9/19/02 REL356 Addendum to IB 40-226 (Dated January 2001)

1) This document has additional data to those at Page 1-6:

<u>1.1) Below 56/64kbps Digital Communication, it is added:</u>

"The maximum channel delay time for correct operation of REL356 is 24 milliseconds for relays with Catalogue # MC _ _ _ _ (D,H,E,M,L)_ _ _."

<u>1.2) Below 9600bps Audio Tone Communication Interface, it is added:</u>

"The maximum channel delay time for correct operation of the REL356 is 24 milliseconds for relays with Catalogue # MC _ _ _ _ (T,B)_ _ _ and 15 milliseconds for relays with Catalogue # MC_ _ _ _ (A,B)_ _ _."

2) Addition to page xi under REL356 Revision History:

<u>Version 1.31</u> **(08/29/02)**

"This version includes the following changes from V 1.21:

- **The addition of a settable timer (by setting) for the channel alarm contact,**
- **New setting parameter: CHAT = 0.0-10.0 sec, step 0.1 sec,**
- **The addition of a selectable (by setting) Transfer Trip Alarm contact,**
- **New setting parameter GSAL = GS/TTRP,**
- **New Voltage Transformer ratio setting. The setting range for VTR 300 - 7000 has been changed to 200 – 7000".**

3) Correction at page 5-7:

"Test Conditions: Case 2 – C0=0, C1=0.1, C2=0.7, OTH=0.50 (OTH=0.70 for V1.15 or lower) should be changed with <u>Test Conditions: Case 2 – C0=1, C1=0.1, C2=0.7, OTH=0.50 (OTH=0.70 for V1.15 or lower)</u>"

4) Correction at page 5-9:

Figure below <u>Dual Unit Back to Back Test – Internal faults</u>:

"TB6-6, TB6-6, TB6-8, TB6-8, TB6-10, TB6-10 should be changed with <u>TB6-5, TB6-6, TB6-7, TB6-8, TB6-9, TB6-10".</u>

ABB

Instruction Booklet
REL356

January 2001 (IB 40-226)

This Instruction Book is applicable to the REL 356 Versions 1.21 and all previous versions.

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Introduction

The REL 356 numerical current differential protection provides high speed protection for long and short lines. It is particularly suitable for lines too short to be effectively protected by distance relays and for tapped load applications. The current-only measuring principle offers advantages such as insensitivity to power swings, mutuals and problems associated with ccvt's. Communication interfaces for 9600 bps audiotone or 64 kbps direct digital or fiber optic are available. The REL 356 protection system also provides digital fault recording, fault locating and extensive target records.

Features

- numerical processing
- proven sequence filter for current differential measurement
- trip time 18 – 26 msec typical for digital communication
- 64/56 kbps digital communication for optical fiber or multiplexers
- modem version for leased telephone lines, analog microwave or metallic pilot wires
- automatic channel delay measurement
- independent Direct Transfer Trip
- directional or non-directional high set phase and ground independent trip
- built-in optional distance back-up

REL356 Revision History

Main board

Version 1.21 (10/01/00)

Same as v 1.20 except an internal code modification due to new modem design.

Version 1.20 (05/01/00)

This version includes the following changes from v 1.15:

- Added setting SOBT to allow longer reset time of the 52b contact.
- Added setting for OPBR so that the selections are OPBR=IE/52B/BOTH/OUT.
- Extended setting range for IPL and IGL
- Improved 2nd harmonic filtering
- Metering display of IT (composite current), OP (operating value) and RES (restraint value)
- OP and RES are now set in rms value instead of peak value

Version 1.15 (11/01/99)

Same as v 1.14 except a setting range change of TDES, trip-desensitizing feature.

Version 1.13 (03/29/99)

Same as v 1.12 except that distance back-up can be enabled.

Version 1.12 (03/23/99)

Same as v 1.11 and v 1.10 except

- Change of communication error display to FEPH (frame errors per hour).
- Added CDT, change detector supervision, of pilot trip.
- Added a 60 seconds trip limiting timer to prevent accidental overheating for standing relay trip.

Version 1.11 (10/20/98)

Same as v 1.10 but for digital communication versions.

Version 1.10 (08/27/98)

Same as v 1.00 with target display improvements. Modem version only.

Version 1.00 (08/12/97)

Initial release.

DCI, digital communication interface

Version 1.10 (10/20/98)

Improved noise immunity. Part number 1614C53G06.

Version 1.00 (08/12/97)

Initial release. Part number 1614C53G01.

CODEC, coder-decoder

Version 1.12 (10/20/98)

Improved noise immunity.

Version 1.10 (08/12/97)

Initial release.

Modem module

Version 1.10 (09/01/00)

New design due to obsolete Rockwell modem. Style number changed to “A” for channel selection. Note that the style “A” modem is incompatible with the older style “T” modem. The modems have to be of the same style in the two line ends.

Version 1.00 (08/12/97)

Initial release.

Product Overview

Application

The REL 356 is a dual-microprocessor based, composite sequence filter, current differential protection system. The REL 356 operates on the principles inherited from previous successful current differential systems (LCBII); but adapted and improved using numerical techniques.

The REL 356 is a pilot system, utilizing a communication channel with wide choice of analog and digital communication options.

The REL 356 is a high speed relaying system and is suitable for application to any voltage level. Its principle of operation makes it ideal for short lines and tapped lines with a power transformer, where traditional distance protection are not practical.

The REL 356 is a current-only system and provides all benefits associated with relaying systems not needing potential transformers such as:

- Unaffected by CCVT transients
- Unaffected by power swings
- Not affected by mutuals on parallel lines

An optional distance relaying system has been included to provide back-up for loss of communication channel. This back-up system consists of a two zone distance unit and logic for non-pilot relaying system. Phase and ground distance units are included.

The current differential protection is inherently immune to system swings and the relay will block the tripping. However, if power swing trip is desired, blinders have been provided for detecting this condition. OST (Out-of-Step Trip) is included in the optional distance back-up system.

An overcurrent tripping function is also included in the relaying system. The high set overcurrent function activates instantaneous trip when the phase (IPH) or the ground (IGH) threshold units detect currents above the settings. These units may be supervised by the directional units. The phase units are supervised by FDOP (Forward Directional Overcurrent Phase) and the ground unit is supervised by FDOG (Forward Directional Overcurrent Ground). Connection of external voltage transformers is required to activate the directional units.

The REL 356 also requires the connection to voltage transformers for out-of-step trip, distance protection, fault location, loss-of-potential and loss-of-current detection.

Because of the setting ranges available in the relaying system, it is possible to accommodate different ct ratios at the two terminals of the transmission line.

The REL 356 relay has the capability, through its channel modem, to accurately measure the communication channel delay. A continuous channel delay measurement with delay compensation is provided.

REL 356 System Operation

The basic operation of the REL 356 relay system performs a true differential comparison of line current flowing through each terminal of the protected line. A pilot channel, either fiber optic or audio tone, is used to bring in the remote terminal signals for comparison to the local signals. The unique methods used to represent the three phase current and securely transmit the remote signal produce the application flexibility and fidelity of the REL 356.

Current only systems, like the REL 356, compare the currents measured at the terminals of the transmission line. In a current differential system, the phasor relationship determines whether the condition is external or internal.

For an internal fault, the currents are essentially in phase at the terminals of the transmission line. For an external fault, the currents are 180° out of phase. Figure 1-1 illustrates the concept.

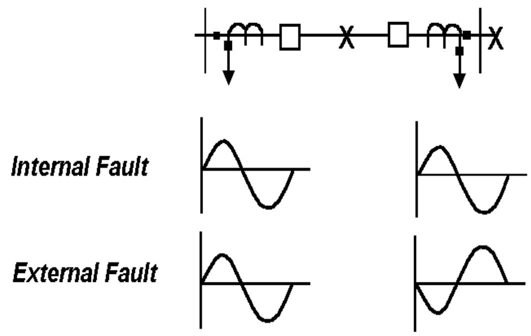


Figure 1-1. Fault Recognition

Standard Features

- Current differential protection algorithm
- Numerical processing
- Multiple microprocessor design
- Current change detectors and selectable voltage change detectors
- Direct transfer trip
- Channel independent high set phase and ground overcurrent units, directional or non-directional
- Fault locator
- High speed operation, typical 1½ cycle
- Close into fault detection
- Open breaker and stub bus trip
- Contact outputs for
  - Breaker trip
  - General start
  - Breaker failure initiation
  - Reclose initiate and block
  - System failure alarm
  - Channel failure alarm
  - Trip alarm
- RS232C series communications port
- Adaptive protection communication channel delay compensation
- Digital fault recording
  - 10 analog waveforms from local and remote measurements
  - 64 digital channels
  - 12 samples per cycle
- Local HMI interface
- 19” rack mounting

Communication Channel Options

REL 356 is available with eight different communication interfaces:

- 9600 bps audiotone
- British Telecom audiotone
- 56/64 kbps direct digital
- 56/64 kbps 820 nm multi-mode fiber
- 56/64 kbps 1300 nm single mode fiber, short reach
- 56/64 kbps 1300 nm single mode fiber, medium reach
- 56/64 kbps 1300 nm single mode fiber, long reach
- 56/64 kbps direct digital with G.703 interface

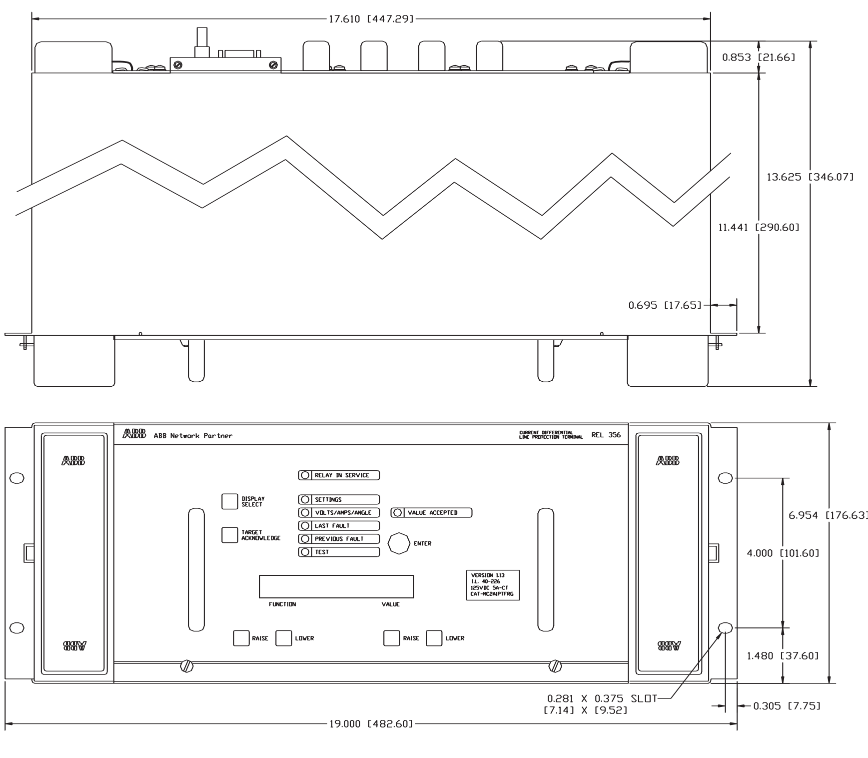
Optional Features

- Two zone distance back-up, phase and ground
- Directional ground back-up
- Loss of potential block
- Loss of current supervision
- Power swing block or trip
- Extended contact output with selectable transfer trip contacts
- Dual power supplies
- RS232C series communication port with IRIG-B input port
- Modbus PONI

Platform Overview

The REL 356 relay assembly consists of an outer-chassis and an inner-chassis which slides into the outer-chassis. The REL 356 conforms to the following dimensions and weight:

- Height 7” (requires 4 rack units @ 1.75” each); 177 mm
- Width 19”; 483 mm
- Depth 13.6”; 345 mm
- Weight 38 lbs; 17.5 kg



All of the relay circuitry, with the exception of the input isolation transformers and first-line surge protection, are mounted on the inner chassis, to which the front panel is attached. The outer chassis has a backplate, which is a receptacle for all external connections, including the digital communication interface. Two optional FT-14 switches are mounted in the two peripheral areas of the outer chassis. The FT-14 switches permit convenient and safe disconnection of trip, ac and dc circuits, and provide for injection of test signals.

REL 356 Modules

The inner and outer chassis, together, contain standard modules, plus the optional relay output board. The backplane module and digital communication interface (DCI) are connected to the backplate of the outer chassis. The remaining modules are attached to the inner chassis:

- Interconnect module
- Relay output modules
- Contact input module
- Microprocessor module
- Display module
- Power supply module
- Analog input module
- Modem module for 9600 bps audio tone channel version
- CODEC (coder-decoder) module for 56/64 kbps digital communication

Hardware Structure

The basic hardware consists of:

- Input transformers for analog signals (currents only, or currents and voltages)
- A front-end filter, multiplexer and A/D converter of those input signal
- One CPU for analog input sampling, Fourier computations, operator interface and non-volative data storage
- One CPU for protection functions, contact input interface, control output interface and communication interface
- Status inputs for logic operations
- Output contacts for control of external devices
- EPROM for program storage
- EEPROM for settings and fault-data storage
- Modem or CODEC module for protection communication

Specifications

Ratings

Nominal ac voltage at 60 Hz	69.3 V rms
Nominal ac current (In)	1 or 5 A rms
Rated frequency	50 or 60 Hz
Maximum permissible ac voltage	
Continuous	160 V rms (limited by maximum input to A/D converter)
10 seconds	240 V rms (limited by input transformer flux density)
Maximum permissible ac current	
Continuous	3 x nominal current (limited by thermal characteristics)
1 second	
Operational	160 A rms at 5 A, 32 A rms at 1 A (limited by maximum input to the A/D converter)
Thermal	100 x nominal current
dc battery voltages, nominal (range)	60/48 Vdc (30 – 70 Vdc) 110/125 Vdc (88 - 140 Vdc) 220/250 Vdc (176 – 280 Vdc)
dc burdens	
normal	15 W
tripping	40 W
ac burdens	
volts per phase	0.02 VA at 70 Vac
current per phase	0.45 VA at 5 A

External connections

Terminal blocks located on the rear of the chassis suitable for #14 square tongue lugs. Wiring to FT-14 switches suitable for #12 wire lugs.

Contact data

Trip contacts	
make and carry	
1 second	30 A
continuous	10 A
break	
resistive	50 W
L/R = 45 msec	25 W
Non-trip contacts	
continuous	1 A
resistive interrupt	0.1 A

Contacts meet IEC255-6A, IEC255-12, IEC255-16, BS142-1982

Binary (Voltage) Input Circuits

Jumper selectable	48, 125 or 250 Vdc
Drop-out threshold	67%

9600 bps Audio Tone Communication Interface

Operating speed	9600 bps
Standards compliance	ITU V.29
Carrier frequency	1,700 Hz
Modulation	QAM – Quadrature Amplitude Modulation
Transmit level	- 1 dBm to – 15 dBm in 2 dBm steps
Receiver sensitivity	- 33 dBm
Channel requirement	4 wire, unconditioned

56/64 kbps Digital Communication

Operating speed	56 or 64 kbps, selectable
Direct digital option	
Electrical standard	RS422/RS485
Mechanical standard	RS530
Maximum distance	4000'/1300 m
Fiber optic options	
Connector	ST
Wave length 820 nm	
Cable	multi-mode
Transmitter output into 50/125 µm cable	- 18 dBm minimum
Receiver input	- 28 dBm minimum
Reach, typical	2 miles/3.3 km
Wave length 1300 nm	
Cable	single-mode
Transmitter output into 9/125 µm cable	
Short reach option	- 20 dB minimum
Reach, typical	7.5 miles/12 km
Medium reach option	- 10 dB minimum
Reach, typical	20 miles/32 km
Long reach option	0 dB minimum
Reach, typical	32 miles/52 km
Receiver input	- 32 dBm minimum
	- 20 dBm maximum*

* Receiver maximum input is determined by receiver saturation and should not be exceeded. An attenuator is delivered to facilitate back-to back testing. The received level should be adjusted to – 26 dBm.

Optional G.703 Interface

The optional G.703 interface adapter complies with CCITT (ITU) G.703 co-directional, 64 kbps specification. For details refer to IL 40-201.7

Optional Computer/Network Interface

- RS232C PONI for single point computer communications
- RS232C PONI with IRIG-B for modulated/de-modulated IRIG-B time synchronization
- Modbus PONI for DNP 3.0 network communications (requires an external MIPC card)
- INCOM PONI for local network communications using INCOM network

Chassis Dimensions and Weight

Height	7” (177.8 mm), 4 rack units
Width	19” (482.6 mm)
Depth including terminal blocks	14” (356 mm)
Weight	68 lb (17.5 kg)

Environmental Data

Ambient temperature range	
Operation	- 20°C to + 60°C
Storage	- 40° C to + 80°C
Insulation test voltage, ANSI C37.90, IEC 255-5	2.8 kV dc, 1 minute 3.2 kV dc, 1 second
Open contacts	1400 V dc, continuous
Impulse voltage withstand, IEC 255-5	1.2/50 µs, 0.5 Joule
Surge withstand voltage, ANSI C37.90.1, IEC 255-22-1	3 kV, 1 MHz
Fast transient voltage, ANSI C37.90.1, IEC 255-22-4	4 kV, 10/100 ns
EMI field strength withstand, ANSI C37.90.2	25 MHz – 1 GHz, 10 V/m
Emission tests, EN 50081-1, class A	
Conducted emissions	150 kHz – 30 MHz
Radiated emissions	30 MHz – 1000 MHz

CT Requirements for REL356 Current Differential Protection

REL356 uses the operating principle of comparing an operating quantity OP with a restraint quantity RES. The operating quantity is formed from:

$$OP = \bar{I}_{TR} + \bar{I}_{TL}$$

where ITR is the remote composite current and ITL is the local composite current. ITR and ITL are formed by local and remote currents, respectively, in the following manner:

$$I_T = -C_1 I_1 + C_2 I_2 + C0 I_0$$

The restraint quantity is formed from:

$$RES = |I_{TR}| + |I_{TL}|$$

Operation is obtained when OP - 0.7 RES > OTH

where

OTH = set operating threshold

The worst case to consider is an external fault with one CT non-saturated while the other saturates. (This is an unlikely case since the CT's will have the same current and with similar characteristic and burden, both will have similar saturation.)

One end will then deliver the undistorted ITL. The other end will deliver some lower value of current, corresponding to x% of a "true" ITR. As this is an external fault ITR and ITL are 180 degrees out of phase and the magnitude of the "true" ITR is equal to the magnitude of ITL. Thus:

$$OP = I_{TL} + (-xI_{TR})$$
$$RES = I_{TL} + xI_{TR}$$

For operation OP > 0.7 RES + OTH

$$I_{TL} + (-xI_{TR}) > 0.7(I_{TL} + xI_{TR}) + OTH$$
$$I_{TL} + (-xI_{TL}) > 0.7(I_{TL} + xI_{TL}) + OTH$$
$$x < \frac{0.3 \cdot I_{TL} - OTH}{1.7 \cdot I_{TL}} \approx 0.176 \quad \text{as OTH} << \mathrm{I}_{TL}$$

The example shows that for an external fault, operation will only take place <u>if the saturated CT delivers **less** than 17.6% current compared to true current</u>. Even for the most severe saturation, a considerably higher amount current of <u>fundamental</u> frequency will be available.

The above example illustrates the high security of the REL 356 relay. It is difficult to derive an exact mathematical formula due to the complexity in mathematically describing CT saturation as a factor of fault current and system dc component. One important factor for the amount of saturation is the remanence present in the CT and this can not easily be taken into account in a theoretical study.

The formula we are giving for CT verification is based on experience. As it is impossible to test all types of CTs for all cases of remanence a factor 2 has been introduced as a safety margin. This means that the relay will operate correctly if the CT satisfies the requirement:

$$V_{k\min} = 2 \cdot I_{k\max}\left(R_{CT} + R_L + R_{356}\right)$$

where

V_{kmin} = minimum knee-point voltage required

I_{kmax} = secondary maximum through fault current, i.e. maximum current for an external fault

R_{CT} = CT secondary resistance

R_L = CT secondary burden, i.e. the sum of the cable resistance and the resistance of any other devices connected to the same CT core

R_{356} = burden of REL 356; 0.06 ohms for 1A and 0.02 ohms for 5A rated current

Catalog Information

Typical catalog number

Options	Cat. #	MC	2	B	2	N	A	N	R	G
Output contacts										
6 trip, 6 BFI, 4 RI, 2 RB		6								
2 trip, 2 BFI, 4 RI, 2 RB		2	2							
Current Rating										
1 A		A								
5 A		B		B						
Battery Voltage										
Single supply										
48/60 Vdc		1								
110/125 Vdc		2			2					
220/250 Vdc		3								
Dual supply										
48/60 Vdc		4								
110/125 Vdc		5								
220/250 Vdc		6								
Distance backup protection										
Backup protection		P								
None		N				N				
Channel interface										
9600 bps audiotone		A					A			
British Telecom audiotone		B								
56/64 kbps direct digital		D								
56/64 kbps 820 nm multi-mode fiber		H								
56/64 kbps 1300 nm single mode fiber, short reach (12 dB)		E								
56/64 kbps 1300 nm single mode fiber, medium reach (22 dB)		M								
56/64 kbps 1300 nm single mode fiber, long reach (32 dB)		L								
Test switches										
FT – 14 test switches		F								
No switches		N						N		
Remote communication device										
RS-232C PONI		R							R	
INCOM® PONI		C								
RS-232C with IRIG-B PONI		B								
Modbus PONI		M								
Digital fault recording		G								G
Accessories										
FT-14 Test plug										
Right side 1355D32G01										
Left side 1355D32G03										

Installation, Operation and Maintenance

Introduction

The REL 356 relay assembly is a numerical (fully digital) current differential transmission line protection system, with optional distance back-up protection and digital fault recording capability. The following communication options are provided:

- 9600 bps Audio tone
- 56/64 kbps Digital communication

REL 356 Construction

The standard nomenclature for ABB relay protection equipment is as follows:

- Cabinet – contains fixed-racks, swing-racks, or open racks
- Rack – contains one or more chassis (e.g., the REL 356)
- Chassis – contains several modules (e.g., Microprocessor or Power Supply)
- Module – contains a number of functional circuits (on printed circuit board)
- Circuit – a complete function on a printed circuit board (e.g., analog-to-digital conversion)
- The REL 356 relay assembly consists of an outer-chassis and an inner-chassis which slides into the outer-chassis. The REL 356 conforms to the following dimensions and weight:
- Height 7" (requires 4 rack units @ 1.75" each); 177 mm
- Width 19"; 483 mm
- Depth 13.6"; 345 mm
- Weight 38 Lbs; 17.5 kg

All of the relay circuitry, with the exception of the input isolation transformers and first-line surge protection, are mounted on the inner chassis, to which the front panel is attached. The outer chassis has a Backplate, which is a receptacle for all external connections, including Digital Communication Interface. Two optional FT-14 switches are mounted in the two peripheral areas of the outer chassis. The FT-14 switches permit convenient and safe disconnection of trip, ac and dc input circuits, and provide for injection of test signals.

REL 356 Modules

The inner and outer chassis, together, contain standard modules, plus the optional relay output. The Backplane module and Digital Communication Interface (DCI) are connected to the Backplate (outer chassis). The remaining modules are attached to the inner chassis:

- Interconnect module
- Relay Output module
- Contact Input module
- Microprocessor module

Backplane Module

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

The Backplane Module receives all external connections and connects directly to the Interconnect module, thru plug-in connectors (J11, J12, J13); and to the Relay Output and Contact Input modules, mounted on the Interconnect module (via connectors JA1, JA2, JA3, JA4), which provide the connections between the inner and outer chassis.

Backplane Module provides connection to DCI module used for 56/64 kbps Digital Communications. The INCOM/PONI® is mounted on the Backplate of the outer chassis and is connected to the Backplane module (via connector J4).

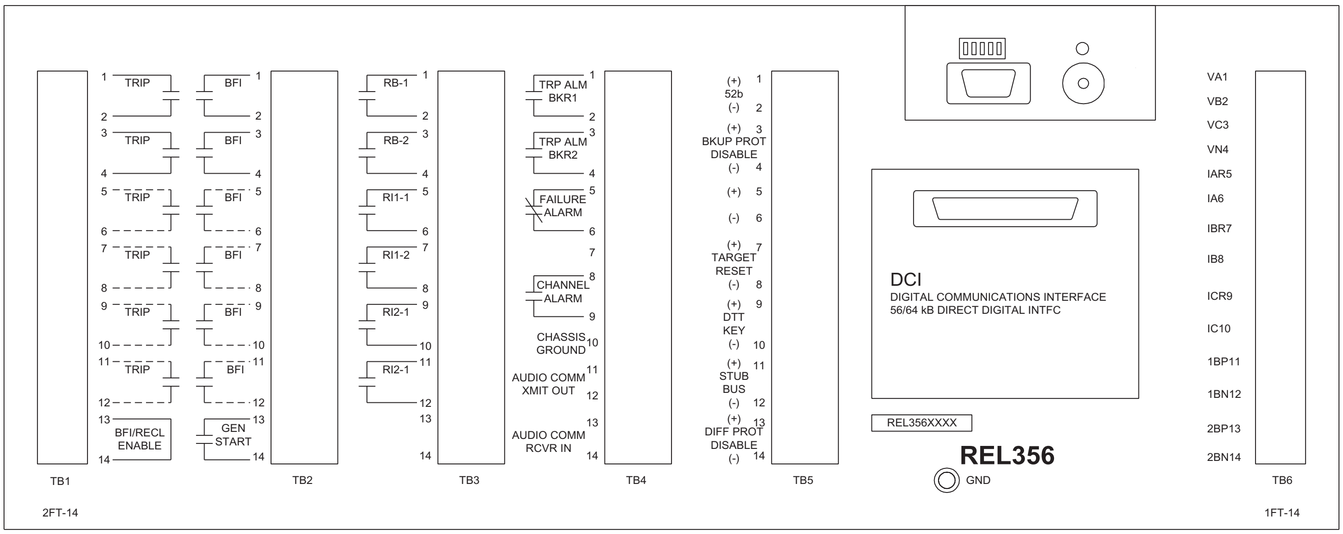


Figure 2-1. Backplane

There are two jumpers on the backplane, JMP1 and JMP2. These jumpers are factory set for the communication option included in the relay. The settings are as follows:

	Audiotone version	*Digital Communication*
JMP1	TP1A	TP1D
JMP2	TP2A	TP2D

Interconnect Module

The Interconnect module becomes the floor of the REL 356 inner chassis; it provides electrical connections from and to all other modules: from the Backplane (at the rear), to the Analog Input and Power Supply modules (at left and right, respectively), to the Relay Output and Contact Input modules in the center, and to the Modem or CODEC, Microprocessor and Display modules at the front of the inner chassis.

The Interconnect module receives inputs V_{AG}, $V_{B\,G}$, V_{CG}, I_A, I_B, I_C from the Backplane module and feeds them to the Analog Input module.

There are two jumpers on the interconnect board, JMP1 and JMP2. These jumpers are factory set for the communication option included in the relay. The settings are as follows:

	Audiotone version	*Digital Communication*
JMP1	OUT	IN
JMP2	OUT	IN

Relay Output Module

There are three versions of this module (they are installed on the Interconnect module):

Version	*Function*	*Connector*
Option	4 trip (form A), 4 BFI contacts (form A)	JB1
Base 1	2 trip (form A), 2 BFI (form A), 2 RB (form A), 1 GS contacts (form A)	JB2
Base 2	4 RI (form A), 2 Trip Alarm (form A), 1 Failure Alarm (form B)	JB3

The Channel Alarm output is provided on the Interconnect Module.

The Option version is used for extended contact output

Contact Input Module

This module provides an opto-isolated interface between:

- Contact inputs contaminated by external noise, and logic level inputs to the Microprocessor module

Voltage selection is made by jumper positions JM3 to JMP9:

Position	*Rated Voltage*
(1 – 2)	48/60 Vdc
(3 – 4)	110/125 Vdc
(5 – 6)	220/250 Vdc

The inputs will de-assert at 67% of the higher rated voltage. For example, for jumper position (3 – 4), the input will drop out when the voltage goes below 125 x 67% = 83.8 V.

Microprocessor Module

This module contains two processor systems (connected via the Dual Port RAM), which perform two main functions:

- Processor 1 samples the analog inputs and provides the operator interface
- Processor 2 is the protection processor

Each processor system (P1 and P2) contains the following elements:

- Microprocessor — 16 bit microcontroller (Intel 80C196) operating at 12 MHz.
- EPROM — an ultraviolet erasable read-only memory for program storage.
- RAM — a read-write, static, random access volatile memory for performing data storage.

Processor 1 (P1) has access to:

- EEPROM — electrically erasable, read-write non-volatile memory for settings and fault-data storage.
- Real-Time Clock — is accessed by Processor 1, to time-stamp the events.

The microprocessor module has a jumper for enabling contact output test, JM1. To enable test, set JM1 in position (1 – 2). To disable contact output test, set JM1 in position (2 – 3). After performing a contact output test, JM1 should be returned to its original position, (2 – 3). This will prevent accidental contact operation when the TEST function is enabled from the front panel.

The front panel has an automatic display saver feature. This feature is factory set to ENABLED by JM2 in position (2 – 3). The display saver feature can be turned off by setting JM2 in position (1 – 2).

Display Module

The Display module interfaces with the Processor 1 system of the Microprocessor module. The Display module contains:

- 2 blue-vacuum fluorescent alphanumeric displays or one LCD display for value and function fields (each field has 4 characters)
- 7 LEDs (with 7 corresponding keys for selection purposes) provide function interpretation capabilities

The LEDs indicate:

- Relay In Service
- Settings
- V/I/Angle
- Last Fault
- Previous Fault
- Value Accepted
- Test

When the “Relay In Service” LED illuminates, the REL 356 relay is in service, there is dc power to the relay and the relay has passed the self-check and self-test. The LED is turned OFF if the relay has at least one of the internal failures shown in the TEST mode.

