom Scheme (Disabled, Enabled)	
Custom Scheme > Time Overcurrent Curve Shape (ANSI, IAC, BS142)	
Custom Scheme > Block Instantaneous on Autoreclose (Disabled, Enabled)	
Custom Scheme > Aux Trip Relay (Main Trip, 86 Lockout, Ground Trip)	
COMMUNICATIONS SETTINGS	
Baud Rate	
Communications Address	

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735/737 Feeder Protection Relay

APPENDIX

A.1 Overcurrent Protection Sample Calculations

A.1.1 Characteristics

Overcurrent Protection for a 13.8 kV Feeder (from Short Circuit Study)

- Feeder rating = 600 A
- CT Ratio = 600:5
- Maximum load on feeder = 546 A
- Fault current for a 3 phase fault at the feeder end = 2800 A
- Fault current for a ground fault at the feeder end = 1100 A

The relay pickup current should be approximately twice the maximum load and allow for coordination with ‘downstream’ devices. The relay must operate for the minimum fault current at the very end of the feeder.

A.1.2 Phase Timed O/C Pickup

- Primary current pickup level = 2 × 546 A = 1092 A
- Secondary current pickup level = 1092 A × (5 / 600)= 9.1 A
- Phase Pickup dial setting = (9.1 A / 5 A) × 100 =182% ≈180%

From coordination curves obtained from the coordination study, obtain a ‘coordinating time interval’ with the slowest downstream relay and/or fuse of approximately 0.3 seconds (normally between 0.2 and 0.5 seconds). Also obtain appropriate curve shape and time multiplier from coordination curves. In this case, ‘very inverse’ and 2 times, respectively.

- Phase Curve Shape dial setting = VERY INVERSE (HI); Phase Time Multiplier dial setting **=** 2

A.1.3 Phase Instantaneous Pickup

The setting of the phase instantaneous element for this feeder is chosen such that it will not operate for faults beyond the first fused tap out from the feeder breaker.

- Fault current at first fuse = 5200 A
- Set phase instantaneous element at 6000 A
- Secondary current pickup level = 6000 A × (5 / 600)= 50 A
- Phase Instantaneous dial setting **=** 50 A / 5 A **=** 10

A.1.4 Ground Pickup

The minimum 'operate current' or pickup must be set above the maximum unbalance current that can be tolerated by the system. This unbalance usually is the result of unequal loading of single phase taps between the three phases. Typical maximum unbalance permitted is 20% of feeder rating, in this case 120 A (0.20 × 600). The relay must also operate for a ground fault at the feeder end.

- Primary ground pickup level = 240 A (120 < pickup level < 1100)
- Secondary ground current pickup level = 240 A × (5 / 600)= 2 A
- Ground Pickup dial setting = (2 A / 5 A) × 100= 40%

From coordination study obtain curve shape and time multiplier.

- Ground Curve Shape dial setting **=** VERY INVERSE (LO); Ground Time Multiplier dial setting **=** 3

A.1.5 Ground Instantaneous

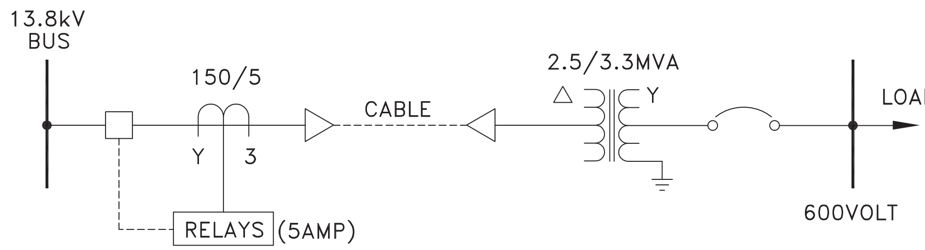
A setting for the ground instantaneous element for this feeder is chosen such that it will not operate for ground faults beyond the first fused tap from the feeder.