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

The 7 push-button switches are used to activate the following functions on the front panel:

- Display Select (the LED’s, to the right of this push-button, indicate the selected function)
- Reset
- Function Raise (move to the following function)
- Function Lower (move to the previous function)
- Value Raise (move to the next higher value)
- Value Lower (move to the next lower value)
- Enter (recessed for security purposes)

Power Supply Module

Three different styles of power supply boards are required to accommodate the input voltage ranges listed below. The REL 356 relay is capable of continued operation during a 200 msec voltage dip from the dc battery input; the magnitude of this voltage dip is also shown in the table:

Nominal Battery (Vdc)	Input Range (Vdc)	Voltage Dip (Vdc)
48/60	38-70	28
110/125	88-145	73
220/250	176-280	146

As an option this module contains two independent power supplies, with diode-auctioneered outputs for reliability purposes; both supplies are powered from a dc battery voltage. The switching power supply, operating at 25 kHz, generates transformer-isolated voltages as follows:

System Voltage	Circuitry Supplied	System Voltage	Circuitry Supplied	System Voltage	Circuitry Supplied
8.5 Vdc	Processor Board +5 Vdc Supply	-12 Vdc	Analog circuitry	-24 Vdc	Channel Modem VF Display COPS Chips
+12 Vdc	Analog Circuitry	+24 Vdc	Channel Modem, PONI Module	6.5 Vac	Vacuum Fluorescent Display Filament

Analog Input Module

This module interfaces with the voltage and current transformers that are mounted on the Backplane module. These transformers provide the following ac values: V_A, V_B, V_C, I_A, I_B, I_C. These values are applied to active third-order Butterworth antialiasing filters, with a cut-off frequency determined by the Nyquist criterion and the system sampling rate. Values I_A, I_B, I_C are summed to produce $3I_0$.

All 7 inputs (V_A, V_B, V_C, I_A, I_B, I_C, $3I_0$) are connected to the multiplexer and to the A/D converter. The A/D converter is a self-calibrating 12-bit (plus sign), with an internal track-and-hold amplifier. Additionally, the autoranging circuitry provides 16 bits of dynamic range needed to measure high fault current values.

Modem Module (9600 bps Audio Tone Option)

This module interconnects two REL 356 systems, located at each end of the protected line. A 4-wire communication channel of sufficient quality to provide reliable data interchange is required. The modem, operating at a carrier frequency of 1700 Hz, conforms to ITU V.29 standards, and provides a communication speed of 9600 bps.

The modem is under the control of an on-board digital signal processor and interfaces, via a parallel bus, with the Microprocessor module.

The analog signals (transmit and receive levels), and digitally-encoded S/N ratio, are also available to the Microprocessor module. The modem transmit level is controlled by the Microprocessor module via the above-mentioned parallel bus.

Modem TXA and RXA are transmitter tone output and receiver tone input lines. TXA is 600 ohms and RXA is high impedance. TXA will output + 5.0 Vdc for 0 dBm modem output. Modem receive input is amplified/rectified and will output + 5.0 Vdc for a 0 dBm input. The dc output is approximately proportional to modem tone output voltage level below 0 dBm.

There are two jumpers on the modem board, J1 and J2. These are factory set for REL356 in position (2 – 3). Position (1 – 2) is for use with REL350.

CODEC (56/64 kbps Digital Communication Option)

This module interconnects two REL 356 systems, located at each end of the protected line.

CODEC (Coder/Decoder) provides digital communication capability at 56 or 64 kbps, selectable via setting.

The CODEC is under the control of an on-board digital signal processor and interfaces via a parallel bus with the Microprocessor module.

The two signals, TX (transmit data) and RX (receive data) interface to the Digital Communication Interface module (DCI).

Digital Communication Interface DCI (56/64 kbps Digital Communication Option)

This module converts 5V logic level serial input and output data lines to/from CODEC module into one of the optional interfaces:

- Fiber optic option, 820 nm, ST connector, multi-mode cable
- 56/64 kbps direct digital option, electrical standard RS422/RS485, mechanical standard RS530. The connector is a male DB-25 plug as required for Data Terminal Equipment (DTE). TXA is on pin 2, RXA pin 3, TXB pin 14 and RXB on pin 16. No clock synchronization input is required. Clock synchronization bit is taken from the received dataframe.
- Fiber optic option, 1300 nm, ST connector, single-mode cable, short reach (12dB budget)
- Fiber optic option, 1300 nm, ST connector, single-mode cable, medium reach (22dB budget)
- Fiber optic option, 1300 nm, ST connector, single-mode cable, long reach (32dB budget)

The DCI assemblies connect to the rear of the REL356 relay via a 4 pin header.

Self-Checking Software

a. Digital Front-end A/D Converter Check

REL 356 continually monitors its ac input subsystems using multiple A/D converter calibration-check inputs. Failures of the converter trigger alarms.

b. Program Memory Check Sum

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

c. Power Up RAM Check

Immediately upon power-up, the relay does a complete RAM memory read/write tests.

d. Nonvolatile RAM Check

All settings and targets are stored in nonvolatile RAM in three identical arrays. These arrays are continuously checked by the program. If all three array copies disagree, a nonvolatile RAM failure is detected.

Unique Remote Communication (WRELCOM) Program

Three optional types of remote interface can be ordered.

- RS232C for single point computer communication. (See IL 40-603, RCP Remote Communication Program.)
- INCOM for local network communication.
- Modbus PONI (See IL 40-616, PONI-M Modbus RS485 User's Guide.)

A special PC software (WRELCOM RCP and OSCAR) program are available for obtaining or sending the setting information to the REL 356. The REL 356 front panel shows two fault events (last and previous faults), but the remote communication, 16 fault events and 3 records of oscillographic data can be obtained and stored. Each record of the oscillographic data contains 8-cycle information (1-prefault and 7-post-fault), with 7 analog inputs and 24 digital data (at the sampling rate of 12 per cycle).

Separating the Inner and Outerchassis

CAUTION: It is recommended that the user of this equipment become acquainted with the information in these instructions before energizing the REL 356 and associated assemblies. Failure to observe this precaution may result in damage to the equipment.

All integrated circuits used on the modules are sensitive to and can be damaged by the discharge of static electricity. Electrostatic discharge precautions should be observed when operating or testing the REL 356.

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

a. Unscrew the front panel screws.
b. Remove the (optional) FT-14 covers if supplied (one on each side of the REL 356).
c. Open all FT-14 switches.
Do Not Touch the outer contacts of any FT-14 switch; they may be energized.
d. Slide out the inner chassis.
e. Close all FT-14 switches.
f. Replace the FT-14 covers.
g. Reverse procedures above when replacing the inner chassis into the outer chassis.

Test Plugs and FT-14 Switches

• Test Plugs are available as accessories; they are inserted into the FT-14 switches for the purpose of System Function Tests.

External Wiring

All external electrical connections pass thru the Backplate on the outer chassis. Seven DIN connectors (J11, J12, J13, JA1, JA2, JA3, JA4) allow for the removal of the inner chassis from the outer chassis.

Electrical inputs to the Backplane module, which are routed either directly thru the Backplate or thru the FT-14 switch to the Backplate include:

- V_A, V_B, V_C and V_N
- I_A /I_{AR}, I_B/I_{BR}, I_C/I_{CR}
- Power Supply (Battery) Inputs
  Primary (IBP, IBN)
  Backup (2BP, 2BN)

Analog input circuitry consists of three current transformers (I_A, I_B, I_C) three voltage transformers, (V_A, V_B and V_C), and low-pass filters. The six transformers are located on the Backplane PC Board. The primary winding of all six transformers are directly-connected to the input terminal TB6/1 thru 12; the secondary windings are connected thru the Interconnect module to the Analog Input module.

As shown in Figure 2-1, dry contact outputs for breaker failure initiation (BFI), reclosing initiation (RI), reclosing block (RB), failure alarm and trip alarm are located on the Backplane PC Board.

As shown in Figure 2-4, the power system ac quantities (V_a, V_b, V_c, V_n, I_a, I_b, I_c), as well as the dc sources are connected to the left side 1FT-14 switch (front view). All the trip contact outputs are connected to the right-side 2FT-14 switch (front view). Switches 13 and 14 on 2FT-14 may be used for disabling the Breaker Failure Initiation/Reclosing Initiation (BFI/RI) control logic.

The INCOM/PONI communication box is mounted thru the Backplate of the outer chassis and connected to the Backplane module. An RS-232C serial port is provided for remote transmission of target data. The serial port is also available for networking, data communications, and remote settings.

REL 356 FRONT PANEL DISPLAY

The front panel display consists of a vacuum fluorescent display set of seven LED indicators, seven key switches.

Vacuum Fluorescent Display

The vacuum fluorescent or LCD display contains 2X4 alphanumeric characters for the function field and the value field. The display is blocked momentarily every minute for the purpose of self-check; this will not affect the relay protection function. A “DISPLAY SAVER” feature turns-off the display if no key activity for 3 minutes is detected.

Indicators

There are 7 LED indicators on the front panel display:

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

When the “Relay-in-Service” LED illuminates, the REL 356 Relay is in service, there is dc power to the relay and the relay has passed the self-check and self-test. The LED is turned “OFF” if the Relay-in-service relay has at least one of the internal failures shown in the “Test” mode.

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

The 5 indicators used for the display selection are:

- Settings
- Volts/Amps/Angle
- LAST FAULT
- PREVIOUS FAULT
- Test

One of these indicators is always illuminated, indicating the mode selected.

Key Switches

The front panel contains 7 keys:

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

The “Display Select” key is used to select one of the five display modes, which is indicated when the proper LED illuminates. When a fault is detected, the “LAST FAULT” flashes once per second. If two faults are recorded, the “LAST FAULT” flashes twice per second, and the prior fault will be moved from “LAST FAULT” to “PREVIOUS FAULT”. The new fault data will be stored in the “LAST FAULT” register. By depressing the “Reset Targets” key, the flashing LED indicators are cleared, and the LED will revert back to the Metering mode. The information in the “PREVIOUS FAULT” and “LAST FAULT” will not be reset from the front panel key switch, but will be reset from External Reset (TB5-7 and TB5-8) and the remote reset through the Communication Interface.

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

Front Panel Operation

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

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

Settings Mode

In order to determine the REL 356 settings that have been entered into the system, continually depress the “DISPLAY SELECT” key until the “SETTINGS” LED is illuminated. Then depress the “FUNCTION RAISE” or “FUNCTION LOWER” key, in order to scroll thru the REL 356 SETTINGS functions. For each settings function displayed, depress the “VALUE RAISE” or “VALUE LOWER” key in order to scroll thru the REL 356 values available for the particular function. (Each value that appears, as each different function appears in the function field, is considered to be the “current value” used for that particular function.)

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

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

Metering (Volts/Amps/Angle) Mode

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

NOTE: All displayed Phase Angles use V_A as reference.

Target (LAST and PREVIOUS FAULT) Mode

The last two Fault records are assessable at the Front panel. The “LAST FAULT” information is of the most recent fault, the “PREVIOUS FAULT” information is of the fault prior to the “LAST FAULT”. These displays contain the target information along with the “Frozen” data at the time of trip. The “LAST FAULT” register shows one or two records stored by flashing the LED once or twice per second, respectively.

As soon as a fault event is detected, the most recent two sets of target data are available for display. The “LAST FAULT” is the data associated with the most recent trip event. The “PREVIOUS FAULT” contains the data from the prior trip event. If a single fault occurs, the “LAST FAULT” LED flashes. If a reclosing is applied and the system trips, the original “LAST FAULT” information will be transferred to the “PREVIOUS FAULT” memory. The latest trip information will be stored in the “LAST FAULT” memory, and its LED flashes twice per second. To reset the flashing LEDs, depress the “Reset Targets” key once. The target information in “LAST FAULT” and “PREVIOUS FAULT”, will not be reset from the front panel key switch.

There are 2 ways to reset the targets:

- Using the “Target Reset” Contact Input.
- With the INCOM command, using the communication channel.

Test Mode Function

The test display mode provides diagnostic and testing capabilities for REL 356. Relay status display, local delay time computation, and relay testing are among the functions provided. The test mode functions are listed in Table 2-1.

Table 2-1. Test Mode Functions

Function	Description
STAT	Relay Self-Check Status
SRT	Monitor Standing Relay Trip Signal
TRIP	Relay Test: Trip Relays
BFI	Relay Test: BFI Relays
SRI	Relay Test: RI Relay (RI1)
3RI	Relay Test: RI Relay (RI2)
RB	Relay Test: Reclose Block Relay
GS	Relay Test: General Start Relay
FALM	Relay Test: Failure Alarm Relay
TALM	Relay Test: Trip Alarm Relay
CALM	Relay Test: Channel Alarm Relay
OPTI	Display Opto Input Status

Contact Input Test

The Contact Input module can be conveniently tested, using the Contact Input Test Function.

To activate this function, continually depress the DISPLAY key until the “TEST” LED is illuminated. Then depress the “FUNCTION RAISE’ or “FUNCTION LOWER” key until the word “OPTI” appears in the FUNCTION field.

The “VALUE” field will display the status of the contact inputs, using two hexadecimal digits, as explained below.

When the contacts close (voltage is applied across two input terminals), the corresponding bit is set to binary “1”; an open set of contacts results in a binary “0”. The following correspondence exists:

FUNCTION	BIT NUMBER
Direct Transfer Trip	0
Stub Bus	1
Differential Protection Disable	2
Target Reset	3
52b	4
Not Used	5
Not Used	6
Not Used	7

For example, the functions listed below,

- DTT (closed)
- Differential Protection Disable (closed)
- Target Reset (closed)
- 52b contact (closed)
- Remaining contacts (open)

will result in the following binary pattern:

Bit Pattern	0 0 0 1	1 1 0 1
Bit Number	7 6 5 4	3 2 1 0
HEX "Value" Field Display	1	D

For reference, refer to Table 2-2 for the binary-to-hexadecimal conversion.

Table 2-2. Binary-to-Hexadecimal Conversion

BIT NUMBER				
3/7	2/6	1/5	0/4	HEX DIGIT
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9
1	0	1	0	A
1	0	1	1	B
1	1	0	0	C
1	1	0	1	D
1	1	1	0	E
1	1	1	1	F

Relay Output Test

All relay outputs can be tested using the procedure described below:

(1) Open the FT switch, using the red handles of the breaker trip circuits, making sure that the following jumper is not disturbed:

BFI/RECLOSE ENABLE

(2) Install jumper JMI in position 1-2 on the Microprocessor module.

(3) Continually depress the "DISPLAY" key until the "TEST" LED is illuminated; then depress the "FUNCTION RAISE" or "FUNCTION LOWER" key until the words "TRIP" and "RELY" appear in the FUNCTION and VALUE fields, respectively.

(4) Activate the “ENTER” key for the desired duration of the output relays operation.

(5) Depress the “FUNCTION RAISE” key to select the following parameters, as desired:

FUNCTION FIELD	VALUE FIELD	DESCRIPTION
TRIP	RELY	TRIP (A, B, C)
* BFI	RELY	Breaker Failure Initiate
* RI (RI1-1,2)	RELY	Single Pole Reclose Initiate
* RI (RI2-1,2)	RELY	3 Pole Reclose Initiate
RB	RELY	Recloser Blocking
GS	RELY	General Start
FALM	RELY	Failure Alarm
TALM	RELY	Trip Alarm
CALM	RELY	Channel Alarm

Note: * These outputs are enabled only if a connection is made from TB1-13 to TB1-14.

(6) Activate the “ENTER” key to operate selected output relays.

(7) After completion of this test, restore the system to its operating state by moving JM1 to position 2-3 on the Microprocessor module, and closing the FT switch red handles.

Self Check

The results of the system self-check routines are accessible using the following procedure:

a. Continually depress the “DISPLAY” key until the “TEST” LED is illuminated; then depress the “FUNCTION RAISE” or “FUNCTION LOWER” key until the word “STAT” appears in the FUNCTION FIELD.

b. The VALUE FIELD will display the status of the relay in hexadecimal format:

RELAY STATUS

DESCRIPTION	BIT NUMBER
External RAM Failure	0 Least Significant Right-Most Position
EEPROM Failure	1
ROM Checksum Failure	2
Dual-Port RAM Failure	3
Analog Input Failure	4
Processor Failure	5
± 12V P.S.Fail	6
Modem Failure	7
EEPROM Warning	8
Power Supply 1 Failure	9
Power Supply 2 Failure	10
Dual Port RAM Com Status Warning	11
Failure Detected by Processor 1	12
Failure Detected by Processor 2	13
0	14
0	15 Most Significant Left-Most Position

A bit set to “1” signifies that the corresponding failure has been detected. For example, the following failures will result in a bit pattern:

ROM CHECKSUM	(Bit 2)
Analog Input	(Bit 4)
Processor 1	(Bit 12)

The bit pattern which results is shown below:

Bit Pattern	0 0 0 1	0 0 0 0	0 0 0 1	0 1 0 0
Bit Number	15 14 13 12	11 10 9 8	7 6 5 4	3 2 1 0
Hex “VALUE” Display	1	0	1	4

For normal error-free system performance, the “VALUE” field display is “0”.

The status display is generated by “OR”ing, the self-test status from Processor 1 and Processor 2. A zero value indicates that no self-test failure has occurred. A non-zero value in the low byte (bits 0 to 7) represents an REL 356 failure condition which enables the failure alarm, and disables tripping. A non-zero value in the third character from the right (bits 8 to 11) indicate a self-test- warning which enables the failure alarm, but does not disable tripping. The left-most character (bits 12 to 15) indicates which processor(s) detected the failure.

Test Enable

A digital fault record is triggered, when the ENTER key is depressed, while the TEST mode TEST function is selected on the front panel.

Standing Relay Trip

A real-time status monitor of the Standing Relay Trip (SRT) logic signal is provided as a test mode function. The value of the SRT function is YES if any of the trip relays is enabled, other-wise, the value is “NO”.

CAUTION: The user should verify that SRT = “NO” prior to putting the REL 356 in service after testing.

Network Interface

Three options are available for interfacing between REL 356 and a variety of local and remote communication devices.

- RS-232C/PONI - for single point computer communication
- INCOM/PONI - for local network communication
- PONI-M RS485 - for Modbus network communication

An IBM PC or compatible computer, with software provided (WRELCOM), can be used to monitor the settings, 16 fault data records, 3 oscillographic records, and metering information. For a remote setting, SETR should be set to “YES”; then the settings can be changed (remotely) with a user-defined password. If a user loses his assigned password, a new password can be installed by turning the REL 356 relay’s dc power supply “OFF” and then “ON”. REL 356 allows a change of password within the next 15 minutes, by using a default “PASSWORD”.

The RS232 PONI allows communication speed from 300 baud to 19200 baud. The baud rate is selected by dip-switches on the PONI:

Baud	switch 1	switch 2	switch 3
300	0	0	0
1200	0	0	1
2400	0	1	0
4800	0	1	1
9600	1	0	0
19200	1	0	1

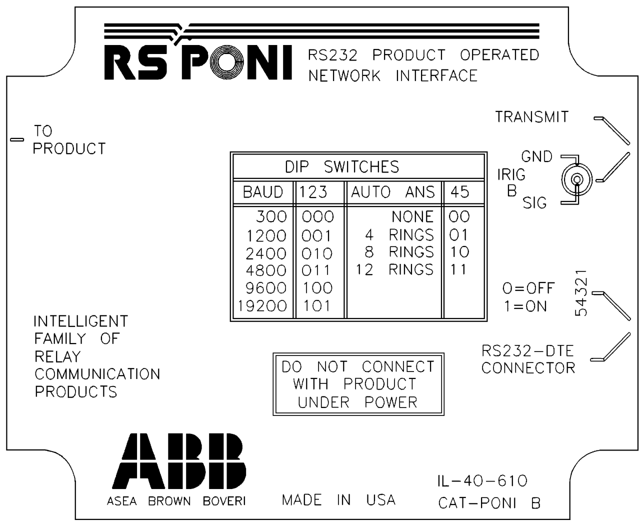


Figure 2-2. RS232/PONI Communication Interface Device

When in the remote mode, the computer can disable the local setting by showing SET = REM (in the Metering mode). Then, the setting cannot be changed locally. In this situation, the only way to change a setting locally would be to turn the dc power "OFF" and then "ON". The computer will allow for a local setting change within 15 minutes. Refer to the IL 40-603 (Remote Communication Program) for detailed information.

For REL 356 Modbus Communicaton, see IL 40-616, Poni-M RS485 Product Operated Network Interface User's Guide.

Digital Fault Recording

Refer to ABB Publications:

- IL 40-603 Remote Communication Program
- IL 40-606 Oscillographic and Recording Program

REL 356 Settings

The REL 356 setting mnemonics and the appropriate setting information is in Table 3-1, i.e., setting name, format, setting range (min, max, step), units and related notes.

Monitoring Functions

The REL 356 monitoring functions display on-line system information (see Table 2-3; monitoring values and conditions are listed in Table 2-4). All angles are computed using VAG as the reference angle.

Table 2-3. Monitoring Functions

Function	Description	Format	Units
CHRX	REL 356 channel receive status	NORM/OPBR/DSBL/CHTB	
CHTX	REL 356 channel transmit status	NORM/OPBR/DSBL	
IA	IA metered current magnitude	XXX.X	Amps
∠IA	IA metered current angle	XXXX	deg
VAG	VAG metered voltage magnitude	XXX.X	volts
∠VAG	VAG metered voltage angle	XXXX	deg
IB	IB metered current magnitude	XXX.X	Amp
∠IB	IB metered current angle	XXXX	deg
VBG	VBG metered voltage magnitude	XXX.X	volts
∠VBG	VBG metered voltage angle	XXXX	deg
IC	IC metered current magnitude	XXX.X	Amps
∠IC	IC metered current angle	XXXX	deg
VCG	VCG metered voltage magnitude	XXX.X	volts
∠VCG	VCG metered voltage angle	XXXX	deg
3I0	3I0 metered current magnitude	XXX.X	volts
∠3I0	3I0 metered current angle	XXXX	deg
DATE	Date (month, day)	MM.DD	
TIME	Time (hours, minutes)	HH.MM	
SET	Setting access status	BOTH/LOC/REM	
LOP	Loss-of-potential indication	YES/NO	
LOI	Loss-of-current indication	YES/NO	
OSB	Out-of-step blocking indication	YES/NO	
MLDT	Measured local delay time from Modem/CODEC	XXX.X/FAIL	msec
*XMTR	Channel transit level	XXXX	dBm
*RCVR	Channel receive level	XXXX	dBm
*SNR	Channel signal-to-noise ratio	XXXX	dB
**FEPH	Channel Error	Value/SYER/CTER/IDER	
IT	IT composite current magnitude	XXX.X	Amps

NOTE: All angles are computed using VAG as the reference angle.
* 9600 bps audio tone option
** 56/64 kbps digital communication option

Table 2-4. Target (Fault Data) Information

Target	Description	Format	Units
FTYP	Fault Type	AB/BG/CG/AB/BC/CA/ABC	
BK1	breaker current flowed	YES/NO	
BK2	breaker current flowed	YES/NO	
BK3	breaker current flowed	YES/NO	
BK4	breaker current flowed	YES/NO	
BK5	breaker current flowed	YES/NO	
BK6	breaker current flowed	YES/NO	
IAH	High set phase A fault	YES/NO	
IBH	High set phase B fault	YES/NO	
ICH	High set phase C fault	YES/NO	
IGH	High set ground fault	YES/NO	
PLT	Pilot Trip	YES/NO	
OP	Operating current magnitude	XXX.X	Amps
RES	Restraint current magnitude	XXX.X	Amps
DSBL	Differential protection disabled	YES/NO	
RIFT	Reclose-into-fault trip	YES/NO	
SBT	Stub-bus trip	YES/NO	
OBKT	Open breaker trip	YES/NO	
OST	Out-of-step trip	YES/NO	
TG	Time overcurrent ground trip	YES/NO	
Z2P	Zone 2 phase fault	YES/NO	
Z2G	Zone 2 ground fault	YES/NO	
Z3P	Zone 3 phase fault	YES/NO	
TTRP	Direct Transfer Trip	YES/NO	
Z3G	Zone 3 ground fault	YES/NO	
Z	Fault impedance	XX.XX	ohms
FANG	Fault impedance angle	XXX.X	deg
DMI	Fault distance in miles	XXX.X	mi

Notes: The "YES/NO" targets are displayed only if they are "YES". The impedance is dependent upon the CTYP setting. The internal impedance values are for a 5A ct. The impedance value is multiplied by 5 if a 1 A ct is used (CTYP = 1). The angles are not displayed if the magnitude of the value or the reference is less than 0.5 a or 0.7 rms.

* 9600 bps Audio Tone Channel
** 56/64 kbps Digital Communication

Table 2-4. Target (Fault Data) Information Continued

Target	Description	Format	Units
DKM	Fault distance in kilometers	XXX.X	km
PFLC	Pre-fault load current	XXX.X	amps
PFLV	Pre-fault voltage	XXX.X	volts
LP	Pre-fault load angle	XXX.X	deg
VAG	VAG fault voltage magnitude VAG fault voltage angle	XXX.X XXX.X	volts deg
VBG	VBG fault voltage magnitude VBG fault voltage angle	XXX.X XXX.X	volts deg
VCG	VCG fault voltage magnitude VCG fault voltage angle	XXX.X XXX.X	volts deg
3V0	3V0 fault voltage magnitude 3V0 fault voltage angle	XXX.X XXX.X	volts deg
IA	IA fault voltage magnitude IA fault voltage angle	XXX.X XXX.X	amps deg
IB	IB fault voltage magnitude IB fault voltage angle	XXX.X XXX.X	volts deg
IC	IC fault voltage magnitude IC fault voltage angle	XXX.X XXX.X	amps deg
3I0	3I0 fault voltage magnitude 3I0 fault voltage angle	XXX.X XXX.X	volts deg
DATE	Date of fault (month.day)	MM.DD	
YEAR	Year of fault	YYYY	
TIME	Time of fault (hours.minutes)	HH.MM	
SEC	Time of fault (seconds)	XXXX	sec
MSEC	Time of fault (milliseconds)	XXXX	msec
LDT	LDT used at the time of trip	XXX.X	msec
XMTR	Channel transmit level	XXXX	dBm
*RCVR	Channel receive level	XXXX	dBm
*SNR	Channel signal-to-noise ratio	XXXX	dB
**FEPH	Channel error	XXXX/FAIL	

Notes: The "YES/NO" targets are displayed only if they are "YES". The impedance is dependent upon the CTYP setting. The internal impedance values are for a 5A ct. The impedance value is multiplied by 5 if a 1 A ct is used (CTYP = 1). The angles are not displayed if the magnitude of the value or the reference is less than 0.5 a or 0.7 rms.

* 9600 bps Audio Tone Channel
** 56/64 kbps Digital Communication

Target (Fault Data) Information

The REL 356 stores 16 sets of targets (fault data). All 16 sets are accessible through INCOM®, but only the two most recent sets of data are accessible from the front panel (see Table 2-3).

The first part of the fault data contains "Yes/No" targets (see Table 2-4), which identify the cause of the trip and the status of certain system inputs and outputs; the second part of the fault data contains values, including currents, voltages, fault impedance, and distance to the fault.

Communication Channel Testing

Monitoring functions display the following communication channel information:

MLDT — Provides Communication Delay (in msec)

9600 bps Audio Tone Option Only

XMTR — provides transmitter output level (in dBm)

RCVR — provides receiver input level (in dBm)

SNR — provides signal-to-noise-ratio (in dB)

56/64 kbps Option Only

FEPH	Bit Error
DISPLAY VALUE	# of Frames in Error in the previous hour (NA will be displayed for the first 5 minutes after power up)
CHTB	Channel Trouble

Communication Channel Interface

REL 356 processors and intelligent data communication equipment (Modem or CODEC) continuously monitor status of communication channel interface used for current differential protection.

The communication between two relays is full-duplex i.e., each relay continuously transmits and receives serial data.

The status of receiver and transmitter are displayed in the monitoring function fields CHRX and CHTX respectively.

Receiver Status

CHRX has the following definitions:

NORM –	Normal, error-free reception
CHTB –	Channel trouble, CRC error, excessive noise, corrupted frame, etc.
DCER –	Failure to communicate with local DCE (modem, codec)
NODM –	Failure to measure communication delay time
IDER –	Unit ID error
TTRP –	Reception of direct transfer trip code from the remote end
DSBL –	Reception of differential protection disable code from the far end
OPBR –	Reception of open breaker information from the remote relay

Transmitter Status

The following definitions are used for CHTX:

NORM –	Normal state transmission
TTRP –	Transmission of direct transfer trip code to the far end

DSBL	–	Transmission of differential protection disable tothe remote relay
OPBR	–	Transmission of open breaker information to the distant unit
DCER	–	Failure to communicate with the local DCE (Modem or CODEC)

Routine Visual Inspection

With the exception of Routine Visual Inspection, the REL 356 relay assembly should be maintenance-free. A program of Routine Visual Inspection should include:

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

Acceptance Testing

The customer should perform the REL 356 Acceptance Tests on receipt of shipment.

Normal Precautions

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

CAUTION: With the exception of checking to insure proper mating of connectors, or setting jumpers, the following procedures are normally not recommended. (If there is a problem with the REL 356, it should be returned to the factory.)

Disassembly Procedures

a. Remove the inner chassis from the outer chassis, by unscrewing the lockscrew (on the front panel), and unsnapping the two covers from the FT-14 switches.

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

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

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

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

e. Remove the Modem, Relay Output and Contact Input modules by unscrewing 2 mounting screws from the brackets and unplugging these modules from the Interconnect module.

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

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

System Diagrams

A typical system diagram for the REL 356 is show in DWG 2097D40 sheets 1-3, page 2-22.

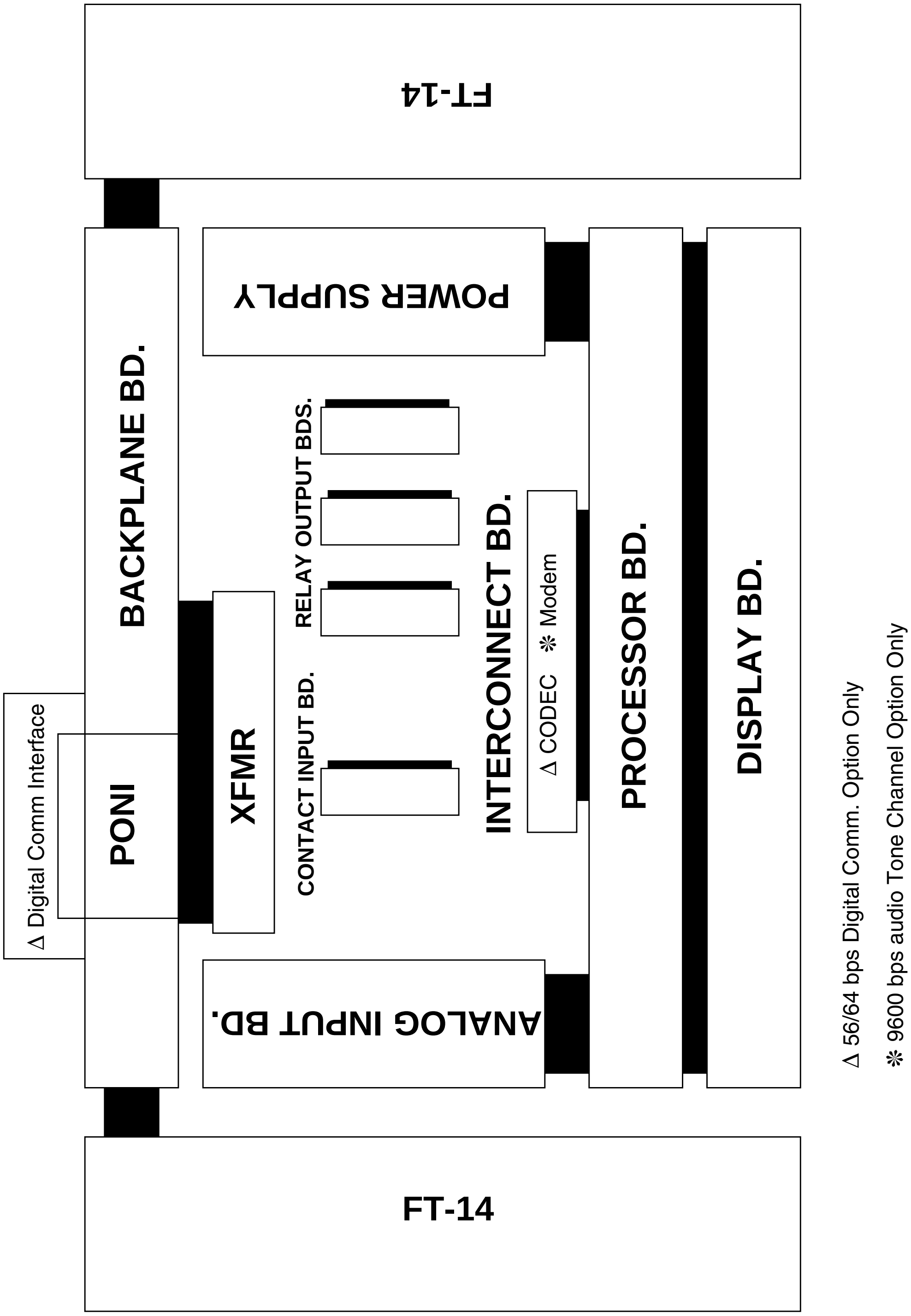


Figure 2-3. Layout of REL 356 Modules Within Inner and Outer Chassis

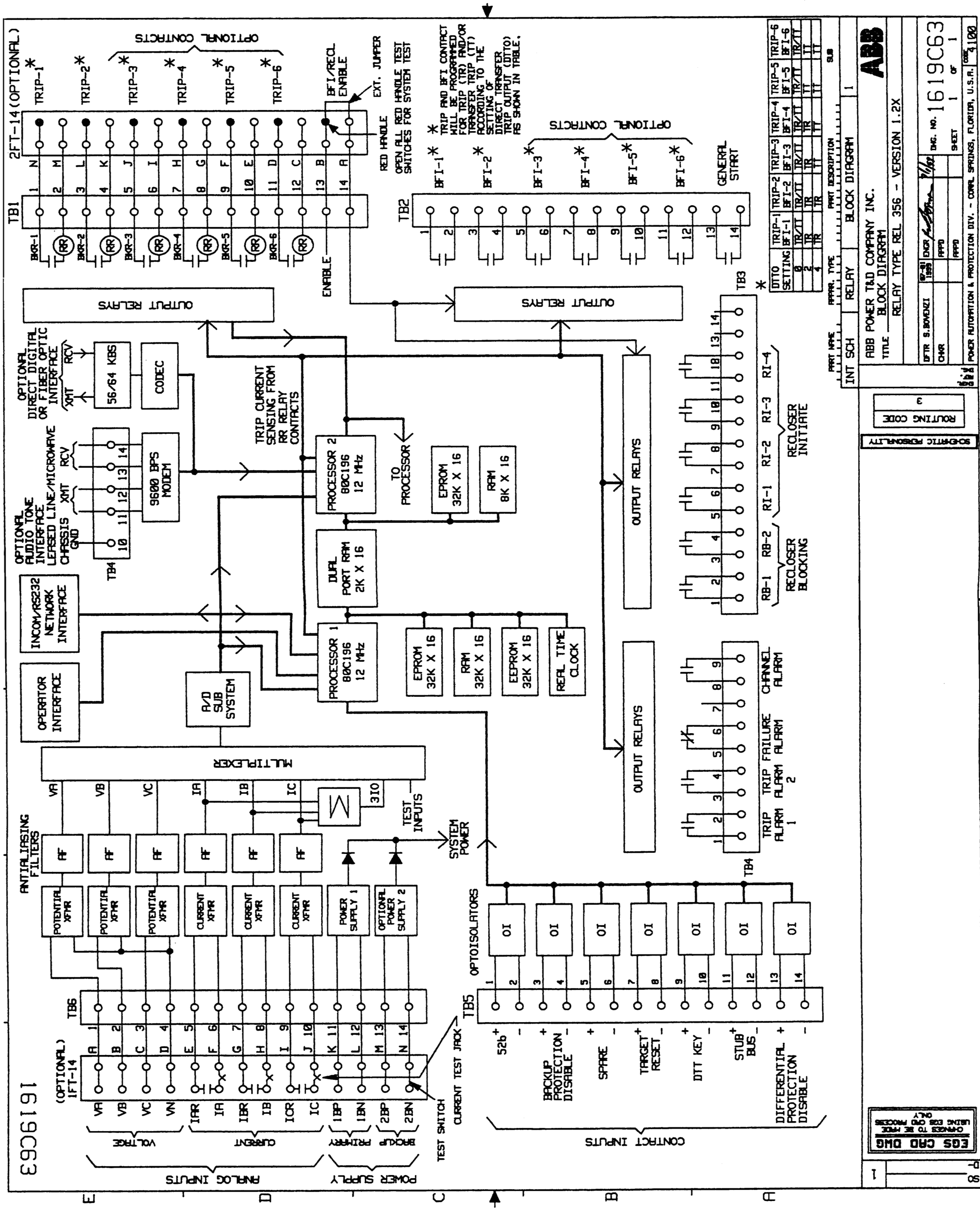
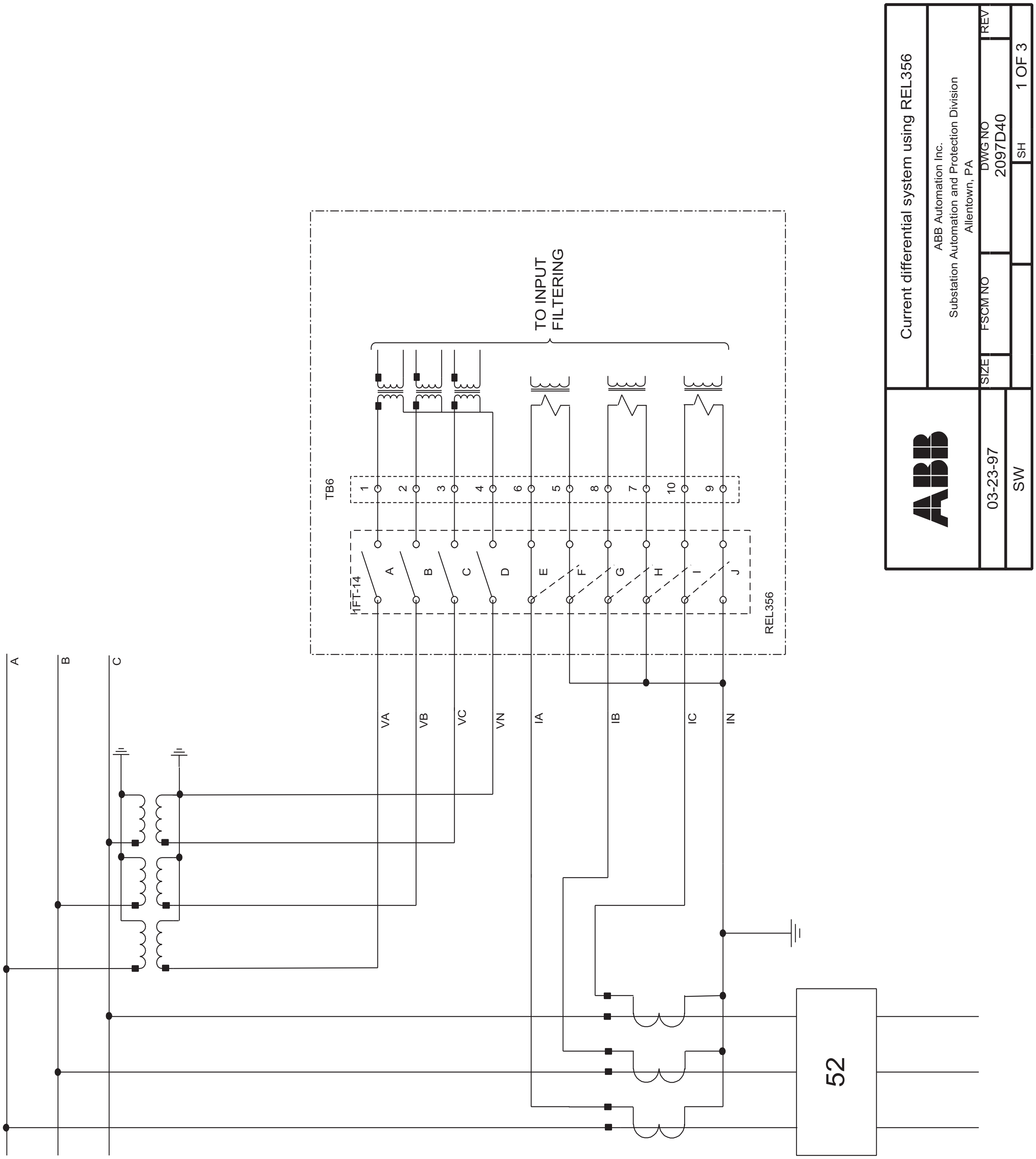


Figure 2-4. Block Diagram of REL 356 Relay


Current differential system using REL356
ABB Automation Inc.
Substation Automation and Protection Division
Allentown, PA
SIZE
FSCM NO
DWG NO
2097D40
REV
SH
1 OF 3
03-23-97
SW
TO INPUT
FILTERING
TB6
1FT-14
REL356
A
B
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VB
VC
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IA
IB
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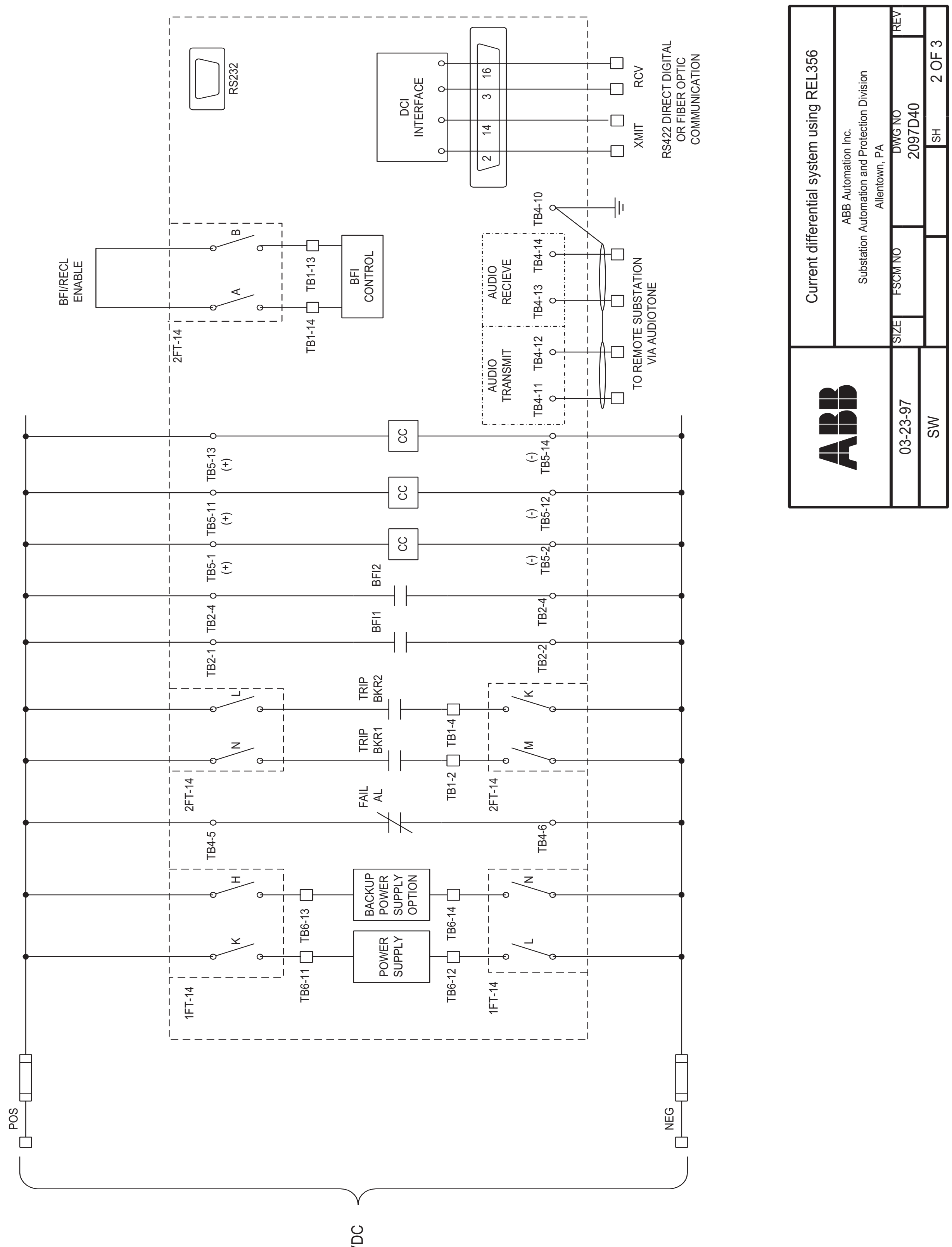
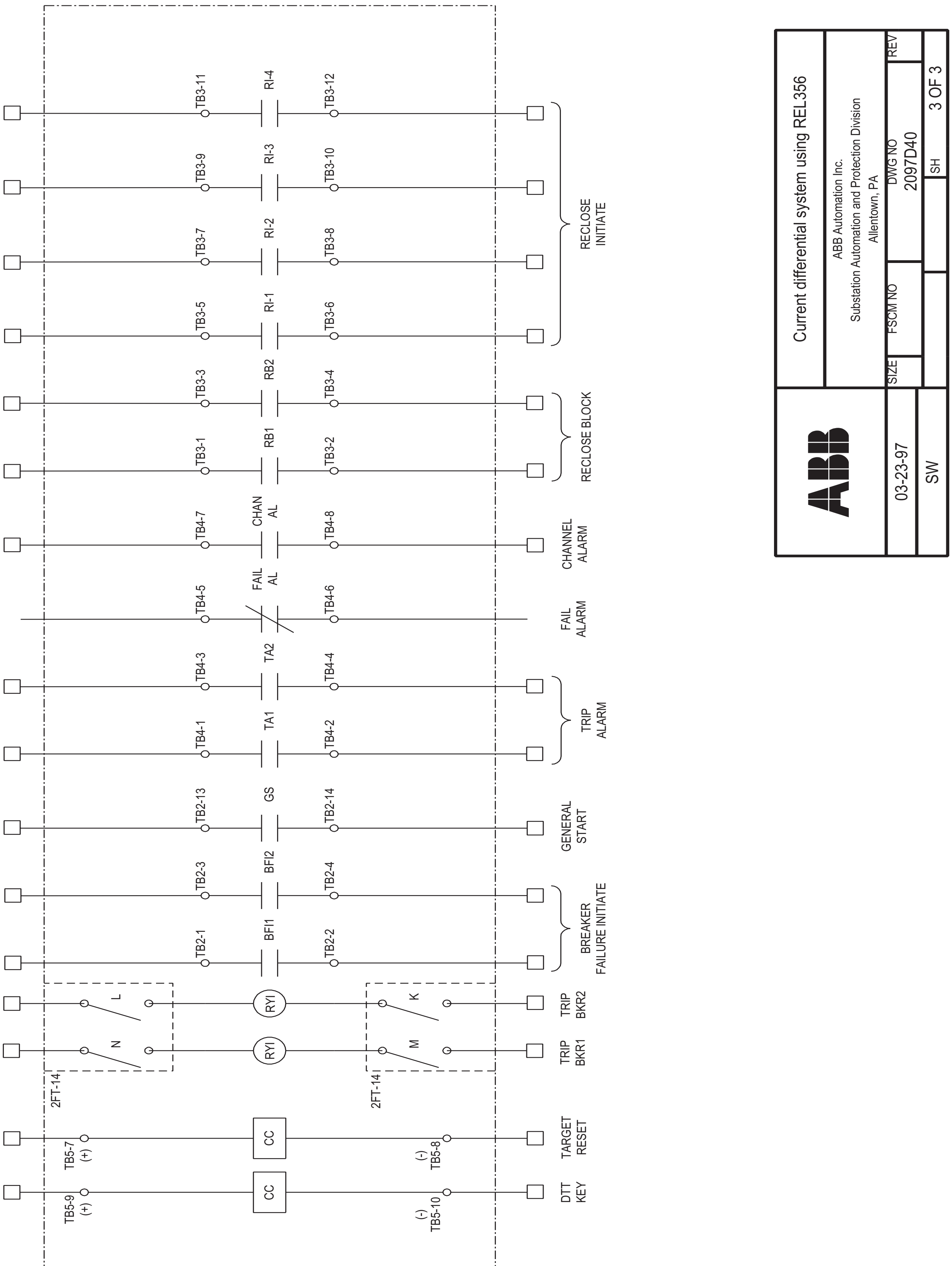
IN
52


RS232
DCI INTERFACE
16
3
14
2
RCV
XMIT
RS422 DIRECT DIGITAL OR FIBER OPTIC COMMUNICATION
BFI/RECL ENABLE
B
A
TB1-13
TB1-14
BFI CONTROL
2FT-14
AUDIO RECIEVE
AUDIO TRANSMIT
TB4-10
TB4-14
TB4-13
TB4-12
TB4-11
TO REMOTE SUBSTATION VIA AUDIOTONE
CC
TB5-13 (+)
TB5-14 (-)
TB5-11 (+)
TB5-12 (-)
TB5-1 (+)
TB5-2 (-)
BFI2
TB2-4
BFI1
TB2-1
TB2-2
TRIP BKR2
TRIP BKR1
L
K
N
M
TB1-4
TB1-2
FAIL AL
TB4-5
TB4-6
H
BACKUP POWER SUPPLY OPTION
POWER SUPPLY
TB6-13
TB6-14
TB6-11
TB6-12
1FT-14
POS
NEG
VDC
Current differential system using REL356
ABB Automation Inc.
Substation Automation and Protection Division
Allentown, PA
SIZE
FSCM NO
DWG NO
2097D40
REV
SH
2 OF 3
03-23-97
SW


TB3-11
RI-4
TB3-12
TB3-9
RI-3
TB3-10
TB3-7
RI-2
TB3-8
TB3-5
RI-1
TB3-6
RECLOSE INITIATE
TB3-3
RB2
TB3-4
TB3-1
RB1
TB3-2
RECLOSE BLOCK
TB4-7
CHAN AL
TB4-8
CHANNEL ALARM
TB4-5
FAIL AL
TB4-6
FAIL ALARM
TB4-3
TA2
TB4-4
TB4-1
TA1
TB4-2
TRIP ALARM
TB2-13
GS
TB2-14
GENERAL START
TB2-3
BFI2
TB2-4
TB2-1
BFI1
TB2-2
BREAKER FAILURE INITIATE
L
RYI
K
TRIP BKR2
N
RYI
M
TRIP BKR1
2FT-14
2FT-14
TB5-7 (+)
CC
(-) TB5-8
TARGET RESET
TB5-9 (+)
CC
(-) TB5-10
DTT KEY
Current differential system using REL356
ABB Automation Inc.
Substation Automation and Protection Division
Allentown, PA
03-23-97
SW
SIZE
FSCM NO
DWG NO
2097D40
REV
SH
3 OF 3

Settings and Applications

Introduction

REL 356 can be set through the front panel HMI or through remote communication by PC program or network.

This section will follow the sequence of settings displayed in the front panel display when the relay system is in the settings mode.

Reference will be made to current levels based on 5 A secondary ct's. For 1 A ct's, multiply the current levels by 0.2.

Table 3-1. Setting Table

Setting	Name	Format	Min	Max	Step	Units	Notes
VERS	Software Version	XX.XX	0.01	99.99			
FREQ	Rated frequency setting selection	50/60				Hz	
RP	Enable readouts in primary values	YES/NO					
CTYP	Current transformer type: 1A or 5A ct	XXXX	1	5	4	A	CTYP= In
CTR	Current transformer ratio	XX.XX	30	5000	5		
VTR	Voltage transformer ratio	XXXX	300	7000	10		
OSC	Triggering for storing oscillographic data	TRIP/ITRG/ΔVΔI					
FDAT	Triggering for storing fault target data	TRIP/ITRG					
TRGG	Ground current pickup level trigger for OSC and FDAT	XX.XX	0.5	10.0	0.5	A	1
TRGP	Phase current pickup level trigger for OSC and FDAT	XX.XX	0.5	10.0	0.5	A	1
CD	Change detector option	ΔV ΔI					
DDTT	Dedicated direct transfer trip	XXXX	0	4	2		7
ILTS	IL Trip supervision	IN/OUT					
RBEN	Reclose block enable	NORB/ALRB					
SOBT	Stub/open breaker timer	XXXX	8	150		msec	
OPBR	Open breaker selection	IE/52B/BOTH/OUT					
IE	Very low set phase current pickup value in amps	X.XXX	0.20	0.50	0.01		1
IPL	Low set phase current pickup value in amps	XX.XX	0.5	20.0	0.1		1
IPH	High set phase trip current pickup setting in amps	XX.XX	4.0	80.0	0.1		1, 3
IGL	Low set ground current pickup value in amps	XX.XX	0.5	20.0	0.1		1
IGH	High set ground trip current pickup setting in amps	XX.XX	4.0	80.0	0.1		1, 3

Note 1:	For 5 A relay. Setting and step are a factor of 5 lower for 1 A relay.
Note 2:	These settings have a "BLK" option for disabling a corresponding function.
Note 3:	These settings have a "OUT" option for disabling a corresponding function.
Note 4:	The impedance setting. The setting ranges shown are for 5 A ct. The displayed setting range is multiplied by 5 if a 1 A ct is used (CTYP = 1).
Note 5:	9600 bps Audio Tone option.
Note 6:	56/64 kbps Digital Communication option.
Note 7:	Only if optional extended output is included.
Note 8:	Only if optional backup system is included.

Table 3-1. Setting Table Continued

Setting	Name	Format	Min	Max	Step	Units	Notes
TDES	Trip Desensitizing	X.XXX	1.1 X P.U.	10 X P.U.	0.1 X P.U.		
OTH	Operating threshold	X.XXX	0.000	3.950	0.05	A	
C0	Zero sequence coefficient	X.XXX	0.000	5.000	0.05		
C1	Positive sequence coefficient	X.XXX	0.000	5.000	0.05		
C2	Negative sequence coefficient	X.XXX	0.000	5.000	0.05		
ALDT	Enable automatic LDT compensation	YES/NO					
LDFL	Select LDT leader/follower mode	LEAD/FOLO					
LDT	Local delay time setting	XXX.X	0.0	32.0	0.1	msec	
UNID	Unit ID	XXXX	0	15	1		
KBPS	Communication speed (56 or 64 kbps)	64/56					6
TTRP	Transfer trip	IN/OUT					
XCLK	Source of Transmit Clock	INT/EXT					6
LPBK	Loopback Test	YES/NO					
XMTR	Modem transmitter level setting	XXXX	-15	-1	2	dBm	5
RLSD	Receiver level signal detect setting	-43/-33/-26/-16				dBm	5
XPUD	Primary Ohms per unit	X.XXX	0.100	1.500	0.001	ohms	
DTYP	Selection of distance units for XPUD setting	MI/KM					
PANG	Positive sequence line impedance angle	XXXX	10	90	1	deg	
GANG	Zero sequence line impedance angle	XXXX	10	90	1	deg	
ZR	Line impedance ratio (Z0L/Z1L)	XXX.X	0.1	10.0	0.1		
BKUP	Backup Protection Enable	IN/OUT					8
LOPB	Loss-of-potential blocking selection	YES/NO					8
FDOP	Directional Overcurrent Phase	IN/OUT					
FDOG	Directional Overcurrent Ground	IN/OUT					
DIRU	Directional Unit Selection	ZSEQ/NSEQ					
IOM	Medium set ground current pickup value in amps	XX.XX	0.5	10.0	0.1		1, 8
TOG	Timer for Ground Overcurrent Unit	XX.XX	0.10	9.99	0.01	sec	2, 8
Z2P	Zone 2 phase distance setting in ohms	XX.XX	0.01	50.00	0.01	ohms	4, 8
T2P	Zone 2 phase time delay in seconds	XX.XX	0.00	2.99	0.01	sec	2, 8

Note 1: For 5 A relay. Setting and step are a factor of 5 lower for 1 A relay.

Note 2: These settings have a "BLK" option for disabling a corresponding function.

Note 3: These settings have a "OUT" option for disabling a corresponding function.

Note 4: The impedance setting. The setting ranges shown are for 5 A ct. The displayed setting range is multiplied by 5 if a 1 A ct is used (CTYP = 1).

Note 5: 9600 bps Audio Tone option.

Note 6: 56/64 kbps Digital Communication option.

Note 7: Only if optional extended output is included.

Note 8: Only if optional backup system is included.

Table 3-1. Setting Table Continued

Setting	Name	Format	Min	Max	Step	Units	Notes
Z2GF	Zone 2 ground forward distance setting in ohms	XX.XX	0.01	50.00	0.01	ohms	4, 8
Z2GR	Zone 2 ground reverse distance setting in ohms	XX.XX	0.01	50.00	0.01	ohms	4, 8
T2G	Zone 2 ground time delay in seconds	XX.XX	0.00	2.99	0.01	sec	2, 8
Z3P	Zone 3 phase distance setting in ohms	XX.XX	0.01	50.00	0.01	ohms	4, 8
T3P	Zone 3 phase time delay in seconds	XX.XX	0.10	2.99	0.01	sec	2, 8
Z3GF	Zone 3 ground forward distance setting in ohms	XX.XX	0.01	50.00	0.01	ohms	4, 8
Z3GR	Zone 3 ground reverse distance setting in ohms	XX.XX	0.01	50.00	0.01	ohms	4, 8
T3G	Zone 3 ground time delay in seconds	XX.XX	0.10	2.99	0.01	sec	2, 8
OST	Out-of-step trip enable	NO/WAYI/WAYO					8
OSB	Enable out-of-step blocking for backup protection	NONE/Z2/Z3/BOTH					8
RT	Inside blinder setting in ohms	XX.XX	1.00	15.00	0.10	ohms	4, 8
RU	Outside blinder setting in ohms	XX.XX	3.00	15.00	0.10	ohms	4, 8
OST1	Out-of-step block timer	XX.XX	0.50	5.0	0.05	cycles	8
OST2	Out-of-step trip-on-the-way-in timer	XX.XX	0.50	4.00	0.05	cycles	8
OST3	Out-of-step trip-on-the-way-out timer	XX.XX	0.50	5.0	0.05	cycles	8
OSOT	Out-of-step override timer in milliseconds	XX.XX	24	240	1	cycles	3, 8
SETR	Enable INCOM remote setting feature	YES/NO					
TIME	Enable setting of real time clock	YES/NO					
YEAR	RTC setting year	XXXX	1980	2079	1	year	
MNTH	RTC setting month	XX	1	12	1	month	
DAY	RTC setting day	XX	1	31	1	day	
WDAY	RTC setting day of week	SUN/MON/TUES/WED/THUR/FRI/SAT					
HOUR	RTC setting hours	XX	0	23	1	hour	
MIN	RTC setting minutes	XX	0	59	1	minute	

Note 1: For 5 A relay. Setting and step are a factor of 5 lower for 1 A relay.
Note 2: These settings have a "BLK" option for disabling a corresponding function.
Note 3: These settings have a "OUT" option for disabling a corresponding function.
Note 4: The impedance setting. The setting ranges shown are for 5 A ct. The displayed setting range is multiplied by 5 if a 1 A ct is used (CTYP = 1).
Note 5: 9600 bps Audio Tone option.
Note 6: 56/64 kbps Digital Communication option.
Note 7: Only if optional extended output is included.
Note 8: Only if optional backup system is included.

Relay System Setup

Firmware Version (VERS)

Indicates the firmware version in the REL 356. This instruction book is for v 1.21 and earlier.

System Frequency (FREQ)

Select either 50 or 60 Hz.

Readout in Primary Values (RP)

A YES setting enables the REL 356 system to display all the monitored voltages and currents in primary kA and kV, based on the current transformer ratio (CTR) and voltage transformer ratio (VTR) entered.

Current Transformer Type (CTYP)

Select either 1 or 5 A, depending on the secondary current rating of the line ct.

For example: Enter CTYP = 5 if a 1200/5 ct is being used.