- Ground fault current at first fuse = 2100 A
- Level for ground instantaneous element = 2400 A primary
- Secondary ground instantaneous level = 2400 A × (5 / 600) = 20 A
- Ground Instantaneous dial setting = 20 A / 5 A = 4

A.2 Feeder Dedicated to a Transformer

A.2.1 Characteristics

Feeder Dedicated to a Transformer:



804609A1.DWG

From short circuit study:

- Maximum load current = $\dfrac{3300\text{ kVA}}{\sqrt{3} \times 13.8\text{ kV}}$ = 138 A
- Maximum transformer inrush = $\dfrac{2500\text{ kVA}}{\sqrt{3} \times 13.8\text{ kV}} \times 12$ = 1255 A
- 3Φ fault in high voltage cable = 1760 A
- Ground fault in high voltage cable = 2100 A
- 3Φ fault in 600 V cable = 20600 A

A.2.2 Phase Timed O/C Pickup

The phase time overcurrent pickup is approximately equal to 1.2 to 1.5 times the maximum current, for example: 1.3 × 138 A = 179.4 A. Thus,

- Phase Pickup dial setting = $\dfrac{179.4\text{ A}}{150\text{ A}} \times 100 = 120\%$

From time coordination curves established in the coordination study, with a minimum coordination between devices of 0.3 seconds (normally between 0.2 and 0.5 seconds), determine curve shape and time multiplier.

- Phase Curve Shape dial setting = VERY INVERSE
- Phase Time Multiplier dial setting = 3

A.2.3 Phase Instantaneous

It is desirable to operate this protection for a fault on the 600V bus.

- Fault current at 13.8 kV = $\dfrac{20600\text{ A} \times 600\text{ A}}{13800\text{ A}}$ = 895 A = 895 Amps

This current is less than the maximum possible transformer inrush current of 1255 A. Thus this value cannot be used. Instead set instantaneous pickup at 120% of inrush level.

Instantaneous pickup current level = 1.2 × 1255 = 1506 A

Phase Instantaneous dial setting **=** 1506 A / 150 A ≈ 10

A.3 Dos and Don'ts

A.3.1 Checklist

For accurate, reliable operation of the 735/737 it is imperative that the practices and recommendations listed below be adhered to at all times.

1. **735/737 Grounding**

   Users are requested to ground the 735/737 relays to a solid ground, preferably directly to the main GROUND BUS using a heavy gauge or braided cable. Do not rely on the metal switchgear enclosure to provide a solid ground. Each relay should have its own path to ground. Do not daisy chain grounds together. See Section 2.2.6 SYSTEM GROUNDING on page 2–12 for more details.

2. **Grounding of Phase and Ground CTs**

   All phase and ground CTs must be grounded. The potential difference between the CTs ground and the ground bus should be minimal (ideally zero). If the secondary windings were not grounded capacitive coupling could allow the secondary voltage to float up to the voltage of the mains. This could pose a serious safety hazard.

To help shield the lines from noise a twisted pair is recommended for all CT connections.

3. **RS485 Communications Port**

   The 735/737 can provide for direct or remote communication (via a modem). An RS232 to RS485 converter is used to tie it to a PC/PLC or DCS system. The 735/737 supports Modbus RTU protocol functions 03, 04, 05, 06, 07, and 16. For more information refer to Chapter 4: COMMUNICATIONS.

   RS485 communications was chosen to be used with the 735/737 because it allows communications over long distances of up to 4000 ft. Care, however, must be taken to ensure reliable trouble free operation.

   - A shielded twisted pair (preferably a 24 gauge Belden 9841 type or 120 equivalent) must be used and routed away from power carrying cables, such as power supply, contactors, breakers and CT cables.
   - A termination resistor and capacitor in series (120 W / 0.5 W resistor and 1 nF / 50 V capacitor) must be used at each end of the communication link. This matches the characteristic impedance of the line. The termination must be placed across the A– and B+ terminals at the master and at the + and – terminals (H9 and H10) of the last relay on the communications link. This is to prevent reflections and ringing on the line. If a different value of resistor is used there is a risk of overloading the line causing erroneous, intermittent or no communications.
   - It is highly recommended that the connection from the 735/737 to the interfacing master device be made without the use of any stub lengths or terminal blocks. This is to minimize ringing and reflections on the line.
   - The shield should only be grounded at one point. This is at the master. If it were to be grounded at more than one point a potential difference between grounds might exist. This could create a ground loop. The shield must however be connected to all 735/737 relays on the communication link (terminal H8). This is the floating ground

for the RS485 port which provides the ground reference as well as the reference for the internal noise suppression circuitry for the RS485 port.