Current Transformer Ratio (CTR)

This setting is used for load current monitoring, if it is selected to be displayed in primary kA. It has no effect on the protective relaying system. Note that the metering accuracy for currents is 5% or 0.1 A secondary. The 0.1 A step will be multiplied with CTR, why the error will appear larger on a primary basis.

For example: Set CTR = 240 if a 1200/5 ct is being used.

Voltage Transformer Ratio (VTR)

This setting is used for the system voltage monitoring, if it is selected to be displayed in primary kV. It has no effect on the protective system.

For example: Set VTR = 575 if 69,000 V to 120 V vt's are being used.

Digital Fault Recording Information

Trigger for Storing Oscillographic Data (OSC)

Indicates trigger for oscillographic data gathering. The user can select to trigger oscillographic data when:

- TRIP — The REL356 system tripped
- ITRG — The REL356 system detected the operation of either the TRGP (phase) or TRGG (ground) overcurrent elements (see below)
- $\Delta V \Delta I$ — The voltage and/or current change detectors operated

The change detectors (CD) pick up when the current or voltage change between the corresponding data samples, spaced one cycle apart, exceeds 12.5%, minimum 0.5 A or 7 V.

The use of CD as a trigger of oscillographic data is of little practical value when a relay is connected to the power system. Numerous changes due to sudden load changes, remote switching, distant faults, etc. make the resulting oscillographic records difficult to relate to events of importance. During testing however, it can sometimes be useful to use this setting to capture records for external faults.

Trigger for Storing Fault Records (FDAT)

Indicates trigger for fault record gathering. The user can select to trigger fault records when:

- TRIP The REL 356 system tripped
- ITRG The REL 356 system detected the operation of either the TRGP (phase) or TRGG (ground) overcurrent elements (see below)

Ground Trigger Pick Up Level (TRGG)

This setting controls the level of current magnitude on the ground current, which when exceeded triggers oscillographic data and/or fault records, depending on the settings above.

In case OSC and/or FDAT are not set to ITRG, this setting is ignored by the system.

Phase Trigger Pick Up Level (TRGP)

This setting controls the level of current magnitude on the phase currents, which when exceeded triggers oscillographic data and/or fault records, depending on the settings above.

In case OSC and/or FDAT are not set to ITRG, this setting is ignored by the system.

Protection System Settings

Change Detector (CD)

The change detector CD is used for supervision of the differential trip function. All relay current inputs (I_A, I_B, I_C and I_G) and voltage inputs (V_A, V_B, and V_C) are sampled and converted to numbers 12 times per cycle. The present samples are compared to the corresponding samples taken one cycle earlier.

The change detector is asserted if the absolute difference of present and old sample exceeds 12.5% of the old sample and the difference is larger than 0.1 p.u. for current and 7 V for voltage.

The CD can be generated either by using the current change detectors (ΔI) or the current and voltage change detectors (ΔVΔI). The ΔVΔI setting is recommended when the system has voltage inputs and the relay will be used in a weak feed application where the change in current might not be sufficient to trigger the change detector.

Dedicated Direct Transfer Trip (DDTT)

When the extended output board with additional trip contacts is not included, no DDTT setting is available and a received transfer trip signal will always result in closure of the two main trip contacts, TRIP–1 and TRIP–2.

When the extended output board is included, the following setting options are available:

DDTT = 0
All trips, trips from the local relay as well as received direct transfer trip, result in closing of all six trip and all six BFI contacts; TRIP-1, TRIP-2, TRIP-3, TRIP-4, TRIP-5, TRIP-6, BFI-1, BFI-2, BFI-3, BFI-4, BFI-5 and BFI-6.

DDTT = 2
Trips from the local relay will result in closing of trip and BFI contacts TRIP–1, TRIP-2, TRIP-3, TRIP-4, BFI-1, BFI-2, BFI-3 and BFI-4. Received transfer trip will close contacts TRIP-5, TRIP-6, BFI-5 and BFI-6.

DDTT = 4
Trips from the local relay will result in closing of trip and BFI contacts TRIP–1, TRIP-2, BFI-1 and BFI-2. Received transfer trip will close contacts TRIP-3, TRIP-4, TRIP-5, TRIP-6, BFI-3, BFI-4, BFI-5 and BFI-6.

The settings are summarized in the table below where TRIP is trip from the local relay (differential or back-up trip) and TTRP is received transfer trip from the remote end:

DDTT	TRIP-1/BFI-1	TRIP-2/BFI-2	TRIP-3/BFI-3	TRIP-4/BFI-4	TRIP-5/BFI-5	TRIP-6/BFI-6
0	TRIP/TTRP	TRIP/TTRP	TRIP/TTRP	TRIP/TTRP	TRIP/TTRP	TRIP/TTRP
2	TRIP	TRIP	TRIP	TRIP	TTRP	TTRP
4	TRIP	TRIP	TTRP	TTRP	TTRP	TTRP

Low Set Current Supervision (ILTS)

The user can select to supervise differential trip but the low set current elements, IPL and IGL. With ILTS = IN, higher security is achieved. However, for weak feed applications when the local fault current may not exceed the set IPL or IGL current levels, ILTS should be set to OUT in order to allow the weak terminal to trip on current differential operation.

Reclose Block Enable (RBEN)

The following settings are provided for system flexibility:

NORB Normal Reclose Block. The RB contacts will close for the following trips:

- Reclose into fault
- Trip from the back-up system
- Out-of-step trip
- High set overcurrent trip
- Transfer trip

ALRB All Reclose Block. The RB contacts will close for all trips.

Stub/Open Breaker Timer (SOBT)

The SOBT timer provides a time delay for the stub bus and open breaker trip functions. When using 52b inputs for the open breaker detection, the reset time of the breaker contacts should be carefully considered. If the contact reset time is greater than the set SOBT time, reclosing will be unsuccessful. The reason is as follows: after a trip, with both breakers open, one end closes back into the line successfully. The second end closes in but has slow resetting 52b contacts why OPBR (open breaker) code is still being received by the remote end at the time load current starts to flow. The remote end will then trip from the low set IPL elements if OPBK function is used. The SOBT timer thus needs to be set longer than the 52b contact reset time plus channel delay plus 8 msec margin.

The 52b contact reset time is generally close to zero when the breaker contacts are used directly but might be much longer when connected to the relay via an external auxiliary relay.

For example: Set SOBT = 20 msec for a digital channel with 1.3 msec channel delay and 52b auxiliary contact reset time of 10 msec.

Open Breaker (OPBR)

The following settings are available for open breaker keying:

- IE Keying is initiated when the line current is lower than the IE setting. Note that the line charging current must exceed this setting, which limits the use of this option on short lines.
- 52B Keying is initiated when the 52b contact at the local end is closed.
- BOTH Keying is initiated either when the load current is lower than the IE setting or when 52b is closed.

- OUT No open breaker keying. Note that this will disable the Open Breaker function in the remote end as no open breaker code will be received there.

Very Low Set Phase Current Unit (IE)

This unit is used with the open breaker keying logic (OPBR). It should be set sensitive enough to pick up when the local breaker is closed.

Note that the minimum setting is 0.04 x In (0.2 A for a 5 A ct). The charging current of a very short line might be insufficient to operate this element why open breaker condition would be given even when the breaker is closed. In that case, the 52b contact should be used.

Note that there is $\pm$ 20% hysteresis associated with this setting. Open breaker keying will start when the current drops below 0.8 x IE and will remain so until it increases above 1.2 x IE.

In case OPBK is set to 52B or OUT, this setting is ignored by the system.

Low Set Phase Unit (IPL)

The low set overcurrent units supervise differential trip when ILTS is set IN.

The low set units are also used for tripping during stub bus and open breaker conditions, if these functions are used. To prevent trip from the stub bus logic during line energizing, the phase IPL unit should be set at 1.5 times the net line charging current, but must be at least 0.5 A.

Net line charging current is defined as: the steady state net single end line charging phase current, as measured under balanced conditions (all local poles closed and all remote poles open). Net line charging current indicates the distributed capacitive current minus any line side shunt reactor current.

High Set Phase Overcurrent Unit (IPH)

This unit is provided in the REL356 system to supplement the current differential protection by providing a non-pilot direct trip capability for high current faults. The IPH unit should be set above the maximum expected external fault current with a security margin.

The IPH unit should be set for 1.25 times the maximum through current for an external three phase fault.

The high set overcurrent units can be made directional when FDOP, the phase directional unit, is set to IN, and three phase voltage is applied to the relay. IPH is then supervised by FDOP.

Low Set Ground Unit (IGL)

The low set ground overcurrent unit supervises differential trip when ILTS is set IN. The low set units are also used for tripping during stub bus and open breaker conditions, if these functions are used.

Since the effect of charging current is minimum for the ground subsystem, the setting should only allow for inherent unbalance under normal operation. A minimum setting of 0.5 A is recommended.

High Set Ground Overcurrent Unit (IGH)

The high set ground unit should follow the same guidelines as the high set phase units.

The high set ground overcurrent unit can be made directional when FDOG, the ground directional unit, is set to IN, and three phase voltage is applied to the relay. IGH is then supervised by FDOG.

Current Differential System Settings

Trip Desensitizing (TDES)

This setting temporarily desensitizes the differential protection by increasing the operating threshold, OTH, for 30 cycles after closing the line breaker (de-energization of the 52b input). This setting can be used to prevent false tripping on large inrush currents that may be produces by a tapped transformer in the protected zone.

The setting is a multiple of the nominal operating threshold, OTH, and has a range of 1 to 10 times nominal pickup. It can also be set to OUT and no desensitizing on 52b de-energization will occur.

The trip desensitizing characteristic is a linear ramp which multiplies the tripping threshold immediately on de-energization of the 52b input to the value to the TDES setting and then slowly over a time period of 30 cycles lowers the trip threshold back to its nominal value.

Trip desensitizing is not recommended when the transformers are external to the protected zone. In this case the inrush current will be seen as an external fault and the REL356 relays will remain stable.

Operating Threshold (OTH)

The operating threshold determines the differential current required for operation according to the formula:

$$OP - 0.7 \cdot RES \geq OTH$$

where
$OP = |IT_L + IT_R|$
and
$RES = |IT_L| + |IT_R|$
$IT = - C1I1 + C0I0 + C2I2$

For internal three phase faults, $IT = -C1I1$, $\angle IT_L \cong \angle IT_R$

A 20% margin is recommended, i.e.

$OTH < 0.80\ (OP_{min} – RES_{min}) = 0.80\ (|IT_L| + |IT_R|) \times 0.3$

For single end infeed conditions, only one current is present, IT_L or IT_R. The equations then turn into:

$OP = |IT_L|$
$RES = |IT_L|$

With the recommended 20% margin, OTH should then be set to:

$OTH < 0.80\ (OP_{min} – RES_{min}) = 0.80 \times ITL \times 0.3 = 0.80 \times C1I1 \times 0.3$

Different CT ratios can be used in the two line ends by adjusting the operating threshold, OTH, so that the same level is achieved on a primary basis. For example, if one end has a ratio of 240 and OTH is set to 0.5 A, the other end with ratio 120 should have an OTH setting of 1.0 A. Note that the sequence filter settings, C1, C2 and C0, should always be the same at the two line ends.

Note that for versions 1.15 and earlier, OTH is set in peak value why the above setting recommendations should be adjusted with a factor $\sqrt{2}$. This means that the recommended setting for double end infeed is:

$$OTH \leq \sqrt{2} \cdot 0.8 \cdot (OP_{min} - RES_{min})$$

and for single end infeed:

$$OTH \le \sqrt{2} \cdot 0.8(OP_{\min} - RES_{\min}) = \sqrt{2} \cdot 0.8 \cdot ITL \cdot 0.3 = \sqrt{2} \cdot 0.80 \cdot C_1 I_1 \cdot 0.3$$

Sequence Coefficients (C0, C1, C2)

REL 356 uses sequence filters to obtain positive, negative and zero sequence currents. These currents are then combined into one quantity:

$$IT = C0 \cdot I_0 - C1 \cdot I_1 + C2 \cdot I_2$$

where

I_0, I_1 and I_2 are the zero sequence, the positive sequence and the negative sequence currents.

In order to minimize the influence of load, C1 should be set to a relatively low value. We recommend to use C1 = 0.1.

C0 and C2 will both multiply fault currents. Setting recommendations C1 and C2 for three cases are made:

Case 1) Minimum fault current for a ground fault $I_{\Phi Gmin}$ > 50% of minimum fault current for a three phase fault, $I_{3\Phi min}$.

Case 2) Minimum fault current for a ground fault $I_{\Phi Gmin}$ < 50% of minimum fault current for a three phase fault, $I_{3\Phi min}$.

Case 3) Minimum fault current for a ground fault $I_{\Phi Gmin}$ < 12.5% of minimum fault current for a three phase fault, $I_{3\Phi min}$.

Case 1

Either C2 or C0 can be used for fault detection of any unsymmetrical fault. The use of negative sequence, C2, is preferable as the negative sequence currents are more consistent at the two line terminals. We therefore recommend to set C0 = 0.

A high value of C2 would increase the sensitivity but in order not to make the relay responding to system unbalances a “moderate” setting is recommended. Good sensitivity with high security is achieved with setting C2 = 0.7.

The recommended settings
C1 = 0.1
C2 = 0.7
C0 = 0.0
gives the following sensitivity for different faults:

<u>Three phase faults</u>

$$IT_{\min} = -C1 \cdot I_{3\phi \min} = -0.1 \cdot I_{3\phi \min}$$

<u>Phase-phase faults</u>

$$\left| IT_{\min} \right| = \left| \frac{1}{\sqrt{3}} (-C1 + C2 \cdot e^{\pm j60^\circ}) \cdot I_{\phi\phi \min} \right| = 0.38 \cdot I_{\phi\phi \min} = 0.38 \cdot \frac{\sqrt{3}}{2} \cdot I_{3\phi \min} = 0.33 \cdot I_{3\phi \min}$$

<u>Single phase to ground faults</u>

$$IT_{\min} = \frac{1}{3}(-C1 + C2 + C0) \cdot I_{\phi G \min} = 0.2 \cdot I_{\phi G \min}$$

Case 2

When the minimum ground fault current is substantially smaller than the minimum three phase fault current, C0 can be given a value to increase the sensitivity for ground fault.

The recommended settings
C1 = 0.1
C2 = 0.7
C0 = according to Figure 3-1
gives the following sensitivity for different faults:

Three phase faults

$$IT_{\min} = -C1 \cdot I_{3\phi \min} = -0.1 \cdot I_{3\phi \min}$$

Phase-phase faults

$$\left|IT_{\min}\right| = \left|\frac{1}{\sqrt{3}}(-C1 + C2 \cdot e^{\pm j60^{\circ}}) \cdot I_{\phi\phi \min}\right| = 0.38 \cdot I_{\phi\phi \min} = 0.38 \cdot \frac{\sqrt{3}}{2} \cdot I_{3\phi \min} = 0.33 \cdot I_{3\phi \min}$$

Single phase to ground faults

The value of C0 is determined from Figure 3-1. Calculate the ratio $I_{3\Phi min}/I_{\Phi Gmin}$ and find this number on the vertical axis. Find the C0 for the calculated current ratio based on the curve corresponding to the least sensitive fault type.

Selecting C0 is this way results in the same sensitivity for minimum ground fault current as for minimum three phase fault current.

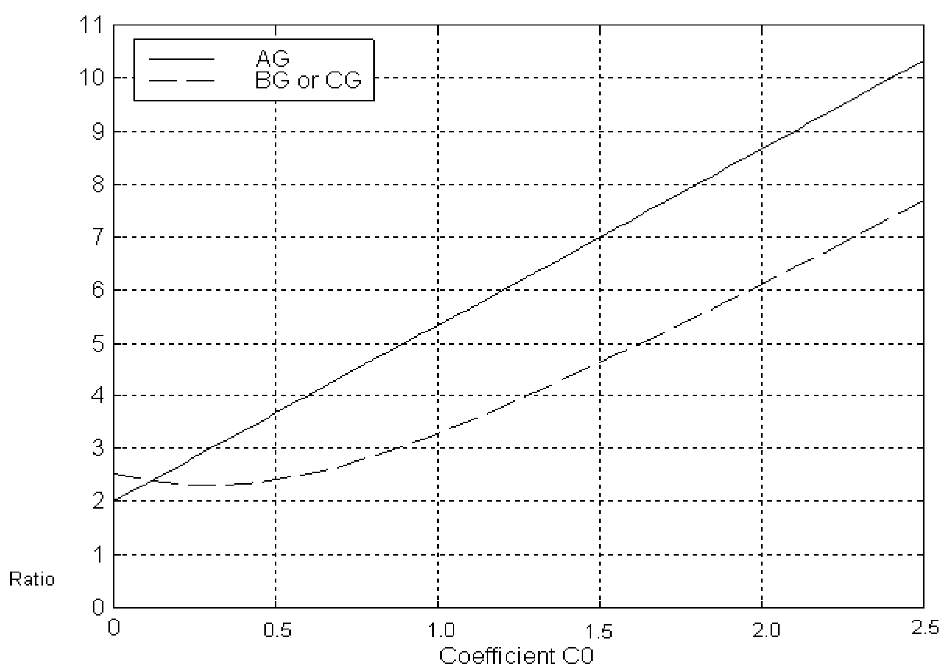


Figure 3-1. Ratio of $I_{3\Phi min}/I_{\Phi Gmin}$ vs. C0 (C1 = 0.1, C2 = 0.7)

Case 3

When the minimum ground fault current is less than 12.5% of minimum three phase fault current C0 should be set to 2.5.

The recommended settings
C1 = 0.1
C2 = 0.7
C0 = 2.5
gives the following sensitivity for different faults:

Three phase faults

$$IT_{\min} = -C1 \cdot I_{3\phi \min} = -0.1 \cdot I_{3\phi \min}$$

Phase-phase faults

$$\left|IT_{\min}\right| = \left|\frac{1}{\sqrt{3}}(-C1 + C2 \cdot e^{\pm j60^{o}}) \cdot I_{\phi\phi \min}\right| = 0.38 \cdot I_{\phi\phi \min} = 0.38 \cdot \frac{\sqrt{3}}{2} \cdot I_{3\phi \min} = 0.33 \cdot I_{3\phi \min}$$

Single phase to ground faults

$$IT_{\min} = \frac{1}{3}(-C1 + C2 + C0) \cdot I_{\phi G \min} = 1.0 \cdot I_{\phi G \min}$$

Automatic Channel Delay Measurement (ALDT)

The relay logic continuously performs a communication channel delay measurement. To use this feature, set ALDT to YES. If fixed channel delay, as set by LDT, is to be used, set ALDT to NO.

Lead/Follow Mode (LDFL)

The LDFL is used for automatic channel delay measurement. One terminal should always be set to LEAD and the other to FOLO.

Local Delay Timer (LDT)

REL 356 uses the LDT setting when no automatic channel delay measurement is being used (ALDT = NO). If fixed channel delay is used, LDT should be set to the channel delay displayed in MLDT function of the monitoring functions.

The LDT setting is used for loop-back testing, when automatic delay measurement cannot be performed. Then, set LDT = 1.3 for digital versions and 19.3 for audiotone version. (NOTE: The 19.3 msec delay is valid for modem version A, i.e. cat.# MCxxxxAxxx. For modem version T, LDT should be set to 10.8 msec.)

When ALDT = YES, the LDT setting is ignored by the system.

Unit Identification (UNID)

This setting eliminates the possibility of connecting two wrong units to each other due to cross connection in the communication channel matrix.

The UNID numbers in the two units should be adjacent, i.e.

0 in one	and	1 in the other
2 in one	and	3 in the other
10 in one	and	11 in the other

The lower value of the pair should always be an even number.

Communication Speed Selection (KBPS) – 56/64 kbps versions only

This setting allows 56 kbps or 64 kbps communication speed selection. This setting should be coordinated with any external communication multiplexer used in the system. A vast majority of applications are 64 kbps.

Transfer Trip (TTRP)

The transfer trip function as initiated by a contact closure (TB5 9 to 10) can be enabled or disabled (IN or OUT).

When enabled (TTRP = IN), contact closure will result in transmission of transfer trip code to the remote end. When received at the remote unit for at least 10 msec, tripping will take place. The remote REL356 will close either its basic trip contacts, and/or contacts on the extended output board as determined by the setting DDTT.

Transmit clock source (XCLK) – 56/64 kbps versions only

This setting establishes the source of the transmit data clock. If XCLK = EXT, the transmit data clock is extracted from the received data stream. If XCLK = INT, the clock originates from the internal crystal clock oscillator.

For systems using external multiplexers (T1 or E1 type) the setting should be XCLK = EXT. Note that the data clock is extracted from the received data stream so that no connection to any “clock” output on the multiplexer is needed.

For systems using dedicated fiber (850 nm or 1300 nm) the setting should be XCLK = INT.

Loopback (LPBK)

This setting should be LPBK = NO during normal operation.

The LPBK setting is only set to YES for testing when the relay is connected in loopback mode, i.e. the communication wires are cross connected so that the relay communicates with itself. Loopback mode disables the automatic channel delay measurement and unit ID check as these can no be performed during loopback condition.

Transmitter Level (XMTR) – Audiotone version only

This setting defines the output power from the unit’s transmitter in –dBm. It should be set in accordance with specifications for the channel used. For metallic pilot wire applications, the maximum setting is recommended, i.e. –1 dBm.

Receiver Level Signal Detector (RLSD) – Audiotone version only

This setting defines the minimum threshold for declaring channel trouble (CHTB) in –dBm.

Fault Locator and Distance System Common Settings

Ohms per Unit Distance (XPUD)

This setting is used by the fault locator algorithm to estimate a calculated distance to the fault. The units of XPUD will be in primary ohms per mile or kilometer, depending on the setting of DTYP.

For example: Set XPUD = 0.8 if DTYP = MI and the line reactance is 0.8 primary ohms/mile.

Distance Unit Type (DTYP)

Either miles (MI) or kilometers (km) can be selected. This setting should match the units used in XPUD.

Positive Sequence Impedance Angle (PANG)

This setting relates directly to the positive sequence angle of the line. It defines the Zone 2 and Zone 3 phase impedance unit maximum torque angle in degrees. This setting is also used for defining the slope of the blinders for OST and OSB an for the fault locator algorithm.

Zero Sequence Impedance Angle (GANG)

This setting defines the impedance angle of the zero sequence (ZI0) impedance of the line. Zone 2 and Zone 3 ground impedance units use this angle for their operation.

Zero Sequence to Positive Sequence Impedance Ratio (ZR)

This setting is used for all ground fault measurements. It reflects the magnitude ratio of the zero sequence impedance to the positive sequence impedance of the line and is determined as ZR = ZL0/ZL1.

For example: If ZL0 = 15 ohms @ 60° and ZL1 = 3 ohms @ 75° set ZR = 15/3 = 5.0

Backup System Settings – Versions with Distance Option only

Backup System Enable (BKUP)

This setting determines if and when the distance backup system will be activated. There are three possible BKUP settings:

BKUP = NONE	The backup distance system, even though included, will be deactivated at all times and will not trip.
BKUP = CT	The backup distance system will be activated 150 msec after a CT (channel trouble) condition occurs. It will stay enabled until the channel comes back into service when it will automatically be switched out.
BKUP = CTDD	The backup distance system will be activated 150 msec after a CT (channel trouble) condition occurs or a differential protection disable condition occurs. Differential protection disable can be activated by a energizing a local or remote input. The backup system will stay enabled until the channel comes back into service or the disable condition resets and will then automatically be switched out.

Loss of Potential Block (LOPB)

This setting enables the loss of potential logic (V0 and notI0) to block all Zone 2 and Zone 3 impedance units if the logic is satisfied.

The loss of potential logic does not affect the differential protection which uses currents only.

Directional Units Settings

Forward Directional Phase Unit (FDOP)

If the system has voltage inputs, then the high set phase overcurrent units (IPH) can be made directional if FDOP is set to IN.

Forward Directional Ground Unit (FDOG)

If the system has voltage inputs, then the high set ground overcurrent unit (IPG) can be made directional if FDOG is set to IN.

Ground Directional Unit Polarization (DIRU)

The ground directional unit can be zero sequence or negative sequence polarized. When zero sequence polarized, it uses all zero sequence quantities to determine the power flow direction and is sensitive to zero sequence mutuals between parallel lines. When negative sequence polarized it uses all neagtive sequence quantities to determine the power flow direction and its operation is not influence by mutual effects. Set DIRU = ZSEQ if mutuals are not a consideration and DIRU = NSEQ if strong zero sequence mutuals are present for the transmission line.

Ground Backup Unit Settings – Versions with Distance Option only

Medium Set Ground Overcurrent Unit (IOM)

This overcurrent unit supervises the trips of the ground units in the impedance backup system. If TOG is set, it is also used for tripping after a time delay. The IOM unit measures 3I0 and should be set above maximum unbalance during load conditions.

The recommended setting is IOM = 0.5 A.

Ground Overcurrent Timer (TOG)

This timer starts timing after IOM has operated. The relay system will trip when the timer has operated. It is used as complement to the ground distance units for high resistive ground faults. This unit needs to be coordinated with down-stream devices.

As with the distance units, the ground time overcurrent function is only enabled during channel failure or when the differential protection is blocked, as selected by the BKUP setting.

Zone 2 and Zone 3 Settings - Versions with Distance Option only

Settings for Zone 2 and Zone 3 protective systems are similar. Application of the distance units follow the standard application for a conventional step distance, non-pilot relaying system.

Even though they are called Zone 2 and Zone 3, functionally they can serve as one underreaching instantaneous zone and one overreaching time delayed zone as a conventional Zone 1 and Zone 2 stepped system.

If used as an instantaneous underreaching zone, Zone 2 should be set to never overreach the remote end. Recommended setting is 80% of the line impedance. Zone 3 should be set to underreach any Zone 1 covering the adjacent lines coming out of the remote terminal. Zone 3 should also cover at least 100% of the protected line plus 20% of the shortest adjacent line under all conditions.

Zone 3 timers, for phase and ground, should be set to coordinate with the forward and reverse adjacent high speed trips. The timer should include the breaking time of the slowest adjacent breaker plus a tolerance of two to three cycles.

The characteristic of the distance measuring elements are determined by the settings PANG, GANG, ZR specified above and the reach settings ZGF, ZGR, and ZP.

Ground units in both zones are self polarized and have a forward reach (ZGF) and a reverse reach (ZGR). The FDOG (forward ground directional unit) is used to supervise the forward direction while the reverse reach is used to define the overall size of the characteristic and thus the reach along the R-axis.

The phase to phase and three phase units in REL 356 have only a forward reach, ZP. These units are inherently directional.

Zone 2 Phase Reach (Z2P)

This setting coordinates the Zone 2 reach for phase to phase faults and three phase faults. The setting is in secondary ohms.

Zone 2 Phase Timer (T2P)

Selects the time delay for Zone 2 phase fault detection. When set to zero, Zone 2 should be set underreaching. The setting is in seconds.

Zone 2 Forward Ground Reach (Z2GF)

This setting controls the forward reach of the Zone 2 ground unit. The setting is in secondary ohms.

Zone 2 Reverse Ground Reach (Z2GR)

This setting controls the reverse reach of the Zone 2 ground unit. The setting is in secondary ohms. The Z2GR setting is determined by the desired reach along the R-axis.

Zone 2 Ground Timer (T2G)

Selects the time delay for Zone 2 phase fault detection. When set to zero, Zone 2 should be set underreaching. The setting is in seconds.

Zone 3 Phase Reach (Z3P)

This setting coordinates the Zone 3 reach for phase to phase faults and three phase faults. The setting is in secondary ohms.

Zone 3 Phase Timer (T3P)

Selects the time delay for Zone 3 phase fault detection. The setting is in seconds.

Zone 3 Forward Ground Reach (Z3GF)

This setting controls the forward reach of the Zone 3 ground unit. The setting is in secondary ohms.

Zone 3 Reverse Ground Reach (Z3GR)

This setting controls the reverse reach of the Zone 3 ground unit. The setting is in secondary ohms.

Zone 3 Ground Timer (T3G)

Selects the time delay for Zone 3 phase fault detection. The setting is in seconds.

Out of Step Settings – Versions with Distance Option only

Current differential protection is immune to power swings. When voltage inputs are part of the REL 356, blinders are provided for power swing detection. The out of step trip and block logic is provided as part of the distance option. Out of step block is only enabled when the distance backup protection is switched due to channel trouble or differential block as determined by the setting BKUP. Out of step trip, when selected, is always active regardless of the BKUP setting.

Out of Step Trip (OST)

This setting enables the out of step trip logic. The setting options are:

OUT	No OST trip
WAYI	Trip on the way into the operating characteristic of the relay
WAYO	Trip on the way out of the operating characteristic of the relay

Out of Step Block (OSB)

This setting enables the out of step block logic that blocks the Zone 2 and/or Zone 3 distance units for out of step conditions. The setting options are:

OUT	No OSB used
Z2	Out of step logic blocks Zone 2 impedance elements only
Z3	Out of step logic blocks Zone 3 impedance elements only
BOTH	Out of step logic blocks Zone 2 and Zone 3 impedance elements

Inner Blinder (RT)

This setting is the offset in the perpendicular direction to the line impedance on the R-X diagram in secondary ohms. Apart from its function in the OSB and OST logic, it also performs load restriction of the three phase impedance units.

The resistance RT must have a setting sufficiently low (in ohms) to avoid operation on the minimum stable swing ohms expected. Similarly it must have a setting sufficiently high to accommodate the maximum fault resistance that is likely to be encountered for three phase faults on the protected line. Operation of the three phase distance function for all zones can be avoided for swing angles (between the two equivalent sources) as great as 120° if the inner blinder is given a resistance setting of 0.288 Z_T or less, where Z_T is the protected line positive sequence impedance plus the sum of the lowest positive sequence impedance at each end of the line. The minimum setting should accommodate a three phase fault resistance value of at least 0.1 Z_T ohms based on an arc voltage of 400 volts per foot (primary) and typical phase separation.

Using the average of these two conservative figures a reasonable value to use for the inner blinder resistance is 0.2 Z_T.

Outer Blinder (RU)

This setting is the offset in the perpendicular direction to the line impedance on the R-X diagram in secondary ohms.

The outer blinder resistance setting must be chosen to assure proper distinction between faults and swing conditions. Sustained load must not be allowed to operate the outer blinder. The recommended setting is 3 times the inner blinder setting but not more than 80% of minimum load impedance.

Out of Step Detection Timer (OST1)

This timer is started when the outer blinder, RU, has operated but the inner blinder, RT, has not operated. If the timer times out, an out of step condition has been detected and OSB is active. The recommended setting is 3 cycles.

Out of Step Trip Way In Timer (OST2)

This timer is started when the an out of step condition has been detected and the two blinders have operated. Once it times out, a trip signal is issued for OST. The recommended setting is 2 cycles.

Out of Step Trip Way Out Timer (OST3)

This timer is started when the out of step condition has been detected and the OST2 timer has timed out and both blinders are not operated. This permits controlling the time that the breaker opens. The recommended setting is 0.5 cycles.

Out of Step Trip Override Timer (OSOT)

This timer is started once an out of step condition is identified (output of OST1). A trip signal is generated if OSOT times out and the apparent impedance seen by the relay is inside Zone 2 or Zone 3 reach and inside the RT blinder. The recommended setting is 100 cycles.

Remote Setting and Time Settings

Remote Setting (SETR)

Set SETR = YES if remote setting via RCP is allowed.

Time Settings (TIME, YEAR, MONTH, DAY, WDAY, HOUR, MIN)

To set the clock in the relay, set TIME = YES and enter correct values as appropriate.

Settings for Tapped Load Applications

Introduction

The REL 356 relay may be used where the line is protected as a two-terminal line but has a load tap in the zone of protection. In order to apply and set the relay properly in this environment, there must be a transformer at the load tap. If a transformer is not present, the relays can not be set to limit the zone of protection, and the power line must be treated as a three-terminal line.

An example of a load tapped two-terminal line is shown in Figure 3-2. Careful consideration must be given to the settings that are applied to the relay to assure that all faults, up to and into the transformer, are recognized and all faults beyond the transformer are ignored. In Figure 3-2, a delta-wye transformer is shown with the wye on the load side and with a grounded neutral. This is the most common application. The ZT in Figure 3-2 is the transformer impedance, and Z is the total equivalent impedance looking back into the system from the high voltage terminals of the transformer. What must be considered are the relay energy levels for faults on the line side of the transformer vs. that for faults on the load side.

The relay energy is affected by two things; the sequence network settings and the type of fault. The internal faults that produce the lowest network filter output current and the external faults which produces the highest filter output current must regulate the settings.

If the relay is set to have a negative sequence response, the type of internal phase fault that will produce the lowest sequence network current will be a CA or AB fault. This minimum internal fault is assumed to occur at the transformer high terminals (F1). If the relay is set to have no negative sequence response (C2 = 0), then all combinations of phase-to-phase faults produce a low energy level in the relay. For this phase-to-phase fault, the positive sequence portion of the current is all that will affect the filter output response, and that current level is equal to $V_{LN}(2R_C)$ where V_{LN} is the line to neutral voltage and R_C is the current transformer ratio.

The type of external faults that produce the highest sequence network output for faults on the load side of the transformer must be considered. Ground faults do not produce any zero sequence current in the relays because of the presence of the transformer delta, and therefore, only the positive and negative sequence response need to be considered. If the relay is set for no negative sequence response, it is clearly seen that a three-phase fault on the load side will produce the highest network current output at the relay location. The fault current, in this case, will be $V_{LN}/[(Z+ZT)R_C]$.

The case where the relay is set to have a negative sequence response (C2≠0), presents a more difficult analysis. Due to the fact that the positive sequence constant (C1) is opposite in sign to the negative sequence constant (C2), and considering the fact that the high side positive sequence current will lead the low side current by 30 degrees, and the high side negative sequence current will lag the low side current by 30 degrees for a standard transformer, it can be shown that a phase B-to-C fault or a phase C-to-A fault will produce the highest sequence output of all the low voltage phase faults. A C-to-G fault will produce the highest filter output current for phase-to-ground faults on the low voltage side of the transformer. It depends on the values of Z and ZT as to whether the phase-to-phase or phase-to-ground fault produces the larger output. Therefore both must be considered.

Settings for OTH, C0, C1 and C2 for Tapped Load Applications

The relay setting OTH and the sequence filter constants, C1, C2 and C0, should be first selected according to normal conditions following the recommendations on page 3-9. Then, the relay setting and the selected constants need to be checked to make sure they satisfy the special requirements for tap load applications:

if $C_2 = 0$

$$0.3 \cdot C_1 \cdot \frac{V_{LN}}{2 \cdot |Z| \cdot R_C} > OTH > 0.3 \cdot C_1 \cdot \frac{V_{LN}}{|Z + Z_T| \cdot R_C} \tag{1}$$

if $C_2 \neq 0$

$$0.3 \cdot \left|C_1 + C_2 e^{-j60^\circ}\right| \cdot \frac{V_{LN}}{2 \cdot |Z| \cdot R_C} > OTH > 0.3 \cdot \left|C_1 + C_2 e^{j120^\circ}\right| \cdot \frac{V_{LN}}{2 \cdot |Z + Z_T| \cdot R_C} \tag{2}$$

where

V_{LN} is the line-to-neutral voltage,

R_c is the CT ratio,

Z is the total equivalent system impedance looking back into the system from the transformer bank, in high side ohms

Z_T is the transformer impedance, in high side ohms

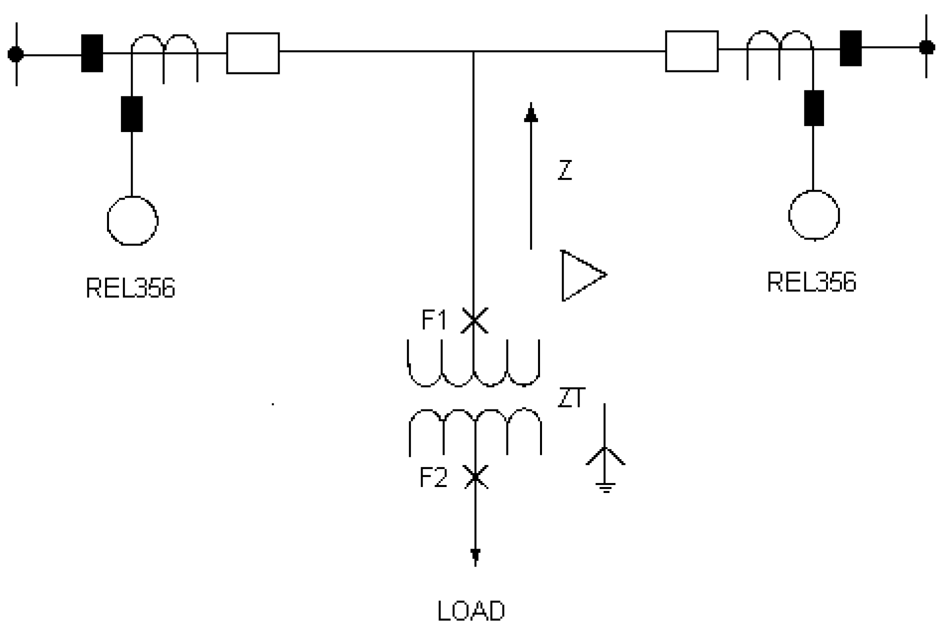


Figure 3-2. Tapped Load Application

Setting Example – General Case

Line Data

For current differential measurement

CT ratio = 1200/5 = 240

Line charging current 120 A primary, 0.5 A secondary

From local terminal, L:
Minimum fault current for internal three phase fault 3600 A primary, 15 A secondary
Minimum fault current for internal phase to ground fault 2400 A primary = 67% of three phase fault current

From remote terminal, R:
Minimum fault current for internal three phase fault 2160 A primary, 9 A secondary
Minimum fault current for internal phase to ground fault 1440 A primary = 67% of three phase fault current

Maximum through current for an external three phase and ground fault 12000 A primary, 50 A secondary
Maximum through current for an external ground fault 12000 A primary, 50 A secondary

Communication media : dedicated fiber, 1.3 msec total channel delay

For fault locating and fault recording

VT ratio = 138000/115 = 1200
Line length = 20 miles
Line impedance per mile 0.971 ohms/mile, primary

For distance backup protection

Zsec = Zprim x CTratio/VTratio = Zprim x 0.2
Z1L = 4.855@79° = 0.952 + j 4.761 ohms primary = 0.190 + j 4.761 ohms secondary
Z0L = 9.710@79° = 1.904 + j 9.522 ohms primary = 0.381 + j 1.904 ohms secondary
Z1SLmin = 2.56@88° ohms primary (local terminal)
Z1SRmin = 4.22@87° ohms primary (remote terminal)
Minimum load impedance (0.8 x 138000)/(1200x$\sqrt{3}$) primary = 10.6 ohms secondary

Relay System Setup

Firmware Version (VERS) **VERS = 1.21**

Indicates the firmware version in the REL 356. This instruction book is for v 1.21 and earlier.

System Frequency (FREQ) **FREQ = 60 Hz**

Select either 50 or 60 Hz.

Readout in Primary Values (RP) **RP = YES**

A YES setting enables the REL 356 system to display all the monitored voltages and currents in primary kA and kV, based on the current transformer ratio (CTR) and voltage transformer ratio (VTR) entered.

Current Transformer Type (CTYP) **CTYP = 5 A**

Select either 1 or 5 A, depending on the secondary current rating of the line ct.

Current Transformer Ratio (CTR) **CTR = 240**

This setting is used for load current monitoring, if it is selected to be displayed in primary kA. It has no effect on the protective relaying system. Note that the metering accuracy for currents is 5% or 0.1 A secondary. The 0.1 A step will be multiplied with CTR, why the error will appear larger on a primary basis.

Different CT ratios can be used in the two line ends by adjusting the operating threshold, OTH, so that the same level is achieved on a primary basis. For example, if one end has a ratio of 240 and OTH is set to 0.5 A, the other end with ratio 120 should have an OTH setting of 1.0 A. Note that the sequence filter settings, C1, C2 and C0, should always be the same at the two line ends.

Voltage Transformer Ratio (VTR) **VTR = 1200**

This setting is used for the system voltage monitoring, if it is selected to be displayed in primary kV. It has no effect on the protective system.

Digital Fault Recording Information

Trigger for Storing Oscillographic Data (OSC) **OSC = TRIP**

Indicates trigger for oscillographic data gathering. The user can select to trigger oscillographic data when:

- TRIP The REL 356 system tripped
- ITRG The REL 356 system detected the operation of either the TRGP (phase) or TRGG (ground) overcurrent elements (see below)
- $\Delta V \Delta I$ The voltage and/or current change detectors operated

The change detectors (CD) pick up when the current or voltage change between the corresponding data samples, spaced one cycle apart, exceeds 12.5%, minimum 0.5 A or 7 V.

The use of CD as a trigger of oscillographic data is of little practical value when a relay is connected to the power system. Numerous changes due to sudden load changes, remote switching, distant faults, etc. make the resulting oscillographic records difficult to relate to events of importance. During testing however, I can sometimes be useful to use this setting to capture records for external faults.

Trigger for Storing Fault Records (FDAT) **FDAT = TRIP**

Indicates trigger for fault record gathering. The user can select to trigger fault records when:

- TRIP The REL 356 system tripped
- ITRG The REL 356 system detected the operation of either the TRGP (phase) or TRGG (ground) overcurrent elements (see below)

Ground Trigger Pick Up Level (TRGG) **TRGG = 0.5 A**

This setting controls the level of current magnitude on the ground current, which when exceeded triggers oscillographic data and/or fault records, depending on the settings above.

In case OSC and/or FDAT are not set to ITRG, this setting is ignored by the system.

ITRG level not used

Phase Trigger Pick Up Level (TRGP) **TRGP = 5.5 A**

This setting controls the level of current magnitude on the phase currents, which when exceeded triggers oscillographic data and/or fault records, depending on the settings above.

In case OSC and/or FDAT are not set to ITRG, this setting is ignored by the system.

ITRG level not used

Protection System Settings

Change Detector (CD) **CD = ΔVΔI**

The change detector CD is used for supervision of the differential trip function. All relay current inputs (I_A, I_B, I_C and I_G) and voltage inputs (V_A, V_B, and V_C) are sampled and converted to numbers 12 times per cycle. The present samples are compared to the corresponding samples taken one cycle earlier.

The change detector is asserted if the absolute difference of present and old sample exceeds 12.5% of the old sample and the difference is larger than 0.1 p.u. for current and 7 V for voltage.

The CD can be generated either by using the current change detectors (ΔI) or the current and voltage change detectors (ΔVΔI). The ΔVΔI setting is recommended when the system has voltage inputs and the relay will be used in a weak feed application where the change in current might not be sufficient to trigger the change detector.

Dedicated Direct Transfer Trip (DDTT) **DDTT = 0**

When the extended output board with additional trip contacts is not included, no DDTT setting is available and a received transfer trip signal will always result in closure of the two main trip contacts, TRIP–1 and TRIP–2.

When the extended output board is included, the following setting options are available:

DDTT = 0
All trips, trips from the local relay as well as received direct transfer trip, result in closing of all six trip and all six BFI contacts; TRIP-1, TRIP-2, TRIP-3, TRIP-4, TRIP-5, TRIP-6, BFI-1, BFI-2, BFI-3, BFI-4, BFI-5 and BFI-6.

DDTT = 2
Trips from the local relay will result in closing of trip and BFI contacts TRIP–1, TRIP-2, TRIP-3, TRIP-4, BFI-1, BFI-2, BFI-3 and BFI-4. Received transfer trip will close contacts TRIP-5, TRIP-6, BFI-5 and BFI-6.

DDTT = 4
Trips from the local relay will result in closing of trip and BFI contacts TRIP–1, TRIP-2, BFI-1 and BFI-2. Received transfer trip will close contacts TRIP-3, TRIP-4, TRIP-5, TRIP-6, BFI-3, BFI-4, BFI-5 and BFI-6.

The settings are summarized in the table below where TRIP is trip from the local relay (differential or back-up trip) and TTRP is received transfer trip from the remote end:

DDTT	TRIP-1/BFI-1	TRIP-2/BFI-2	TRIP-3/BFI-3	TRIP-4/BFI-4	TRIP-5/BFI-5	TRIP-6/BFI-6
0	TRIP/TTRP	TRIP/TTRP	TRIP/TTRP	TRIP/TTRP	TRIP/TTRP	TRIP/TTRP
2	TRIP	TRIP	TRIP	TRIP	TTRP	TTRP
4	TRIP	TRIP	TTRP	TTRP	TTRP	TTRP

Low Set Current Supervision (ILTS) **ILTS = IN**

The user can select to supervise differential trip but the low set current elements, IPL and IGL. With ILTS = IN, higher security is achieved. However, for weak feed applications when the local fault current may not exceed the set IPL or IGL current levels, ILTS should be set to OUT in order to allow the weak terminal to trip on current differential operation.

Weak feed condition not present ⇒ ILTS=IN

Reclose Block Enable (RBEN) **RBEN = NORB**

The following settings are provided for system flexibility:

NORB Normal Reclose Block. The RB contacts will close for the following trips:

- Reclose into fault
- Trip from the back-up system
- Out-of-step trip
- High set overcurrent trip
- Transfer trip

ALRB All Reclose Block. The RB contacts will close for all trips.

Stub/Open Breaker Timer (SOBT) **SOBT = 10 msec**

The SOBT timer provides a time delay for the stub bus and open breaker trip functions. When using 52b inputs for the open breaker detection, the reset time of the breaker contacts should be carefully considered. If the contact reset time is greater than the set SOBT time, reclosing will be unsuccessful. The reason is as follows: after a trip, with both breakers open, one end closes back into the line successfully. The second end closes in but has slow resetting 52b contacts why OPBR (open breaker) code is still being received by the remote end at the time load current starts to flow. The remote end will then trip from the low set IPL elements if OPBK function is used. The SOBT timer thus needs to be set longer than the 52b contact reset time plus channel delay plus 8 msec margin.

52b contact used directly, digital channel delay 1.3 msec ⇒ SOBT > 1.3 + 8 msec

The 52b contact reset time is generally close to zero when the breaker contacts are used directly but might be much longer when connected to the relay via an external auxiliary relay.

Open Breaker (OPBR) **OPBR = 52B**

The following settings are available for open breaker keying:

- IE Keying is initiated when the line current is <u>lower</u> than the IE setting. Note that the line charging current must exceed this setting, which limits the use of this option on short lines.
- 52B Keying is initiated when the 52b contact at the local end is closed.
- BOTH Keying is initiated either when the load current is lower than the IE setting or when 52b is closed.
- OUT No open breaker keying. Note that this will disable the Open Breaker function in the <u>remote</u> end as no open breaker code will be received there.

Very Low Set Phase Current Unit (IE) — ***IE = 0.2 A***

This unit is used with the open breaker keying logic (OPBR). It should be set sensitive enough to pick up when the local breaker is closed.

Note that the minimum setting is 0.04 x In (0.2 A for a 5 A ct). The charging current of a very short line might be insufficient to operate this element why open breaker condition would be given even when the breaker is closed. In that case, the 52b contact should be used.

Note that there is ± 20% hysteresis associated with this setting. Open breaker keying will start when the current drops below 0.8 x IE and will remain so until it increases above 1.2 x IE.

In case OPBK is set to 52B or OUT, this setting is ignored by the system.
OPBK set to 52B why IE setting not used

Low Set Phase Unit (IPL) — ***IPL = 1.0 A***

The low set overcurrent units supervise differential trip when ILTS is set IN.

The low set units are also used for tripping during stub bus and open breaker conditions, if these functions are used. To prevent trip from the stub bus logic during line energizing, the phase IPL unit should be set at 1.5 times the net line charging current, but must be at least 0.5 A.
IPL > 1.5 x charging current = 1.5 x 0.5 = 0.75 ⇒ IPL = 1.0 A

Net line charging current is defined as: the steady state net single end line charging phase current, as measured under balanced conditions (all local poles closed and all remote poles open). Net line charging current indicates the distributed capacitive current minus any line side shunt reactor current.

High Set Phase Overcurrent Unit (IPH) — ***IPH = 62.5 A***

This unit is provided in the REL 356 system to supplement the current differential protection by providing a non-pilot direct trip capability for high current faults. The IPH unit should be set above the maximum expected external fault current with a security margin.

The IPH unit should be set for 1.25 times the maximum through current for an external three phase fault.
IPH = 1.25 x 50 A = 62.5 A

The high set overcurrent units can be made directional when FDOP, the phase directional unit, is set to IN, and three phase voltage is applied to the relay. IPH is then supervised by FDOP.

Low Set Ground Unit (IGL) — ***IGL = 0.5 A***

The low set ground overcurrent unit supervises differential trip when ILTS is set IN.

The low set units are also used for tripping during stub bus and open breaker conditions, if these functions are used.

Since the effect of charging current is minimum for the ground subsystem, the setting should only allow for inherent unbalance under normal operation. A minimum setting of 0.5 A is recommended.

High Set Ground Overcurrent Unit (IGH) **IGH = 62.5 A**

The high set ground unit should follow the same guidelines as the high set phase units.
IGH = 1.25 x 50 A = 62.5 A

The high set ground overcurrent unit can be made directional when FDOG, the ground directional unit, is set to IN, and three phase voltage is applied to the relay. IGH is then supervised by FDOG.

Current Differential System Settings

Trip Desensitizing (TDES) **TDES = OUT**

This setting temporarily desensitizes the differential protection by increasing the operating threshold, OTH, for 30 cycles after closing the line breaker (de-energization of the 52b input). This setting can be used to prevent false tripping on large inrush currents that may be produces by a tapped transformer in the protected zone.

The setting is a multiple of the nominal operating threshold, OTH, and has a range of 1 to 10 times nominal pickup. It can also be set to OUT and no desensitizing on 52b de-energization will occur.

The trip desensitizing characteristic is a linear ramp which multiplies the tripping threshold immediately on de-energization of the 52b input to the value to the TDES setting and then slowly over a time period of 30 cycles lowers the trip threshold back to its nominal value.

Trip desensitizing is not recommended when the transformers are external to the protected zone. In this case the inrush current will be seen as an external fault and the REL 356 relays will remain stable.

Operating Threshold (OTH) **OTH = 0.56**

The operating threshold determines the differential current required for operation according to the formula:

$$OP - 0.7 \cdot RES \geq OTH$$

where
$OP = |IT_L + IT_R|$
and
$RES = |IT_L| + |IT_R|$
$IT = - C1I1 + C0I0 + C2I2$

For internal three phase faults, $IT = -C1I1$, $\angle IT_L \cong \angle IT_R$

A 20% margin is recommended, i.e.

$OTH < 0.80\ (OP_{min} - RES_{min}) = 0.80\ (|IT_L| + |IT_R|) \times 0.3$

$OP = |IT_L + IT_R| = (15 + 9) \times 0.1 = 2.4$
$RES = |IT_L| + |IT_R| = (15 + 9) \times 0.1 = 2.4$
$OTH < 0.8\ (OP - 0.7RES) = 0.8(2.4 - 0.7 \times 2.4) = 0.576$

Select OTH = 0.56

For single end infeed conditions, only one current is present, IT_L or IT_R. The equations then turn into:

$OP = |IT_L|$
$RES = |IT_L|$

With the recommended 20% margin, OTH should then be set to:

OTH < 0.80 (OP_{min} – RES_{min}) = 0.80 x ITL x 0.3 = 0.80 x C1I1 x 0.3

Different CT ratios can be used in the two line ends by adjusting the operating threshold, OTH, so that the same level is achieved on a primary basis. For example, if one end has a ratio of 240 and OTH is set to 0.5 A, the other end with ratio 120 should have an OTH setting of 1.0 A. Note that the sequence filter settings, C1, C2 and C0, should always be the same at the two line ends.

Note that for versions 1.15 and earlier, OTH is set in peak value why the above setting recommendations should be adjusted with a factor $\sqrt{2}$. This means that the recommended setting for double end infeed is:

$$OTH \leq \sqrt{2} \cdot 0.8 \cdot (OP_{\min} - RES_{\min})$$

and for single end infeed:

$$OTH \leq \sqrt{2} \cdot 0.8(OP_{\min} - RES_{\min}) = \sqrt{2} \cdot 0.8 \cdot ITL \cdot 0.3 = \sqrt{2} \cdot 0.80 \cdot C_1 I_1 \cdot 0.3$$

Sequence Coefficients (C0, C1, C2) **C0 = 0.0, C1 = 0.1, C2 = 0.7**

REL 356 uses sequence filters to obtain positive, negative and zero sequence currents. These currents are then combined into one quantity:

$$IT = C0 \cdot I_0 - C1 \cdot I_1 + C2 \cdot I_2$$

where

I_0, I_1 and I_2 are the zero sequence, the positive sequence and the negative sequence currents.

The sequence filter settings, C1, C2 and C0, should always be the same at the two line ends.

In order to minimize the influence of load, C1 should be set to a relatively low value. We recommend to use C1 = 0.1.

C0 and C2 will both multiply fault currents. Setting recommendations C1 and C2 for three cases are made:

Case 1) Minimum fault current for a ground fault $I_{\Phi Gmin}$ > 50% of minimum fault current for a three phase fault, $I_{3\Phi min}$.

Minimum fault current for internal phase to ground fault 2400 A primary = 67% of three phase fault current ⇒ use settings according to Case 1

Case 2) Minimum fault current for a ground fault $I_{\Phi Gmin}$ < 50% of minimum fault current for a three phase fault, $I_{3\Phi min}$.

Case 3) Minimum fault current for a ground fault $I_{\Phi Gmin}$ < 12.5% of minimum fault current for a three phase fault, $I_{3\Phi min}$.

Case 1

Either C2 or C0 can be used for fault detection of any unsymmetrical fault. The use of negative sequence, C2, is preferable as the negative sequence currents are more consistent at the two line terminals. We therefore recommend to set C0 = 0.

A high value of C2 would increase the sensitivity but in order not to make the relay responding to system unbalances a “moderate” setting is recommended. Good sensitivity with high security is achieved with setting C2 = 0.7.

The recommended settings
C1 = 0.1
C2 = 0.7
C0 = 0.0
gives the following sensitivity for different faults:

Three phase faults

$$IT_{\min} = -C1 \cdot I_{3\phi\min} = -0.1 \cdot I_{3\phi\min}$$

Phase-phase faults

$$\left|IT_{\min}\right| = \left|\frac{1}{\sqrt{3}}(-C1 + C2 \cdot e^{\pm j60^{\circ}}) \cdot I_{\phi\phi\min}\right| = 0.38 \cdot I_{\phi\phi\min} = 0.38 \cdot \frac{\sqrt{3}}{2} \cdot I_{3\phi\min} = 0.33 \cdot I_{3\phi\min}$$

Single phase to ground faults

$$IT_{\min} = \frac{1}{3}(-C1 + C2 + C0) \cdot I_{\phi G\min} = 0.2 \cdot I_{\phi G\min}$$

Case 2

When the minimum ground fault current is substantially smaller than the minimum three phase fault current, C0 can be given a value to increase the sensitivity for ground fault.

The recommended settings
C1 = 0.1
C2 = 0.7
C0 = according to Figure 1
gives the following sensitivity for different faults:

Three phase faults

$$IT_{\min} = -C1 \cdot I_{3\phi\min} = -0.1 \cdot I_{3\phi\min}$$

Phase-phase faults

$$\left|IT_{\min}\right| = \left|\frac{1}{\sqrt{3}}(-C1 + C2 \cdot e^{\pm j60^{\circ}}) \cdot I_{\phi\phi\min}\right| = 0.38 \cdot I_{\phi\phi\min} = 0.38 \cdot \frac{\sqrt{3}}{2} \cdot I_{3\phi\min} = 0.33 \cdot I_{3\phi\min}$$

Single phase to ground faults

The value of C0 is determined from Figure 1. Calculate the ratio $I_{3\Phi min}/I_{\Phi Gmin}$ and find this number on the vertical axis. Find the C0 for the calculated current ratio based on the curve corresponding to the least sensitive fault type.

Selecting C0 is this way results in the same sensitivity for minimum ground fault current as for minimum three phase fault current.

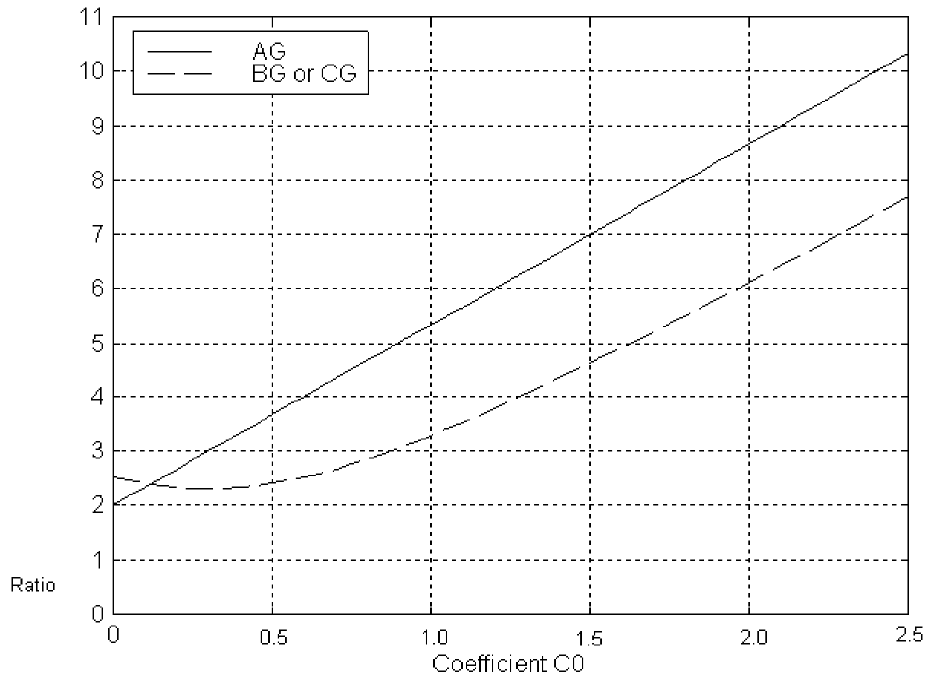


Figure 1. Ratio of $I_{3\Phi min}/I_{\Phi Gmin}$ vs. C0 (C1 = 0.1, C2 = 0.7)

Case 3

When the minimum ground fault current is less than 12.5% of minimum three phase fault current C0 should be set to 2.5.

The recommended settings
C1 = 0.1
C2 = 0.7
C0 = 2.5
gives the following sensitivity for different faults:

Three phase faults

$$IT_{\min} = -C1 \cdot I_{3\phi\min} = -0.1 \cdot I_{3\phi\min}$$

Phase-phase faults

$$\left|IT_{\min}\right| = \left|\frac{1}{\sqrt{3}}(-C1 + C2 \cdot e^{\pm j60^\circ}) \cdot I_{\phi\phi\min}\right| = 0.38 \cdot I_{\phi\phi\min} = 0.38 \cdot \frac{\sqrt{3}}{2} \cdot I_{3\phi\min} = 0.33 \cdot I_{3\phi\min}$$

Single phase to ground faults

$$IT_{\min} = \frac{1}{3}(-C1 + C2 + C0) \cdot I_{\phi G\min} = 1.0 \cdot I_{\phi G\min}$$

Automatic Channel Delay Measurement (ALDT) ***ALDT = YES***

The relay logic continuously performs a communication channel delay measurement. To use this feature, set ALDT to YES. If fixed channel delay, as set by LDT, is to be used, set ALDT to NO.
ALDT is generally always used.

Lead/Follow Mode (LDFL) ***LDFL = LEAD***

The LDFL is used for automatic channel delay measurement. One terminal should always be set to LEAD and the other to FOLO.
If LDFL = LEAD in this end set LDFL = FOLO in the remote end.

Local Delay Timer (LDT) ***LDT = 1.3 msec***

REL 356 uses the LDT setting when no automatic channel delay measurement is being used (ALDT = NO). If fixed channel delay is used, LDT should be set to the channel delay displayed in MLDT function of the monitoring functions.

The LDT setting is used for loop-back testing, when automatic delay measurement can not be performed. Then, set LDT = 1.3 for digital versions and 18.3 for audiotone version.

When ALDT = YES, the DLT setting is ignored by the system.
Set LDT to actual channel delay as measured by the relay in metering mode, MLDT, even though LDT is only used when ALDT=NO, e.g. during testing.