- No more than 32 devices can co-exist on the same communications link. A repeater however may be used. It should be noted that the 735/737 relays have only 31 unique addresses. As each device on the communication link must have a unique address only 31 735/737 relays can be used on a single link. Other devices could however be used as well on the link though.
- RS485 connections are made from the 735/737 + terminal to other devices B or + terminals and from the – terminal to other devices A or – terminals.

4. Ground CTs

It should be noted that the 735/737 does not accept the GE Multilin 2000:1 CT which is actually a 50:0.025 CT. Only CTs with 5 A or 1 A secondaries may be used

5. Front Panel Controls

Front panel phase and ground protection settings should not be altered while the 735/737 is in service. When these rotary switches are positioned between settings, invalid information is passed to the relay's microcomputer. To insure correct operation of the 735/737, make sure all rotary switches are positioned properly.

A.4 Revision History

A.4.1 Change Notes

MANUAL P/N	FIRMWARE REVISION	RELEASE DATE
1601-0048-D1	735.D1	11/12/1992
1601-0048-D2	735.D1.2	12/08/1992
1601-0048-D3	735.D1.2	01/12/1993
1601-0048-D4	25D130D1.000	03/03/1993
1601-0048-D5	25D131D1.000	03/10/1993
1601-0048-D6	25D140D1.000	04/28/1993
1601-0048-D7	25D141D1.000	09/28/1993
1601-0048-D8	25D150D1.000	03/21/1994
1601-0048-D9	25D151D1.000	06/10/1994
1601-0048-DA	25D152D1.000	06/06/1995
1601-0048-DB	25D152D1.000	12/07/2000
1601-0048-DC	25D152D1.000	02/15/2001
1601-0048-DD	25D153D1.000	04/18/2001
1601-0048-DE	25D154D1.000	08/13/2001
1601-0048-DF	25D156D1.000	09/30/2005
1601-0048-DG	25D156D1.000	07/20/2006
1601-0048-DH	25D156D1.000	02/09/2008
1601-0048-DJ	25D156D1.000	04/02/2008
1601-0048-DK	25D156D1.000	05/31/2010

A.4.2 Changes to the Manual

Table A–1: Major Updates for 735 Revision DK

PAGE (DJ)	SECT (DK)	CHANGE	DESCRIPTION
Title	Title	Update	Manual part number to 1601-0048-DK
Table 3-1		Correction	Corrections to Pickup section

Table A–2: Major Updates for 735 Revision DJ

PAGE (DH)	SECT (DJ)	CHANGE	DESCRIPTION
Title	Title	Update	Manual part number to 1601-0048-DJ
General		Update	Minor structural updates

Table A–3: Major Updates for 735 Revision DH

PAGE (DG)	SECT (DH)	CHANGE	DESCRIPTION
Title	Title	Update	Manual part number to 1601-0048-DH
General		Update	Minor structural updates

A.5 Warranty Information

A.5.1 Warranty

GE MULTILIN RELAY WARRANTY

General Electric Multilin Inc. (GE Multilin) warrants each relay it manufactures to be free from defects in material and workmanship under normal use and service for a period of 24 months from date of shipment from factory.

In the event of a failure covered by warranty, GE Multilin will undertake to repair or replace the relay providing the warrantor determined that it is defective and it is returned with all transportation charges prepaid to an authorized service centre or the factory. Repairs or replacement under warranty will be made without charge.

Warranty shall not apply to any relay which has been subject to misuse, negligence, accident, incorrect installation or use not in accordance with instructions nor any unit that has been altered outside a GE Multilin authorized factory outlet.

GE Multilin is not liable for special, indirect or consequential damages or for loss of profit or for expenses sustained as a result of a relay malfunction, incorrect application or adjustment.

For complete text of Warranty (including limitations and disclaimers), refer to GE Multilin Standard Conditions of Sale.

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