Unit Identification (UNID) ***UNID = 0***

This setting eliminates the possibility of connecting two wrong units to each other due to cross connection in the communication channel matrix.

The UNID numbers in the two units should be adjacent, i.e.

0 in one	and	1 in the other
2 in one	and	3 in the other
10 in one	and	11 in the other

The lower value of the pair should always be an even number.
If UNID = 0 in this end, set UNID = 1 in the remote end.

Communication Speed Selection (KBPS) – 56/64 kbps versions only ***KBPS = 64kbps***

This setting allows 56 kbps or 64 kbps communication speed selection. This setting should be coordinated with any external communication multiplexer used in the system. A vast majority of applications are 64 kbps.

Transfer Trip (TTRP) ***TTRP = IN***

The transfer trip function as initiated by a contact closure (TB5 9 to 10) can be enabled or disabled (IN or OUT).

When enabled (TTRP = IN), contact closure will result in transmission of transfer trip code to the remote end. When received at the remote unit for at least 10 msec, tripping will take place. The remote REL 356 will close either its basic trip contacts, and/or contacts on the extended output board as determined by the setting DDTT.

Transmit Clock Source (XCLK) – 56/64 kbps versions only ***XCLK = IN***

This setting establishes the source of the transmit data clock. If XCLK = EXT, the transmit data clock is extracted from the received data stream. If XCLK = INT, the clock originates from the internal crystal clock oscillator.

For systems using external multiplexers (T1 or E1 type) the setting should be XCLK = EXT. Note that the data clock is extracted from the received data stream so that no connection to any "clock" output on the multiplexer is needed.

For systems using dedicated fiber (850 nm or 1300 nm) the setting should be XCLK = INT.
Dedicated fiber ⇒ XCLK = INT.

Loopback (LPBK) **LPBK = NO**

This setting should be LPBK = NO during normal operation.

The LPBK setting is only set to YES for testing when the relay is connected in loopback mode, i.e. the communication wires are cross connected so that the relay communicates with itself. Loopback mode disables the automatic channel delay measurement and unit ID check as these can no be performed during loopback condition.
LPBK = YES is only used during testing. Set LPBK = NO for normal service.

Transmitter Level (XMTR) – Audiotone version only

This setting defines the output power from the unit's transmitter in –dBm. It should be set in accordance with specifications for the channel used. For metallic pilot wire applications, the maximum setting is recommended, i.e. –1 dBm.

Receiver Level Signal Detector (RLSD) – Audiotone version only

This setting defines the minimum threshold for declaring channel trouble (CHTB) in –dBm.

Fault Locator and Distance System Common Settings

Ohms Per Unit Distance (XPUD) **XPUD = 0.971**

This setting is used by the fault locator algorithm to estimate a calculated distance to the fault. The units of XPUD will be in primary ohms per mile or kilometer, depending on the setting of DTYP.
Line impedance per mile 0.971 ohms/mile, primary

Distance Unit Type (DTYP) **DTYP = MI**

Either miles (MI) or kilometers (km) can be selected. This setting should match the units used in XPUD.

Positive Sequence Impedance Angle (PANG) **PANG = 79**

This setting relates directly to the positive sequence angle of the line. It defines the Zone 2 and Zone 3 phase impedance unit maximum torque angle in degrees. This setting is also used for defining the slope of the blinders for OST and OSB an for the fault locator algorithm.
Z1L = 4.855@79° ⇒ PANG = 79

Zero Sequence Impedance Angle (GANG) **GANG = 79**

This setting defines the impedance angle of the zero sequence (ZI0) impedance of the line. Zone 2 and Zone 3 ground impedance units use this angle for their operation.
Z0L = 9.710@79° ⇒ GANG = 79

Zero Sequence to Positive Sequence Impedance Ratio (ZR) **ZR = 2.0**

This setting is used for all ground fault measurements. It reflects the magnitude ratio of the zero sequence impedance to the positive sequence impedance of the line and is determined as ZR = ZL0/ZL1.
ZR = Z0L/Z1L = 9.710/4.855 = 2

Backup System Settings – Versions with Distance Option only

Backup System Enable (BKUP) **BKUP = CT**

This setting determines if and when the distance backup system will be activated. There are three possible BKUP settings:

BKUP = NONE	The backup distance system, even though included, will be deactivated at all times and will not trip.
BKUP = CT	The backup distance system will be activated 150 msec after a CT (channel trouble) condition occurs. It will stay enabled until the channel comes back into service when it will automatically be switched out.
BKUP = CTDD	The backup distance system will be activated 150 msec after a CT (channel trouble) condition occurs or a differential protection disable condition occurs. Differential protection disable can be activated by a energizing a local or remote input. The backup system will stay enabled until the channel comes back into service or the disable condition resets and will then automatically be switched out.

Loss of Potential Block (LOPB) **LOPB = NO**

This setting enables the loss of potential logic (V0 and notI0) to block all Zone 2 and Zone 3 impedance units if the logic is satisfied.

The loss of potential logic does not affect the differential protection which uses currents only.

Directional Units Settings

Forward Directional Phase Unit (FDOP) **FDOP = IN**

If the system has voltage inputs, then the high set phase overcurrent units (IPH) can be made directional if FDOP is set to IN.

Forward Directional Ground Unit (FDOG) **FDOG = IN**

If the system has voltage inputs, then the high set ground overcurrent unit (IPG) can be made directional if FDOG is set to IN.

Ground Directional Unit Polarization (DIRU) **DIRU = ZSEQ**

The ground directional unit can be zero sequence or negative sequence polarized. When zero sequence polarized, it uses all zero sequence quantities to determine the power flow direction and is sensitive to zero sequence mutuals between parallel lines. When negative sequence polarized it uses all neagtive sequence quantities to determine the power flow direction and its operation is not influence by mutual effects. Set DIRU = ZSEQ if mutuals are not a consideration and DIRU = NSEQ if strong zero sequence mutuals are present for the transmission line.

Ground Backup Unit Settings – Versions with Distance Option only

Medium Set Ground Overcurrent Unit (IOM) **IOM = 0.5 A**

This overcurrent unit supervises the trips of the ground units in the impedance backup system. If TOG is set, it is also used for tripping after a time delay. The IOM unit measures 3I0 and should be set above maximum unbalance during load conditions.

The recommended setting is IOM = 0.5 A.

Ground Overcurrent Timer (TOG) ***TOG = BLK***

This timer starts timing after IOM has operated. The relay system will trip when the timer has operated. It is used as complement to the ground distance units for high resistive ground faults. This unit needs to be coordinated with downstream devices.

As with the distance units, the ground time overcurrent function is only enabled during channel failure or when the differential protection is blocked, as selected by the BKUP setting.

Zone 2 and Zone 3 Settings - Versions with Distance Option only

Settings for Zone 2 and Zone 3 protective systems are similar. Application of the distance units follow the standard application for a conventional step distance, non-pilot relaying system.

Even though they are called Zone 2 and Zone 3, functionally they can serve as one underreaching instantaneous zone and one overreaching time delayed zone as a conventional Zone 1 and Zone 2 stepped system.

If used as an instantaneous underreaching zone, Zone 2 should be set to never overreach the remote end. Recommended setting is 80% of the line impedance. Zone 3 should be set to underreach any Zone 1 covering the adjacent lines coming out of the remote terminal. Zone 3 should also cover at least 100% of the protected line plus 20% of the shortest adjacent line under all conditions.

Zone 3 timers, for phase and ground, should be set to coordinate with the forward and reverse adjacent high speed trips. The timer should include the breaking time of the slowest adjacent breaker plus a tolerance of two to three cycles.

The characteristic of the distance measuring elements are determined by the settings PANG, GANG, ZR specified above and the reach settings ZGF, ZGR, and ZP.

Ground units in both zones are self polarized and have a forward reach (ZGF) and a reverse reach (ZGR). The FDOG (forward ground directional unit) is used to supervise the forward direction while the reverse reach is used to define the overall size of the characteristic and thus the reach along the R-axis.

The phase to phase and three phase units in REL 356 have only a forward reach, ZP. These units are inherently directional.

Zone 2 Phase Reach (Z2P) ***Z2P = 0.78 ohms***

This setting coordinates the Zone 2 reach for phase to phase faults and three phase faults. The setting is in secondary ohms.
When using Z2 as an underreaching, instantaneous zone, set Z2P = 80% Z1L (secondary) = 0.8 x 4.855 (primary) x 0.2 = 0.78 secondary $\Rightarrow$ Z2P = 0.78 ohms

Zone 2 Phase Timer (T2P) ***T2P = 0.00 sec***

Selects the time delay for Zone 2 phase fault detection. When set to zero, Zone 2 should be set underreaching. The setting is in seconds.

Zone 2 Forward Ground Reach (Z2GF) ***Z2GF = 0.78 ohms***

This setting controls the forward reach of the Zone 2 ground unit. The setting is in secondary ohms.
When using Z2 as an underreaching, instantaneous zone, set Z2GF = 80% Z1L (secondary) = 0.8 x 4.855 (primary) x 0.2 = 0.78 secondary $\Rightarrow$ Z2GF = 0.78 ohms

Zone 2 Reverse Ground Reach (Z2GR) ***Z2GR = 0.20 ohms***

This setting controls the reverse reach of the Zone 2 ground unit. The setting is in secondary ohms. The Z2GR setting is determined by the desired reach along the R-axis.

Assume 25% of the forward reach gives desired fault resistance coverage ⇒ Z2GR = 0.25 x 0.78 = 0.20 ohms

Zone 2 Ground Timer (T2G) ***T2G = 0.00 sec***

Selects the time delay for Zone 2 phase fault detection. When set to zero, Zone 2 should be set underreaching. The setting is in seconds.

Zone 3 Phase Reach (Z3P) ***Z3P = 1.17 ohms***

This setting coordinates the Zone 3 reach for phase to phase faults and three phase faults. The setting is in secondary ohms.

Z3 is used overreaching. Minimum recommended setting is 1.2 x ZL1 ⇒ Z3P = 1.2 x 4.885 x 0.2 = 1.17 ohms secondary

Zone 3 Phase Timer (T3P) ***T3P = 0.30 sec***

Selects the time delay for Zone 3 phase fault detection. The setting is in seconds.

Zone 3 Forward Ground Reach (Z3GF) ***Z3GF = 1.17 ohms***

This setting controls the forward reach of the Zone 3 ground unit. The setting is in secondary ohms.

Z3 is used overreaching. Minimum recommended setting is 1.2 x ZL1 ⇒ Z3GF = 1.2 x 4.885 x 0.2 = 1.17 ohms secondary

Zone 3 Reverse Ground Reach (Z3GR) ***Z3GR = 0.29 ohms***

This setting controls the reverse reach of the Zone 3 ground unit. The setting is in secondary ohms.

Using the same relation as for Z2 ⇒ Z3GR = 0.25 x Z3GF = 0.25 x 1.17 = 0.29 secondary ohms

Zone 3 Ground Timer (T3G) ***T3G = 0.30 sec***

Selects the time delay for Zone 3 phase fault detection. The setting is in seconds.

Out of Step Settings - Versions with Distance Option only

Current differential protection is immune to power swings. When voltage inputs are part of the REL 356, blinders are provided for power swing detection. The out of step trip and block logic is provided as part of the distance option. Out of step block is only enabled when the distance backup protection is switched due to channel trouble or differential block as determined by the setting BKUP. Out of step trip, when selected, is always active regardless of the BKUP setting.

Out of Step Trip (OST) ***OST = NO***

This setting enables the out of step trip logic. The setting options are:

NO	No OST trip
WAYI	Trip on the way into the operating characteristic of the relay
WAYO	Trip on the way out of the operating characteristic of the relay

Out of Step Block (OSB) ***OSB = BOTH***

This setting enables the out of step block logic that blocks the Zone 2 and/or Zone 3 distance units for out of step conditions. The setting options are:

NONE	No OSB used
Z2	Out of step logic blocks Zone 2 impedance elements only
Z3	Out of step logic blocks Zone 3 impedance elements only
BOTH	Out of step logic blocks Zone 2 and Zone 3 impedance elements

Inner Blinder (RT) ***RT = 1.15 ohms***

This setting is the offset in the perpendicular direction to the line impedance on the R-X diagram in secondary ohms. Apart from its function in the OSB and OST logic, it also performs load restriction of the three phase impedance units.

The resistance RT must have a setting sufficiently low (in ohms) to avoid operation on the minimum stable swing ohms expected. Similarly it must have a setting sufficiently high to accommodate the maximum fault resistance that is likely to be encountered for three phase faults on the protected line. Operation of the three phase distance function for all zones can be avoided for swing angles (between the two equivalent sources) as great as 120° if the inner blinder is given a resistance setting of 0.288 Z_T or less, where Z_T is the protected line positive sequence impedance plus the sum of the lowest positive sequence impedance at each end of the line. The minimum setting should accommodate a three phase fault resistance value of at least 0.1 Z_T ohms based on an arc voltage of 400 volts per foot (primary) and typical phase separation.

Using the average of these two conservative figures a reasonable value to use for the inner blinder resistance is 0.2 Z_T.
RT = 0.2 x Z_T = 0.2 (Z1SA + Z1SB + ZL1) = 0.2(2.56 + 2.22 + 4.86) primary = 5.752 x 0.2 secondary = 1.15 ohms secondary

Outer Blinder (RU) ***RU = 3.45 ohms***

This setting is the offset in the perpendicular direction to the line impedance on the R-X diagram in secondary ohms.

The outer blinder resistance setting must be chosen to assure proper distinction between faults and swing conditions. Sustained load must not be allowed to operate the outer blinder. The recommended setting is 3 times the inner blinder setting but not more than 80% of minimum load impedance.
RU = 3 x RT = 3 x 1.15 = 3.45 ohms < 80% of the minimum load impedance (10.6 ohms)

Out of Step Detection Timer (OST1) ***OST1 = 5.00 cycles***

This timer is started when the outer blinder, RU, has operated but the inner blinder, RT, has not operated. If the timer times out, an out of step condition has been detected and OSB is active. The recommended setting is 3 cycles.
Out-of-step trip not used

Out of Step Trip Way In Timer (OST2) ***OST2 = 5.00 cycles***

This timer is started when the an out of step condition has been detected and the two blinders have operated. Once it times out, a trip signal is issued for OST. The recommended setting is 2 cycles.
Out-of-step trip not used

Out of Step Trip Way Out Timer (OST3) ***OST3 = 5.00 cycles***

This timer is started when the an out of step condition has been detected and the OST2 timer has timed out and both blinders are not operated. This permits controlling the time that the breaker opens. The recommended setting is 0.5 cycles.
Out-of-step trip not used

Out of Step Trip Override Timer (OSOT) **OSOT = 100 cycles**

This timer is started once an out of step condition is identified (output of OST1). A trip signal is generated if OSOT times out and the apparent impedance seen by the relay is inside Zone 2 or Zone 3 reach and inside the RT blinder. The recommended setting is 100 cycles.

Remote Setting and Time Settings

Remote Setting (SETR) **SETR = YES**

Set SETR = YES if remote setting via RCP is allowed.

Time Settings (TIME, YEAR, MONTH, DAY, WDAY, HOUR, MIN)

To set the clock in the relay, set TIME = YES and enter correct values as appropriate.

Setting Example - Tapped Load Application

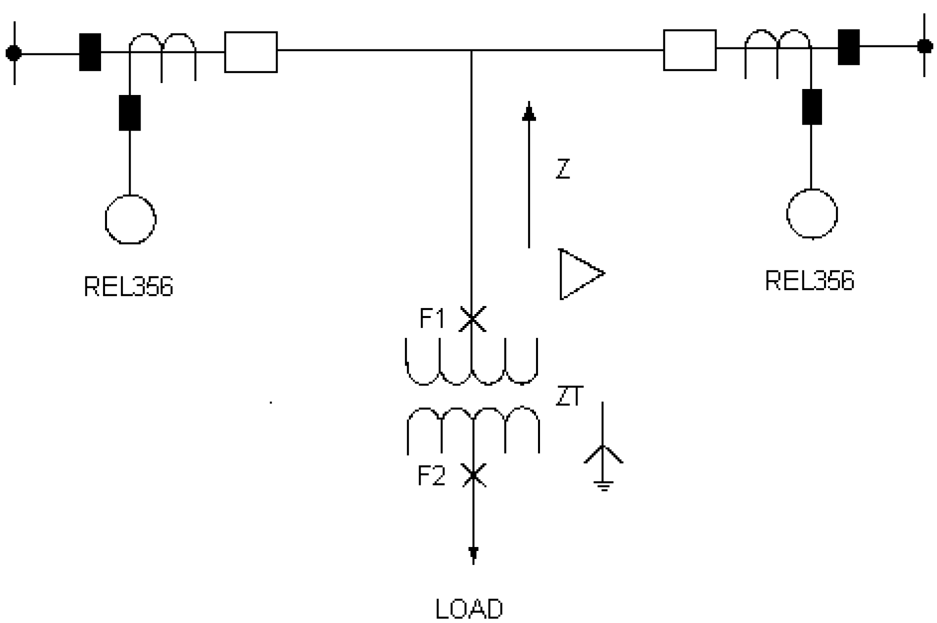


Figure 3-3. Setting Example-Tapped Load Application

Line and Transformer Data

Line data as for the general case:
CT ratio = 1200/5 = 240
VT ratio = 138000/115 = 1200

Z = 4.08 ohms, primary
ZT = 7% on a 20 MVA base

$$ZT(ohms) = ZT(pu) \cdot \frac{kV^2}{MVA} = 0.07 \cdot \frac{138^2}{20} = 66.65$$

Settings for OTH, C0, C1 and C2 for Tapped Load Applications

The relay setting OTH and the sequence filter constants, C1, C2 and C0, should be first selected according to normal conditions following the recommendations. Then, the relay setting and the selected constants need to be checked to make sure they satisfy the special requirements for tap load applications:

Following the procedure for the general case, the following settings were determined:

C1 = 0.1
C2 = 0.7
C0 = 0
OTH = 0.56 A
i.e. use criterion (2)

- if $C_2 = 0$

$$0.3 \cdot C_1 \cdot \frac{V_{LN}}{2 \cdot |Z| \cdot R_C} > OTH > 0.3 \cdot C_1 \cdot \frac{V_{LN}}{|Z + Z_T| \cdot R_C} \qquad (1)$$

- if $C_2 \neq 0$

$$0.3 \cdot \left|C_1 + C_2 e^{-j60^\circ}\right| \cdot \frac{V_{LN}}{2 \cdot |Z| \cdot R_C} > OTH > 0.3 \cdot \left|C_1 + C_2 e^{j120^\circ}\right| \cdot \frac{V_{LN}}{2 \cdot |Z + Z_T| \cdot R_C} \qquad (2)$$

where

V_{LN} is the line-to-neutral voltage, in primary Volts

R_c is the CT ratio,

Z is the total equivalent system impedance looking back into the system from the transformer bank, in high side ohms

Z_T is the transformer impedance, in high side ohms

$$0.3 \cdot \left|C_1 + C_2 e^{-j60^\circ}\right| \cdot \frac{V_{LN}}{2 \cdot |Z| \cdot R_C} > OTH > 0.3 \cdot \left|C_1 + C_2 e^{j120^\circ}\right| \cdot \frac{V_{LN}}{2 \cdot |Z + Z_T| \cdot R_C} \Rightarrow$$

$$0.3 \cdot \left|0.1 + 0.7 e^{-j60^\circ}\right| \cdot \frac{138000}{2 \cdot 4.08 \cdot 240 \cdot \sqrt{3}} = 0.3 \cdot 0.76 \cdot 40.41 = 9.21 > OTH$$

$$0.3 \cdot \left|0.1 + 0.7 e^{j120^\circ}\right| \cdot \frac{138000}{2 \cdot (4.08 + 66.65) \cdot 240 \cdot \sqrt{3}} = 0.3 \cdot 0.66 \cdot 2.34 = 0.46 < OTH$$

Thus the settings established for the general case will be valid also for this tapped load application example.

Measuring Elements and Operational Logic

Composite Sequence Filter

The REL 356 combines the phase currents (IA, IB and IC) measured at the protective relaying terminal into a single quantity. This quantity, IT, is an output of a symmetrical component filter that is proportional to the weighted sum of the sequence components. The quantity IT is defined as:

$$IT = -C_1 I_1 + C_2 I_2 + C_0 I_0$$

The quantity IT is a sine wave that is proportional to the fault current. The C1 (positive sequence coefficient), C2 (negative sequence coefficient) and C0 (zero sequence coefficient) are system settings that control the sensitivity of the relaying system.

An example of a single phase to ground, AG, fault with the corresponding IT quantity is shown in Figure 4-1. The first graph shows the three phase currents and the second the IT filter output for settings C1 = 0.1, C2 = 0.7 and C0 = 0.0.

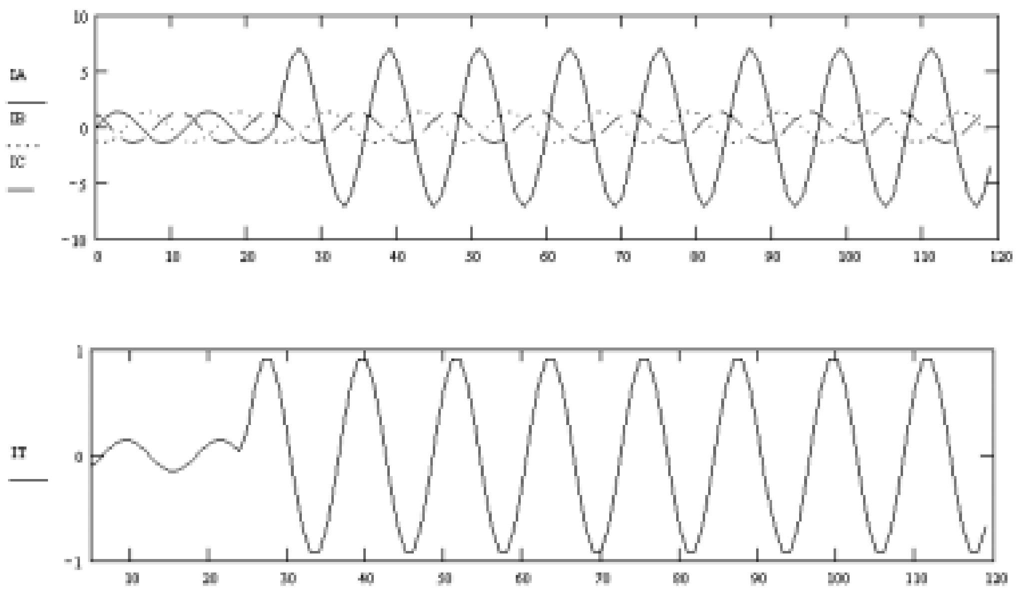


Figure 4-1. IT Filter Output for an A-G Fault

Current Differential Algorithm

For the comparison process, two quantities are generated from the local and remote IT waveforms. The operate quantity is derived by vector addition of the local and remote quantities. The restraint (bias) quantity is obtained by adding the local and remote quantities on a magnitude basis. The resultant output is opposite in polarity to the operate quantity. The operate and restraint quantities are combined and the result fed to a level detector which produces a trip signal.

The quantity IT is converted into the phasor quantity ITL using discrete Fourier transform (DFT) cosine filter (see Figure 4-2). The quantity ITL is applied to

- Communication transmitter and sent to the remote receiver where it is received as ITR. Note that due to channel propagation delay, ITR is delayed with respect to ITL.
- Current differential protection algorithm after compensation for the channel propagation delay, LDT.

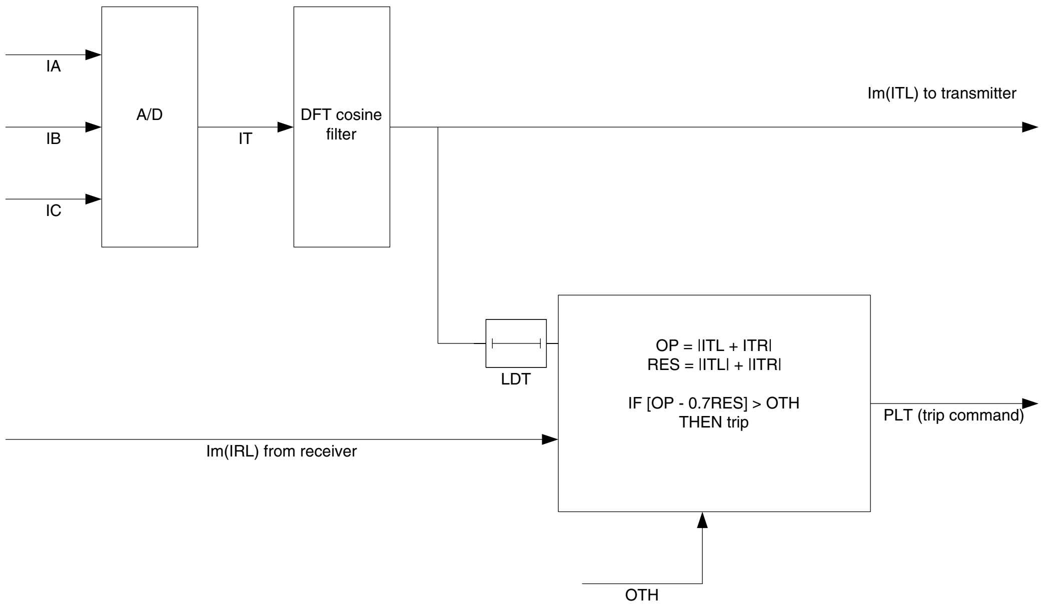


Figure 4-2. Current Differential Logic

Operate quantity

$$OP = \left|ITL + ITR\right| = \sqrt{\left[re(ITL) + re(ITR)\right]^2 + \left[im(ITL) + im(ITR)\right]^2}$$

Restraint quantity

$$RES = \left|ITL + ITR\right| = \sqrt{\left[re(ITL)\right]^2 + \left[im(ITL)\right]^2} + \sqrt{\left[re(ITR)\right]^2 + \left[im(ITR)\right]^2}$$

Trip decision

IF [(OP – 0.7RES) > OTH] THEN TRIP

Where

ITL = local quantity
ITR = remote quantity
OTH = set operating threshold

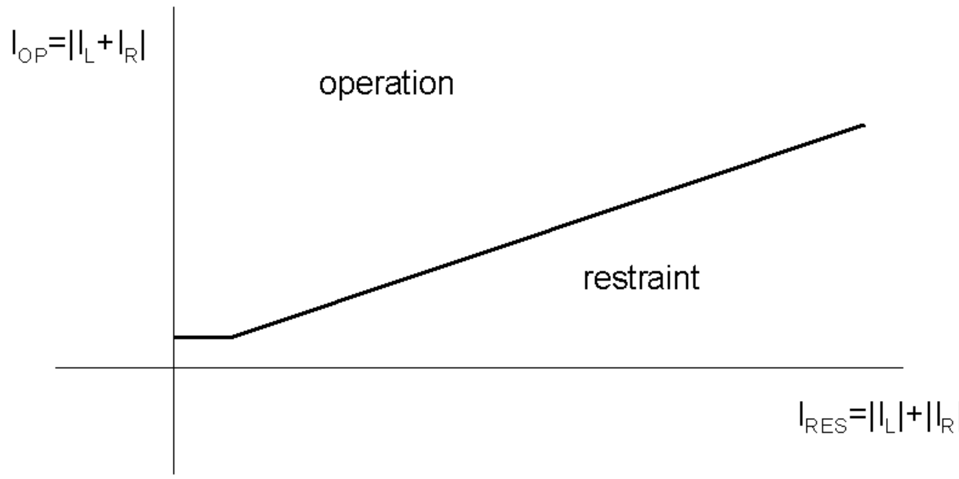


Figure 4-3. Operating Characteristic

External fault

For an external fault, the currents will be 180° out of phase and of equal magnitude:

$$ITR = ITL\angle 180^\circ$$
$$OP = |ITL + ITR| = |ITL + ITL\angle 180^\circ| = 0$$
$$RES = |ITL| + |ITR| = |ITL| + |ITL| = 2 \cdot |ITL|$$
$$OP - 0.7RES = 0 - 1.4 = -1.4$$

which, of course, is less than OTH which is a positive value (settable 0.00 – 3.98).

Internal fault

For an internal fault, the currents will be practically in phase:

$$\angle ITR \cong \angle ITL$$
$$OP = |ITL + ITR| = |ITL| + |ITR|$$
$$RES = |ITL| + |ITR|$$
$$OP - 0.7RES = |ITL| + |ITR| - 0.7(|ITL| + |ITR|) = 0.3(|ITL| + |ITR|) \geq OTH$$

where OTH should be selected so that minimum internal fault current will produce trip.

Communication Channel Options

REL356 is available with eight different communication interfaces:

- 9600 bps audiotone
- British Telecom audiotone
- 56/64 kbps direct digital
- 56/64 kbps 820 nm multi-mode fiber
- 56/64 kbps 1300 nm single mode fiber, short reach
- 56/64 kbps 1300 nm single mode fiber, medium reach
- 56/64 kbps 1300 nm single mode fiber, long reach
- 56/64 kbps direct digital with G.703 interface

Data Communication

The REL 356 sampling rate is 12 samples per cycle. After A/D conversion, the phase currents are converted into the composite current IT and sent over to the remote end. A data frame is sent 4 times per cycle and the differential evaluation is performed with the same frequency. The data frame consists of 32 bits organized as follows:

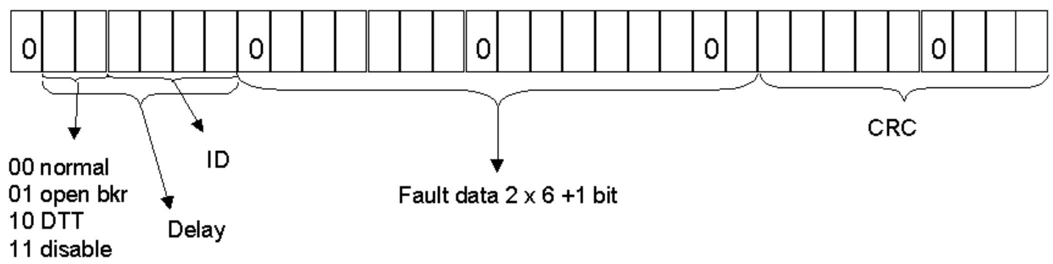


Figure 4-4. Data Frame

The significance of the bits is as follows:

Bit 0	sync
Bit 1-2	special code (normal, open breaker, Direct Transfer Trip, Disable)
Bit 1-6	automatic time delay measurement performed every 64 msec
Bit 3-6	unit ID
Bit 7-22	fault data
Bit 23-31	CRC, Cyclic Redundancy Check

9600 bps Audiotone Interface

The audiotone interface has a built-in modem that enables the REL 356 to be connected directly to an analog channel such as leased phone line, microwave or metallic pilot wire. The modem operates at 9600 bps using Quadrature Amplitude Modulation (QAM) at a carrier frequency of 1,700 Hz. The transmit level is settable between – 1 dBm and –15 dBm. Maximum receiver sensitivity is –43 dBm.

56/64 kbps Digital Communication Interfaces

The digital communication interfaces allow communication via 850 nm multi-mode or 1300 nm single-mode dedicated fiber. The direct digital interface allows connection to a multiplexer (MUX). Settings for selection of 56 or 64 kbps and internal or external clock synchronization are provided. Applications with dedicated fiber use internal clock (INT) and applications with multiplexers use external clock (EXT) as this signal is provided by the MUX.

Adaptive Communication Channel Delay Measurement

The REL 356 continuously measures and updates the channel delay. A measurement is performed every 64 msec, independently from each line end. This loop delay is then divided by two and entered into the differential algorithm to compensate for the actual channel delay.

Relay Functions

Direct Transfer Trip

The REL 356 data frame provides for an independent transfer trip command to be sent to the remote relay by activating an opto-isolated dc voltage input, DTT KEY. When the remote relay receives the Direct Transfer Trip command for > 10 msec, a trip command is issued and the trip output contacts are closed.

When REL 356 is supplied with the optional output board, transfer trip can be selected to trip all 6 contacts, 4 additional contacts, or 2 of the additional contacts.

Change Detector Supervision

The REL 356 has sensitive change detectors, forming the signal CD. The current change detectors will operate for a 12.5% change of the sample value in any phase or ground as compared to the same sample one cycle earlier. The voltage change detectors will operate for a 12.5% change of the sample value in any phase as compared to the same sample one cycle earlier. The change detector operation, CD, can be selected to use current only (CD = ΔI) or current OR voltage (CD = ΔIΔV).

The change detector CD supervises differential trip and is used for triggering DFR records. Current sensing only is suitable for most applications. For weak feed conditions, however, the ΔIΔV setting may be preferable.

Open Breaker Function

REL 356 will sense a local open breaker condition by either the 52b contact or by a current sensing element IE or both. Note that the minimum setting of IE is 0.04 x In (0.2 A for a 5 A relay) why this setting option can not be used on short lines. As an Open Breaker logic condition will be set when the current is below the IE setting, the line charging current has to be larger than this setting.

When the local REL 356 detects an open breaker condition, it sends this information to the remote end. If there is a fault on the line, the remote end REL 356 will then trip from the low set phase and ground overcurrent elements, IPL and IGL, after a set time delay, SOBT.

The relay at the end with the open breaker will not trip as the differential trip is supervised by the change detector, CD.

The Open Breaker function can be disabled by setting OPBK = OUT. Note that this will disable the Open Breaker function in the <u>remote</u> end as no open breaker code will be received there.

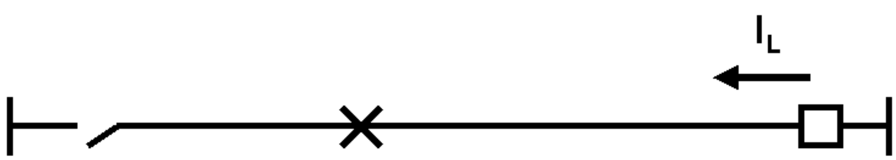


Figure 4-5. Open Breaker Trip

Stub Bus Trip

The stub bus trip is using the same logic as the Open Breaker function. When a binary input senses that the line disconnect is open, the <u>local and remote</u> relay will be enabled to trip from the low set overcurrent elements, IPL and IGL.

The relay at the non-faulted section of the line will not trip as the differential trip is supervised by the change detector, CD.

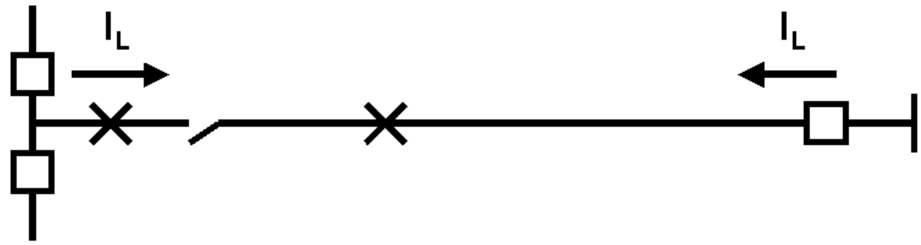


Figure 4-6. Stub Bus Trip

Weak Feed Trip

As seen from the operation algorithm, both relays will measure the same quantities. It is therefore sufficient with fault current infeed from one end only for both relays to trip. Trip is supervised by a sensitive change detector, CD. CD will operate for any current change in any phase or ground larger than 12.5% based on a sample compared to the same sample one cycle earlier. Note that also a phase shift or a drop in current will thus cause the change detector to operate.

In case there is very little pre-fault load, the current change detector might not operate. It is then recommended to use the setting CD = ΔIΔV which enables CD for change in voltage as well. Potential transformers then need to be connected to the relay.

Reclose Initiate Logic

REL 356 provides four reclose initiate (RI) contact outputs to be used with an external recloser. Two reclose block (RB) contacts are also provided, in case the recloser requires this input instead of RI.

The RI contacts will close for the following trips:
- Pilot trip from the differential function
- Stub bus trip
- Open breaker trip

When Reclose Block Enable (RBEN) is set to Normal Reclose Block (NORB) the RB contacts will close for the following trips:
- Reclose into fault
- Trip from the back-up system
- Out-of-step trip
- High set overcurrent trip
- Transfer trip

When RBEN is set to All Reclose Block (ALRB) the RB contacts will close for all trips.

A pilot trip within 500 msec after closing the breaker is interpreted as having reclosed into the same fault, and further reclosing is blocked.

High Set Overcurrent Elements

REL 356 includes four channel independent overcurrent elements, IAH, IBH, ICH and IGH, for faster tripping for close in faults. When potentials are connected to the relay, these units can be made directional, by setting FDOP and FDOG to IN.

The phase directional unit FDOP is based on the angular relationship of a single-phase current and the corresponding pre-fault phase-to-phase voltage phasors. The forward direction is identified if the current phasor leads the voltage phasor. The pair of current and voltage phasors that are compared are I_A and V_{BA}, I_B and V_{CB}, I_C and V_{AC}.

The ground unit can be selected to be either zero sequence voltage polarized or negative sequence voltage polarized. Negative sequence polarization is recommended for parallel lines with mutual coupling.

Zero sequence polarization utilizes the zero sequence components of the currents and voltages into the relay, and the unit operates when $3I_0$ leads $3V_0$ by more than 30° or lags by more than 150°. For the operation of these units, it is required that $3I_0 > 0.5$ A and $3V_0 > 1$ V.

Negative sequence polarization utilizes the negative sequence components of the currents and voltages into the relay and the unit has its maximum torque line when I_2 leads V2 by 98° with the current $3I_2 > 0.5$ A and $3V_2 > 3$ V.

Fault Locator

The REL 356 fault locator feature computes the magnitude and phase angle of the fault impedance and the distance to the fault in both miles and kilometers. The fault impedance is calculated from the voltage and current phasors of the faulted phase(s). Thus, proper faulted phase selection is essential for good fault locator results. The distance to the fault is computed by multiplying the imaginary part of the fault impedance times the voltage and current transformer ratios (VTR/CTR) and dividing by the distance multiplier setting (XPUD). The impedance calculations for the various fault types are:

$$Z_{XG} = \frac{V_{XG}}{I_X + k \cdot I_0}$$

for single line to ground faults,

$$Z_{XY} = \frac{V_{XG} - V_{YG}}{I_X - I_Y}$$

for line to line faults, and

$$Z_{ABC} = \frac{V_A}{I_A}$$

for three phase faults
where X, Y = any A, B, C phase.

Faulted Phase Selector

The REL 356 includes a phase selector for indication of the faulted phase(s). The phase selector is current-only based why connection of voltages is not needed for correct operation. As the REL 356 is intended for three pole trip only, the phase selector is not used in the trip logic but for indication and for fault location calculation.

Note that the phase selector algorithm is based on comparing pre-fault and fault currents why, during secondary injection testing, a sudden change between the pre-fault and fault condition is required for correct indication.

	AG	BG	CG	AB	BC	CA	ABG	BCG	CAG
$\lvert\Delta I_A\rvert > 1.5 * \lvert\Delta I_B\rvert$	X					X			X
$\lvert\Delta I_A\rvert > 1.5 * \lvert\Delta I_C\rvert$	X			X			X		
$\lvert\Delta I_B\rvert > 1.5 * \lvert\Delta I_A\rvert$		X			X			X	
$\lvert\Delta I_B\rvert > 1.5 * \lvert\Delta I_C\rvert$		X		X			X		
$\lvert\Delta I_C\rvert > 1.5 * \lvert\Delta I_A\rvert$			X		X			X	
$\lvert\Delta I_C\rvert > 1.5 * \lvert\Delta I_B\rvert$			X			X			X
none = ABC									

Figure 4-7. Phase Selector

The fault type is identified by any two comparisons being true as shown in Figure 4-7. If no single phase to ground, two phase or two phase to ground fault is identified, the fault is determined to be three phase.

Differential Protection Disable

An opto-isolated input has been provided in the relaying system to disable Local and Remote differential protection when the input is energized by a dc voltage. This input has not effect on the optional distance backup system except where the setting BKUP is set to CTDD, then it will enable the distance protection. See backup distance protection below.

Optional Backup Functions

Distance Protection

The distance units in the REL 356 system are only operative when the communication channel is unsound, with exception of the out of step trip logic that is always active, if OST is set to WAYI or WAYO.

The backup distance relaying system includes two zones of a conventional non-pilot distance protection.

Line measurements techniques applies to each zone include:

- Single phase to ground fault detection
- Three phase fault detection
- Phase to phase fault detection
- Phase to phase to ground fault detection

Zone 2 and Zone 3 Distance Relaying

The optional backup system consists of two zones of distance protection for both phase and ground faults. Each zone consists of four distance units that are able to detect all fault types. The impedance units are three phase to ground units (AG, BG and CG) and a phase to phase unit.

The phase to ground units detect all single phase to ground faults (SLGF), three phase faults and some phase to phase to ground faults within its operating characteristic. The ZGF and ZFG (forward and reverse) settings apply to ground faults and the ZP (forward phase reach) settings apply to three phase faults.

The phase to phase unit detects all phase to phase faults and some phase to phase to ground faults. Since this unit is inherently directional only the forward reach, ZP, is used.

All phase to phase to ground faults are detected by the phase to ground units and/or the phase to phase units.

For indication of a phase distance trip the following conditions have to occur:

- For a three phase fault, the RT (inner) blinder and no OSB (out of step block) and the 3ΦF output of the phase selector and any of the phase ground units have to have operated.
- For a phase to phase fault, only the phase to phase unit needs to operate.
- For a phase to phase to ground fault, either the phase to phase unit or the phase to ground units have to operate.
- For a single phase to ground fault, any of the phase to ground units has to operate.

The phase fault detection is supervised by I_L, the low set phase overcurrent unit.

The phase to ground fault detection is supervised by I_{OM}, the medium set ground overcurrent unit and the ground directional unit FDOG.

The three phase fault detection is supervised by the phase directional units FDOP and the load restriction blinder, RT.

Each zone has its own timer to coordinate with relays further away for step distance relaying. Separate phase and ground timers are provided.

Single Phase to Ground

Single phase to ground fault detection is accomplished by 3 non-directional phase units, A, B and C. The operating and reference quantities are:

$$OP = V_{XG} - \left[I_X + \frac{Z_{0L} - Z_{1L}}{Z_{1L}} \cdot I_0 \right] \cdot Z_{FG}$$

$$REF = j\left[V_{XG} + \left(I_X + \frac{Z_{0L} - Z_{1L}}{Z_{1L}} \cdot I_0 \right) \cdot Z_{RG} \right]$$

V_{XG} = V_{AG}, V_{BG} or V_{CG}
I_X = I_A, I_B or I_C
I_0 = zero sequence relay current
Z_{1L}, Z_{0L} = positive and zero sequence line impedance
Z_{FG} = forward zone reach setting in secondary ohms
Z_{RG} = reverse reach setting in secondary ohms

The unit will produce an output when the operating quantity leads the reference quantity.

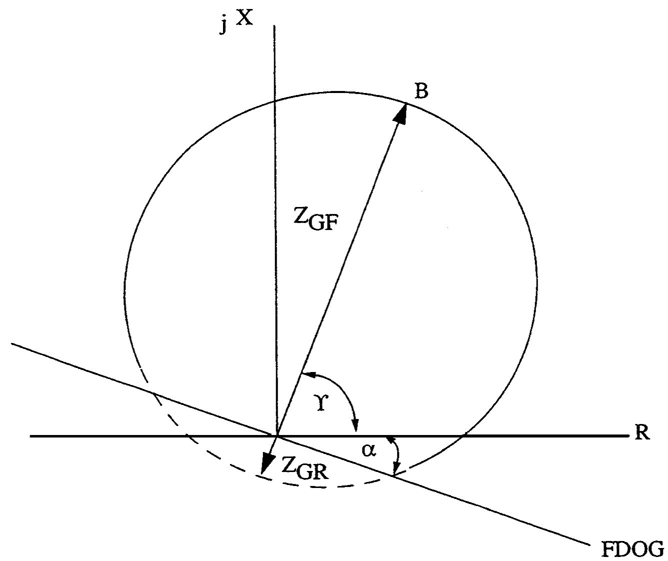


Figure 4-8. Mho Characteristic for Phase to Ground Faults

Three Phase

Three phase fault detection is accomplished by the logic operation of one of the three ground units plus the 3ΦF output from the phase selector. However, for a three phase fault condition, the computation of the distance units will be:

$OP = V_{XG} - I_X Z_P$

$REF = V_Q$

Where

V_Q = V_{CB} for phase A
V_{AC} for phase B
V_{BA} for phase C
V_{XG} = V_{AG}, V_{BG} or V_{CG}
I_X = I_A, I_B or I_C
Z_P = zone reach setting in secondary ohms

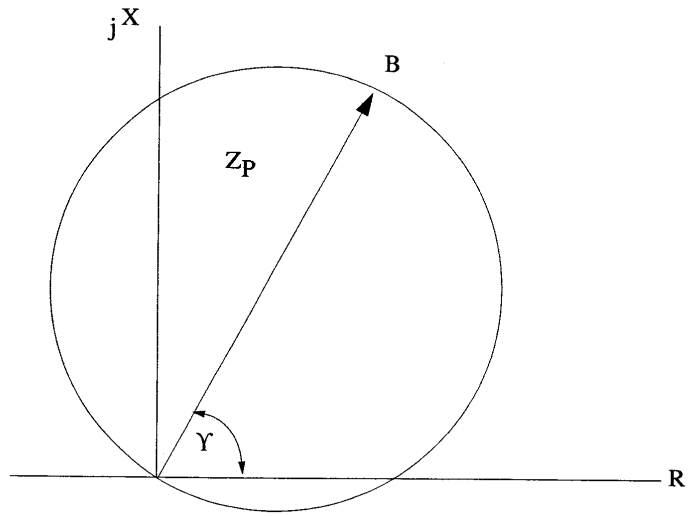


Figure 4-9. Mho Characteristic for Three Phase Faults

Phase to Phase

The phase to phase unit responds to all forward phase to phase faults, and some phase to phase to ground faults. The operating and reference quantities are:

$OP = (V_{AB} – I_{AB}Z_P)$

$REF = (V_{CB} – I_{CB}Z_P)$

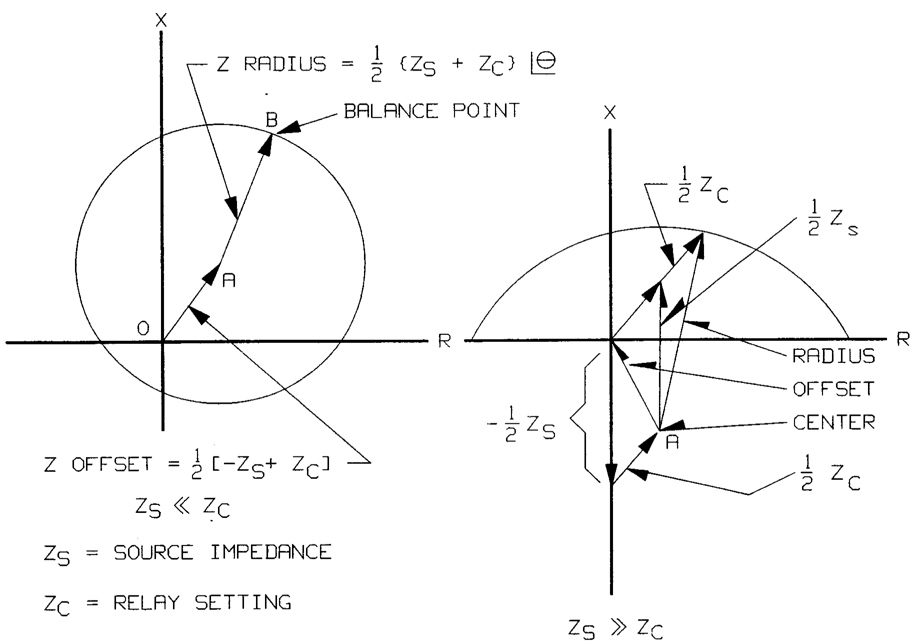


Figure 4-10. Mho Characteristic for Phase to Phase Faults

Backup Protection Disable

An opto isolated dc voltage input has been provided on the rear panel of the relay system to disable the distance backup system. This input has no effect on the primary current differential protection scheme.

Sensitive Directional Ground Overcurrent Unit

FDOG might be used for detecting high fround resistance faults that may not be detected by the ground distance units. The timer, TOG, may be blocked (no FDOG trip) or given a definite time delay for operation once FDOG has operated and IOM has picked up.

Out of Step Trip and Out of Step Block Logic

Out of step detection in REL 356 is achieved by the use of blinders. A two blinder scheme is used. The two blinders are called BO (outer blinder, setting RU) and BI (inner blinder, setting RT) and are parallel to the line impedance setting, i.e. they are tilted by the PANG (phase angle) setting.

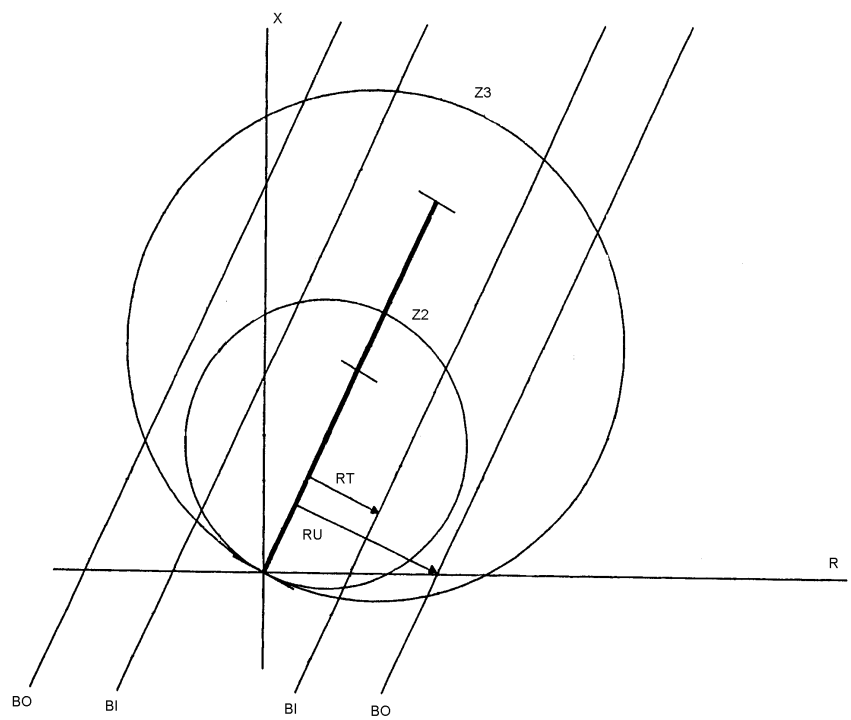


Figure 4-11. Blinders for the Out of Step Logic

The RU and RT settings are the distance perpendicular to the line positive sequence impedance that the blinders are displaced from the latter. The RT setting is also for load restriction and if any three phase fault occurs, the inner blinder, BI has to pickup for tripping in addition to the impedance Zone 2 or 3.

The duration of time it takes BI to operate after BO operates is the indication of an out of step condition. Timer OST1 controls this time. When the timer times out, and out of step condition has been detected. And OSB signal is immediately sent to block the operation of Zone 2 and/or Zone 3 distance units, as determined by the OSB setting (NONE/Z2/Z3/BOTH).

Timer OST2 timer the trip after an OST condition has been detected. When OST2 times out, a trip signal is sent if OST is set to trip on the way in, WAYI.

Timer OST3 starts timing after the inner blinder operates. If the timer has timed out, then tripping will be allowed immediately (with a 20 msec time delay) once the outer blinder resets and OST is set to trip on the way out, WAYO. Otherwise, OST has to time out first.

The OSOT timer is an out of step override timer that bypasses OSB after it has timed out and lets the relay trip.

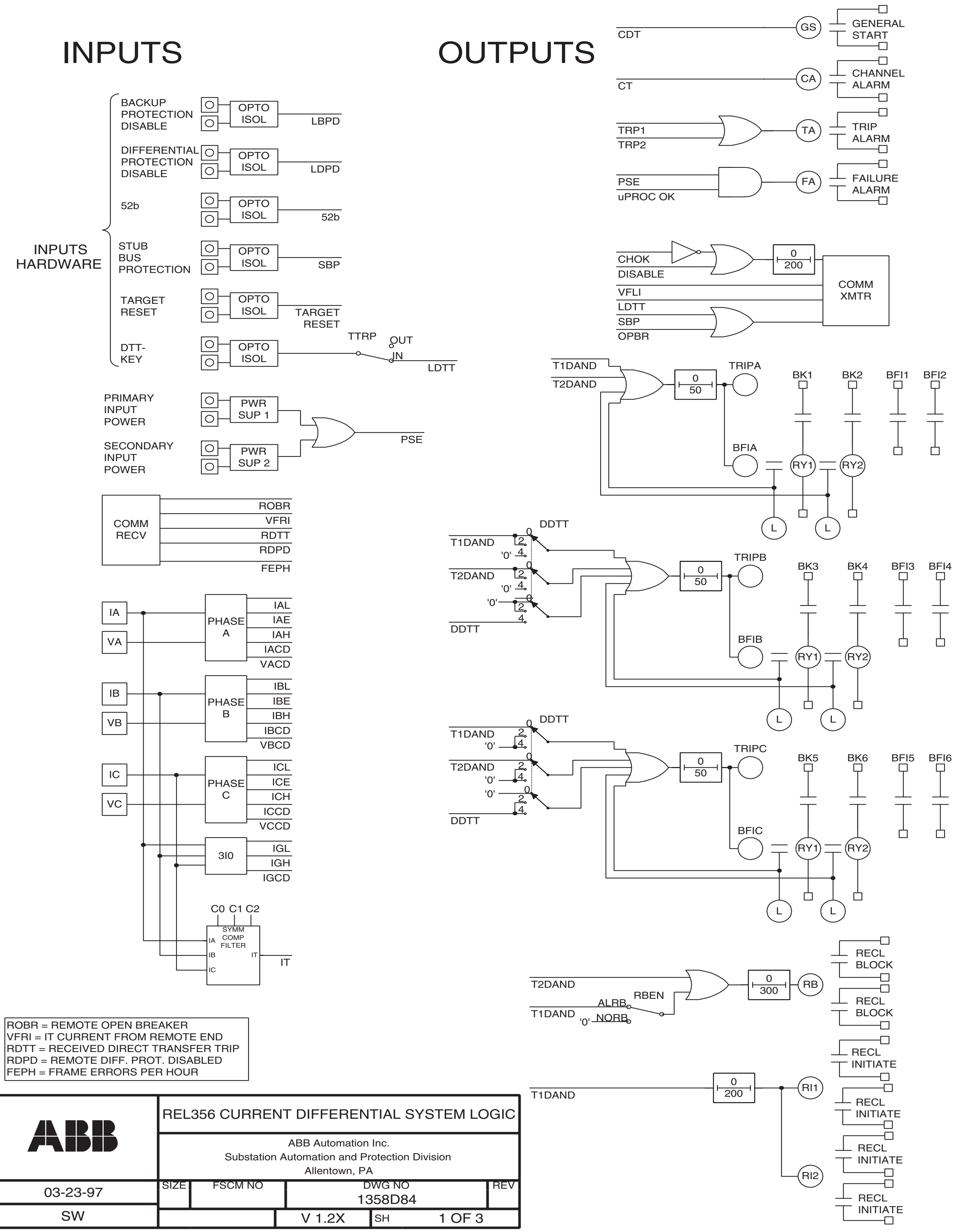
Loss of Potential (LOPB)

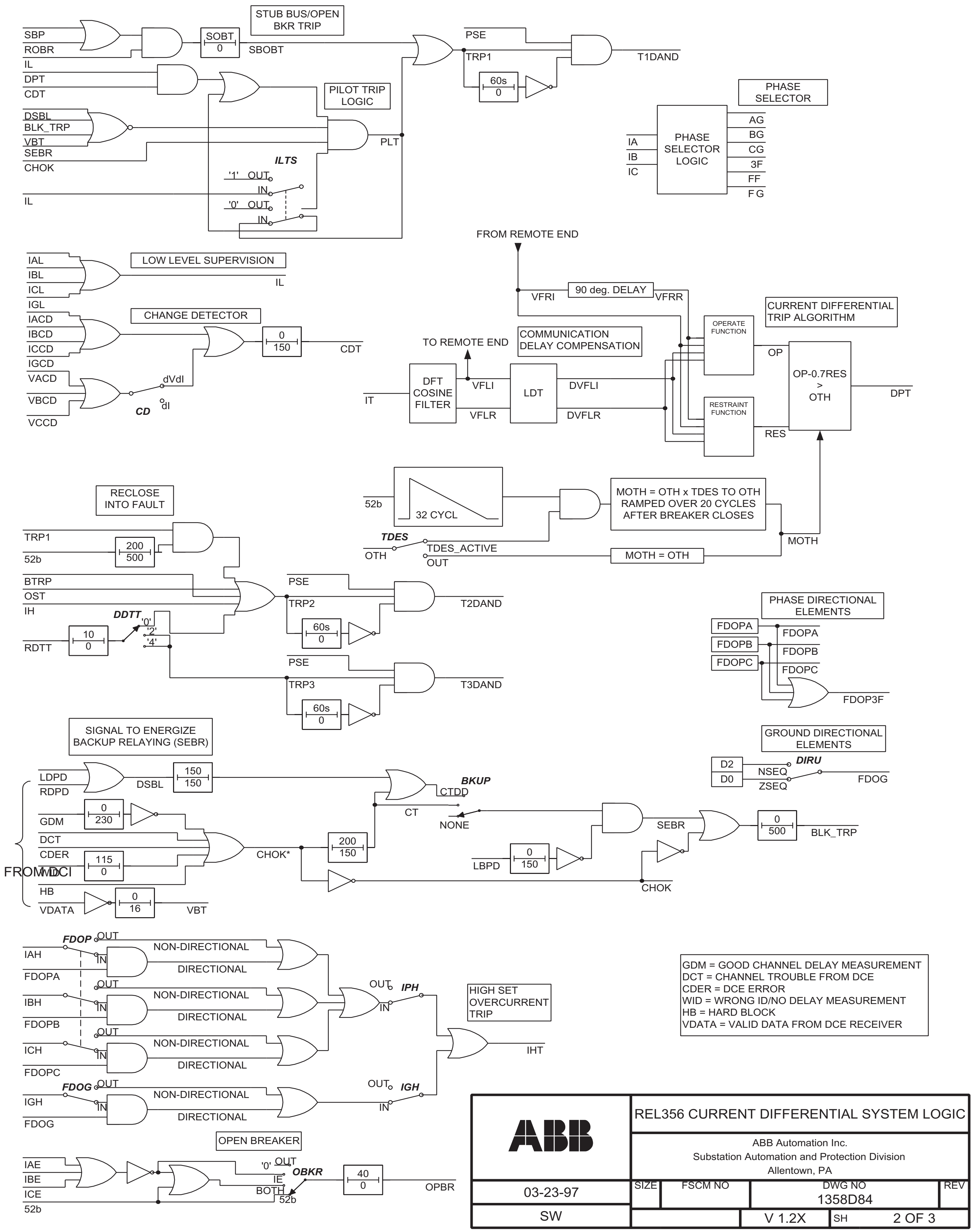
Loss of potential logic is used to supervise the distance measurements in the distance backup system. When this condition exists, all impedance measuring units well have their output blocked.

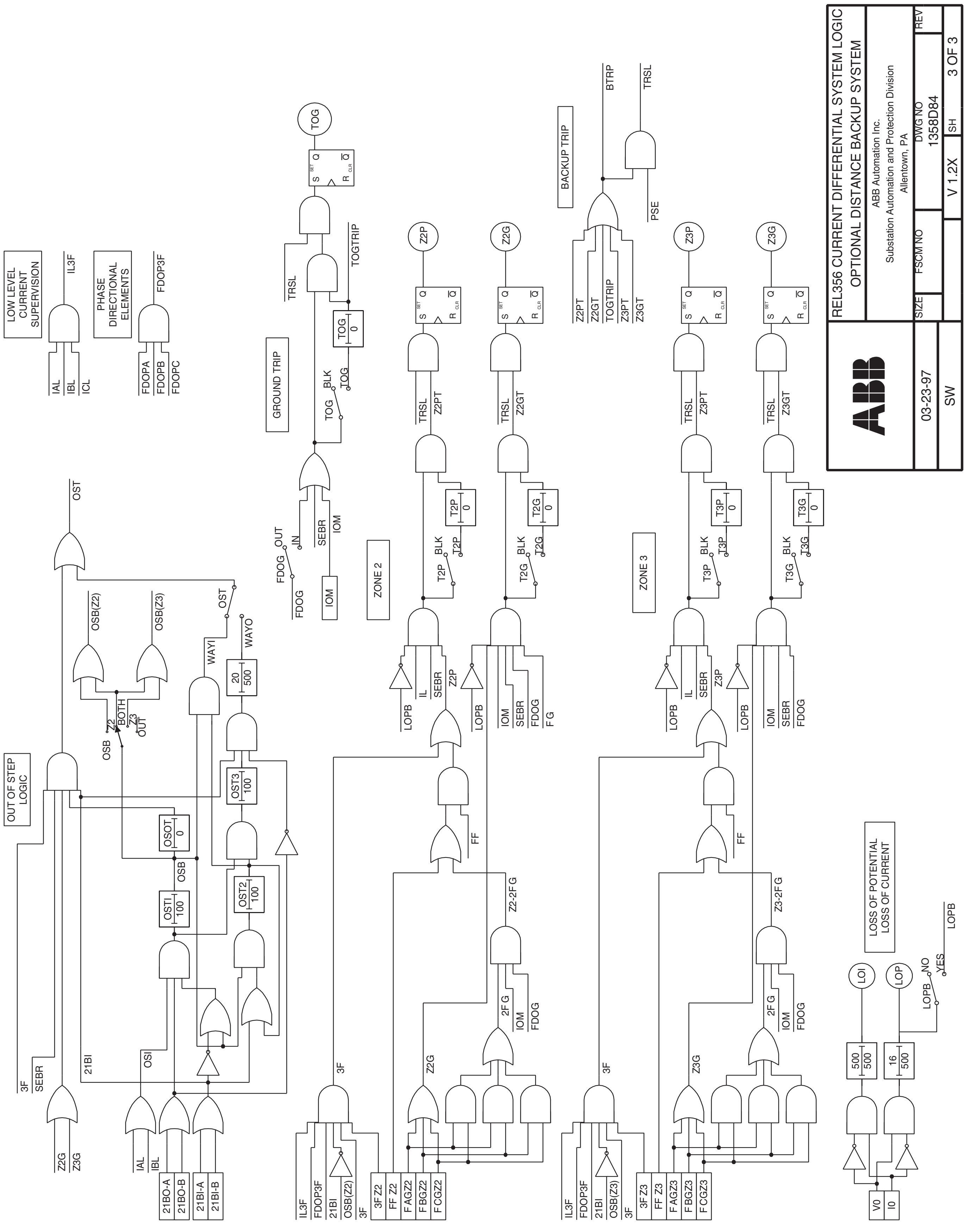
The [V0 x notI0] logic will detect one or two blown fuses, but will fail to detect the unlikely simultaneous failure of all three phase fuses. The operating threshold are 3V0 > 7 V and 3I0 < 0.5 A.

Loss of Current Monitoring

The loss of current logic will indicate loss of one or two current inputs.


INPUTS
OUTPUTS
INPUTS HARDWARE
BACKUP PROTECTION DISABLE
DIFFERENTIAL PROTECTION DISABLE
52b
STUB BUS PROTECTION
TARGET RESET
DTT-KEY
OPTO ISOL
LBPD
LDPD
52b
SBP
TARGET RESET
TTRP
OUT
IN
LDTT
PRIMARY INPUT POWER
SECONDARY INPUT POWER
PWR SUP 1
PWR SUP 2
PSE
COMM RECV
ROBR
VFRI
RDTT
RDPD
FEPH
IA
VA
IB
VB
IC
VC
PHASE A
PHASE B
PHASE C
IAL
IAE
IAH
IACD
VACD
IBL
IBE
IBH
IBCD
VBCD
ICL
ICE
ICH
ICCD
VCCD
3I0
IGL
IGH
IGCD
C0 C1 C2
SYMM COMP FILTER
IT
ROBR = REMOTE OPEN BREAKER
VFRI = IT CURRENT FROM REMOTE END
RDTT = RECEIVED DIRECT TRANSFER TRIP
RDPD = REMOTE DIFF. PROT. DISABLED
FEPH = FRAME ERRORS PER HOUR
CDT
GS
GENERAL START
CT
CA
CHANNEL ALARM
TRP1
TRP2
TA
TRIP ALARM
PSE
uPROC OK
FA
FAILURE ALARM
CHOK
DISABLE
VFLI
LDTT
SBP
OPBR
0
200
COMM XMTR
T1DAND
T2DAND
0
50
TRIPA
BFIA
BK1
BK2
BFI1
BFI2
RY1
RY2
L
DDTT
'0'
2
4
DDTT
TRIPB
BFIB
BK3
BK4
BFI3
BFI4
TRIPC
BFIC
BK5
BK6
BFI5
BFI6
T2DAND
T1DAND
RBEN
ALRB
NORB
0
300
RB
RECL BLOCK
RECL BLOCK
T1DAND
0
200
RI1
RI2
RECL INITIATE
RECL INITIATE
RECL INITIATE
RECL INITIATE
ABB
REL356 CURRENT DIFFERENTIAL SYSTEM LOGIC
ABB Automation Inc.
Substation Automation and Protection Division
Allentown, PA
03-23-97
SW
SIZE
FSCM NO
DWG NO
1358D84
REV
V 1.2X
SH
1 OF 3


STUB BUS/OPEN BKR TRIP
SBP
ROBR
IL
DPT
CDT
DSBL
BLK_TRP
VBT
SEBR
CHOK
IL
SOBT 0
SBOBT
PSE
TRP1
60s 0
T1DAND
PILOT TRIP LOGIC
PLT
ILTS
'1' OUT
IN
'0' OUT
IN
PHASE SELECTOR
IA
IB
IC
PHASE SELECTOR LOGIC
AG
BG
CG
3F
FF
FG
FROM REMOTE END
LOW LEVEL SUPERVISION
IAL
IBL
ICL
IGL
IL
CHANGE DETECTOR
IACD
IBCD
ICCD
IGCD
0 150
CDT
VACD
VBCD
VCCD
dVdI
dI
CD
VFRI
90 deg. DELAY
VFRR
CURRENT DIFFERENTIAL TRIP ALGORITHM
OPERATE FUNCTION
TO REMOTE END
COMMUNICATION DELAY COMPENSATION
OP
OP-0.7RES > OTH
DPT
IT
DFT COSINE FILTER
VFLI
VFLR
LDT
DVFLI
DVFLR
RESTRAINT FUNCTION
RES
RECLOSE INTO FAULT
52b
32 CYCL
MOTH = OTH x TDES TO OTH RAMPED OVER 20 CYCLES AFTER BREAKER CLOSES
TDES
OTH
TDES_ACTIVE
OUT
MOTH = OTH
MOTH
TRP1
52b
200 500
BTRP
OST
IH
PSE
TRP2
60s 0
T2DAND
DDTT
'0'
'2'
'4'
RDTT
10 0
PSE
TRP3
60s 0
T3DAND
PHASE DIRECTIONAL ELEMENTS
FDOPA
FDOPB
FDOPC
FDOP3F
GROUND DIRECTIONAL ELEMENTS
D2
D0
DIRU
NSEQ
ZSEQ
FDOG
SIGNAL TO ENERGIZE BACKUP RELAYING (SEBR)
LDPD
RDPD
DSBL
150 150
BKUP
CTDD
CT
NONE
GDM
0 230
DCT
CDER
115 0
WID
HB
VDATA
0 16
VBT
FROM DCI
CHOK*
200 150
LBPD
0 150
SEBR
0 500
BLK_TRP
CHOK
FDOP
OUT
IN
IAH
FDOPA
NON-DIRECTIONAL
DIRECTIONAL
IBH
FDOPB
ICH
FDOPC
IPH
HIGH SET OVERCURRENT TRIP
IHT
FDOG
IGH
FDOG
IGH
GDM = GOOD CHANNEL DELAY MEASUREMENT
DCT = CHANNEL TROUBLE FROM DCE
CDER = DCE ERROR
WID = WRONG ID/NO DELAY MEASUREMENT
HB = HARD BLOCK
VDATA = VALID DATA FROM DCE RECEIVER
OPEN BREAKER
IAE
IBE
ICE
52b
'0' OUT
IE
BOTH
52b
OBKR
40 0
OPBR
ABB
REL356 CURRENT DIFFERENTIAL SYSTEM LOGIC
ABB Automation Inc.
Substation Automation and Protection Division
Allentown, PA
03-23-97
SIZE
FSCM NO
DWG NO
1358D84
REV
SW
V 1.2X
SH
2 OF 3


REL356 CURRENT DIFFERENTIAL SYSTEM LOGIC
OPTIONAL DISTANCE BACKUP SYSTEM
ABB Automation Inc.
Substation Automation and Protection Division
Allentown, PA
SIZE
FSCM NO
DWG NO
1358D84
REV
03-23-97
SW
V 1.2X
SH
3 OF 3
LOW LEVEL CURRENT SUPERVISION
PHASE DIRECTIONAL ELEMENTS
OUT OF STEP LOGIC
GROUND TRIP
BACKUP TRIP
ZONE 2
ZONE 3
LOSS OF POTENTIAL LOSS OF CURRENT

Testing

Introduction

An acceptance test of the relay verifies the operation of four subsystems.

- Analog Input
- Contact Input
- Relay Output
- Communication

Additionally, Phase Comparison functional tests (simulating internal faults) are performed.

Equipment Needed

Qty.	Description
1	REL 356 Relay
1	Doble, Multi-amp or equivalent 3-Phase Test System

Test Setup

Current and Voltage Inputs

Connect the Relay Test System to REL 356 Relay.

Do not leave fault currents with trip relays energized for long periods of time.

Power

Connect the primary and secondary dc power. Consult the relay name-plate for rated voltage.

NOTE: Before turning on dc power check jumper positions on the Contact Input and Microprocessor modules.

Analog Input and Front Panel Metering Test

STEP 1

Turn on the primary and optional secondary dc input power if used. Make sure that the FREQ setting matches the line frequency, and the RP setting is set to “NO” (Readout in secondary values). The “Relay in Service” LED on the front panel should be lit.

STEP 2

NOTE: All ac voltage & current phase angles in this document are referenced to VA-G voltage (0 degrees). Positive angles LEAD VA-G, negative angles LAG VA-G.

Fault impedance angles (FANG) are displayed as positive for inductive faults and negative for capacitive.

Apply the following ac quantities to the relay:

V (volts) / Angle	I (amps) / Angle
V_a = 70 ∠0° V_b = 70 ∠-120° V_c = 70 ∠+120°	I_a = 10 ∠-45° I_b = 10 ∠-165° I_c = 10 ∠+75°

Using the procedure described in Section 2 “Metering Mode”, read the following parameters:

VAG	= 70	(VOLTS)
∠VAG	= 0	(DEG.)
VBG	= 70	(VOLTS)
∠VBG	= -120	(DEG.)
VCG	= 70	(VOLTS)
∠VCG	= +120	(DEG.)
IA	= 10.0	(AMPS)
∠IA	= -45	(DEG.)
IB	= 10.0	(AMPS)
∠IB	= -165	(DEG.)
IC	= 10.0	(AMPS)
∠IC	= +75	(DEG.)

Verify all metered values to be ± 5% on magnitude and ± 2 degrees on phase angle.

The metering accuracy is ±5 % or 0.1 A secondary current, whichever is the greatest. When reading off currents in primary values, the 0.1 A step error is multiplied by the CT ratio, CTR.

Contact Input Subsystem Test

Make sure that the input voltage selection jumpers on the contact input module correspond to the desired contact “wetting” voltage, as specified in Section 2 “Contact Input Module”.

Apply the rated voltage across the terminals shown in the table below:

Description	Terminal Block	Terminal +	Terminal -	HEX Digit
DTT Key	TB5	9	10	1
STUB BUS	TB5	11	12	2
Diff Protection Disable	TB5	13	14	4
Target RESET	TB5	7	8	8
52b	TB5	1	2	10
	TB5	3	4	20
	TB5	5	6	40

Using procedure described in Section 2 “Contact Input Test”,
verify proper response of the front panel display to contact input status changes.

Relay Output Subsystem Test

Using the procedure described in Section 2 “Relay Output Test”, verify operation of relay output subsystem. The relay contact wiring is shown on Block Diagram. Please note that the Failure Alarm Relay (TB4, 5-6) has a normally closed contact.

Communication Subsystem Test

9600 bps Audio Tone Option

Make the following test connection on the rear of the relay:

TB4-11 to TB4-13
TB4-12 to TB4-14

This connects the Communication XMT pair to RCV pair.

STEP 1

Make sure that 52b contact input (TB-5 terminals 1-2) is de-energized.

Change the “OPBR” setting to “52B” to disable the open breaker code transmission. Change the “ALDT” setting to “NO” since automatic delay time measurement is not possible with communication channel in a “Loopback” configuration. Turn the dc supply connected to the REL 356’s dc (Battery) inputs “off” for 1 second & then back “on” again to re-initialize the modem’s “ALDT” setting on power-up sequence.

Change the “XMTR” setting to “-1” dBm. Press the “DISPLAY SELECT” key on REL 356 front panel several times to select the “VOLTS/AMPS/ANGLE” mode. Use the FUNCTION RAISE/LOWER keys to display the “XMTR” monitoring function. The transmitter output level is measured via the “XMTR” monitoring function should read between +2 an -5 dBm.

Change the “XMTR” setting to “-11” dBm. The transmitter output level as measured via the “XMTR” monitoring function should read between -8 and -15 dBm.

Change the “XMTR” setting back to “-1” dBm. Use the “CHRX” monitoring function for indication of the Channel receiver line status, “CHRX” should read “NORM”.

STEP 2

Temporarily disconnect the XMT to RCV jumper TB4-11 to TB4-13. The display CHRX should change to CHTB (Channel Trouble).

STEP 3

Reconnect TB4-11 to TB4-13. The display CHRX should return to NORM after a short time delay.

56/64 KPBS Digital Communication Option

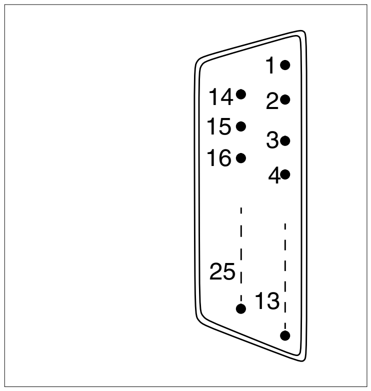
Make following Loopback connections on digital Communication Interface on the rear of the relay.

- Fiber Optic Version (820 nm)
  Using 50/100 mm or larger Multi Mode Cable with ST connectors at each end, connect Fiber Optic Transmitter to Fiber Optic Receiver.
- Fiber Optic Version (1300 nm)
  Using 9/125 mm, Single Mode Cable with ST connectors at each end, connect Fiber Optic Transmitter to Fiber Optic Receiver.

NOTE: For Medium and Long Reach Options (DCI assemblies G07 and G08) the Optical Power Attenuator must be used to limit the Receiver Input Power to maximum of -11 dBm to prevent receiver saturation.

- Direct Digital Version (RS422/RS530)
  Connect Pin 2 to Pin 3 (TXA to RXA)
  Connect Pin 14 to Pin 16 (TXB to RXB)

Pin placement on DB-25 connector used is as follows:



STEP 1

Set: UNID = 0
KBPS = 64
XCLK = INT
LPBK = YES

Make sure that 52b contact input (TB-5 terminals 1-2) is de-energized.

Change the “OPBR” setting to “52B” to disable the open breaker code transmission. Change the “ALDT” setting to “NO” since automatic delay time measurement is not possible with communication channel in a “Loopback” configuration. Turn the dc supply connected to the REL 350’s dc (Battery) inputs “off” for 1 second & then back “on” again to re-initialize the modem’s “ALDT” setting on power-up sequence.

The Monitoring Function CHRX (Received Line Status) should read NORM.

STEP 2

Disconnect above described Loopback Connections. The display CHRX should read CHTB (Channel Trouble).

STEP 3

Reconnect the Loopback Connection. The display CHRX should return to NORM after a short time delay.

Functional Tests - Current Differential System

The following section documents all the various types of test that can be done to verify operating characteristics of the REL 356 relay. If a simple single unit test needs to be performed, the “Singe Unit Loopback Test” will be adequeate for verification purposes. “Dual Units Back to Back Test” are included for lab type back to back verification tests and are not necessary for field installation type testing.

Single Unit Loopback Test - Internal Faults

STEP 1

Enter the following settings:

Freq	=	60	ALDT	=	NO	Z2GR	=	2.0
RP	=	NO	LDFL	=	LEAD	Z2GF	=	4.0
CTYP	=	5	LDT	=	*note*	Z2GR	=	2.0
CTR	=	5000	UNID	=	0	T2G	=	0.1
VTR	=	7000	KBPS	=	64	Z3P	=	7.0
OSC	=	TRIP	TTRP	=	OUT	T3P	=	1.0
FDAT	=	TRIP	XCLK	=	INT	Z3GF	=	7.0
TRGG	=	0.5	LPBK	=	YES	Z3GR	=	3.5
TRGP	=	0.5	XMTR	=		T3G	=	1.0
CD	=	DI	RLSD	=		OST	=	WAYO
DDTT	=	0	XPUD	=	1.500	OSB	=	BOTH
ILTS	=	OUT	DTYP	=	KM	RT	=	2.0
RBEN	=	NORD	PANG	=	75	RU	=	4.0
SOBT	=	16	GANG	=	75	OST1	=	2
OPBR	=	52b	ZR	=	3.0	OST2	=	3
IE	=	0.50	BKUP	=	OUT	OST3	=	3
IPL	=	0.50	LOPB	=	NO	OSOT	=	100
IPH	=	OUT	FDOP	=	IN	SETR	=	YES
IGL	=	0.50	FDOG	=	IN	TIME	=	CURRENT
IGH	=	OUT	DIRU	=	ZSEQ	YEAR	=	CURRENT
TDES	=	5.0	IOM	=	0.5	MNTH	=	CURRENT
OTH	=	0.50	TOG	=	BLK	DAY	=	CURRENT
C0	=	0.0	Z2P	=	4.0	HOUR	=	CURRENT
C1	=	0.10	T2P	=	0.1	MIN	=	CURRENT
C2	=	0.70	Z2GF	=	4.0			

NOTE Set the LDT time to 10.8 msec. for 9600 bps communication channel option A, to 19.3 ms for 9600 bps communication channel option T or 1.3 msec. for 56/64 kbs communication channel.

Modem version A or T is shown in the style number.

STEP 2

Power down the unit.

STEP 3

Make the connections on the reat of the REL 356 that correspond to the type of communication channel that you have as specified in “Communication Subsystem Test” above.

STEP 4

Remove the inner chassis.

a) Note factory settings of jumpers on the Opto-isolated Input module.

b) Make sure that the jumpers are set for the desired battery voltage.

STEP 5

Insert and secure the inner chassis. Power the unit up.

STEP 6

Verify relays response to all types of relay faults by applying the test quantities per the following table. Note: apply all of the fault currents suddenly. Adjust value up or down to find the point where relay just trips. Three different cases are presented, only one needs to be performed.

REL 356 Test Tables V 1.20

The measuring error is 10% of calculated pick-up value or 0.250 A, whichever is greater.

Test Conditions: Case 1 - C0=0, C1=0.1, C2=0.7, OTH=0.50 (OTH=0.70 for V1.15 or lower)

Test Table 1

Fault Type	I Amps ∠ Angle	Calculated Pickup Value	Current Pickup range
AG	I_A = 4.17∠ 0 I_B = 0 ∠ -120 I_C = 0 ∠ -240	4.17A	3.15 – 4.59A
BG	I_A = 0 ∠ 0 I_B = 3.31∠ -120 I_C = 0 ∠ -240	3.31A	2.98 – 3.64A
CG	I_A = 0 ∠ 0 I_B = 0 ∠ -120 I_C = 3.31∠ -240	3.31A	2.98 – 3.64A
AB	I_A = 2.20∠ 0 I_B = 2.20∠ -180 I_C = 0 ∠ -240	2.20A	1.95 – 2.45A
BC	I_A = 0 ∠ 0 I_B = 1.80∠ -120 I_C = 1.80∠ -300	1.80A	1.55 – 2.05A
CA	I_A = 2.20∠ -60 I_B = 0 ∠ -120 I_C = 2.20∠ -240	2.20A	1.95 – 2.45A
ABC	I_A = 8.33∠ 0 I_B = 8.33 ∠ -120 I_C = 8.33 ∠ -240	8.33A	7.50 – 9.16

Test Conditions: Case 2 - C0=0, C1=0.1, C2=0.7, OTH=0.50 (OTH=0.70 for V1.15 or lower)

Test Table 2

Fault Type	I Amps ∠ Angle	Calculated Pickup Value	Current Pickup range
AG	$I_A = 1.56 \angle 0$ $I_B = 0 \angle -120$ $I_C = 0 \angle -240$	1.56A	1.31 – 1.81A
BG	$I_A = 0 \angle 0$ $I_B = 2.54 \angle -120$ $I_C = 0 \angle -240$	2.54A	2.28 – 2.79A
CG	$I_A = 0 \angle 0$ $I_B = 0 \angle -120$ $I_C = 2.54 \angle -240$	2.54A	2.28 – 2.79A
AB	$I_A = 2.20 \angle 0$ $I_B = 2.20 \angle -180$ $I_C = 0 \angle -240$	2.20A	1.95 – 2.45A
BC	$I_A = 0 \angle 0$ $I_B = 1.80 \angle -120$ $I_C = 1.80 \angle -300$	1.80A	1.55 – 2.05A
CA	$I_A = 2.20 \angle -60$ $I_B = 0 \angle -120$ $I_C = 2.20 \angle -240$	2.20A	1.95 – 2.45A
ABC	$I_A = 8.33 \angle 0$ $I_B = 8.33 \angle -120$ $I_C = 8.33 \angle -240$	8.83A	7.50 – 9.16A

Test Conditions: Case 3 - C0=2.5, C1=0.1, C2=0.7, OTH=0.50 (OTH=0.70 for V1.15 or lower)

Test Table 3

Fault Type	I Amps ∠ Angle	Calculated Pickup Value	Current Pickup range
AG	$I_A = 0.81 \angle 0$ $I_B = 0 \angle -120$ $I_C = 0 \angle -240$	0.81A	0.56 – 1.06A
BG	$I_A = 0 \angle 0$ $I_B = 1.08 \angle -120$ $I_C = 0 \angle -240$	1.08A	0.83 – 1.33A
CG	$I_A = 0 \angle 0$ $I_B = 0 \angle -120$ $I_C = 1.08 \angle -240$	1.08A	0.83 – 1.33A
AB	$I_A = 2.20 \angle 0$ $I_B = 2.20 \angle -180$ $I_C = 0 \angle -240$	2.20A	1.95 – 2.45A
BC	$I_A = 0 \angle 0$ $I_B = 1.80 \angle -120$ $I_C = 1.80 \angle -300$	1.80A	1.55 – 2.05A
CA	$I_A = 2.20 \angle -60$ $I_B = 0 \angle -120$ $I_C = 2.20 \angle -240$	2.20A	1.95 – 2.45A
ABC	$I_A = 8.33 \angle 0$ $I_B = 8.33 \angle -120$ $I_C = 8.33 \angle -240$	8.33A	7.50 – 9.16A

Single Unit Loopback Test - External Faults

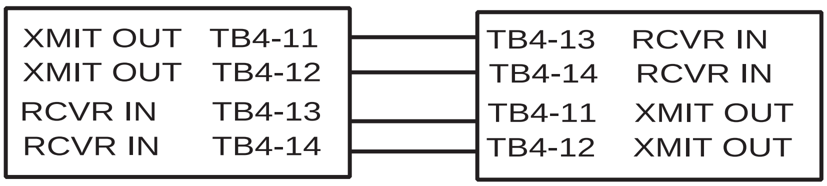
No external fault testing is possible with a single unit since there is no way to invert the signal coming into the receiver to simulate an external fault or load current.

Dual Unit Back to Back Test - External Faults

STEP 1

To test the relays back to back several connections need to be made that are dependent on the communication channel used. Make the connections shown for your option.

9600 Audio Tone Option



56/64 kbps Direct Digital Option

The Direct Digital option requires a DB-25 to DB-25 cable hooked between Unit #1's DCI assembly and Unit #2's DCI. Connectors on the DCI are male gender so the cable needs to be female gender on both ends. Connections are as follows:

Pin 2 tp pin 3 (TXA to RXA)	Pin 3 to pin 2 (RXA to TXA)
Pin 14 to pin 16 (TXB to RXB)	Pin 16 to pin 14 (RXB to TXB)

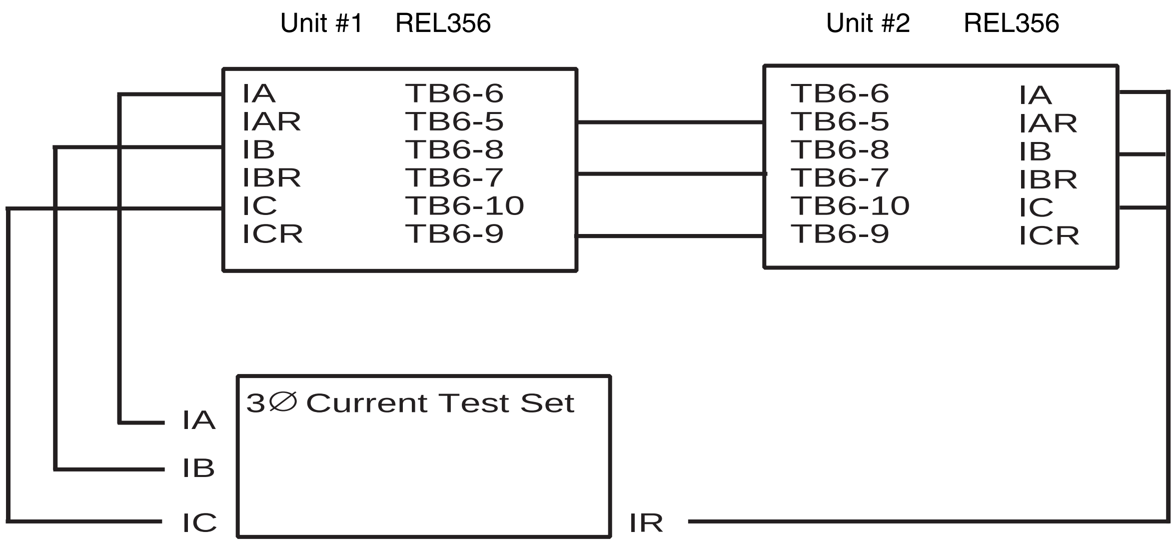
56/64 kbps Fiber Optic Option

The Fiber optic option requires a fiber optic cable with an in-line attenuator be placed between the XMIT connector of Unit #1's DCI to the RCVR connector of Unit #2's DCI. The same connection needs to be made from Unit #2 to Unit #1. Set the in-line attenuators for a received level of -26dbm.

With any one fo the three communciations options chosen a few settings need to be changed before back to back testing can be performed.

Both Units	Unit #1	Unit #2
LPBK = NO ALDT = YES	UNID = 0	UNID = 1

External Fault(s) - Current connections



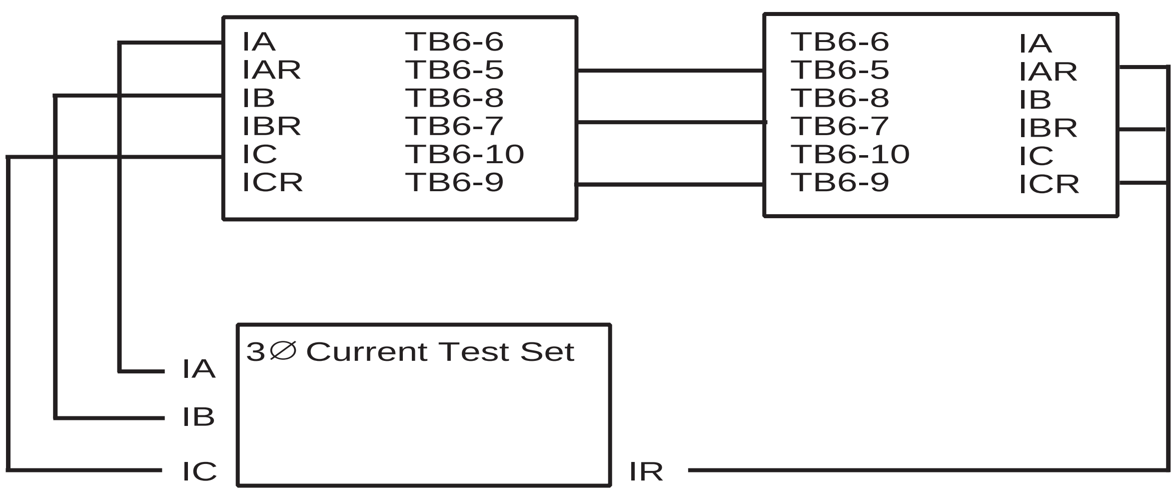
STEP 2

Apply fault currents greater than those shown in Tables 5-1, 5-2 & 5-3 and verify that the relay does not trip on external faults.

Dual Unit Back to Back Test - Internal Faults

To simulate an internal fault, reverse the CT polarity on unit number 2. Test the relay per Tables 5-1, 5-2 & 5-3 by applying faults and verifying that the relay trips.

Internal Fault(s) - Current connections



Functional Tests – Optional Backup System

For units that include the stepped distance backup system the following tests will functionally test all the distance units provided.

Disconnect the loopback connections as described in step 2 on page 5-3, and make sure the front panel display shows CHTB as the signal received. A channel trouble enables the optional backup distance system to operate.

The following inital settings should be used:

PANG	=	75	Z2P	=	4.5
GANG	=	75	T2P	=	0.1
ZR	=	3.0	Z2GF	=	4.5
BKUP	=	IN	Z2GR	=	0.01
LOPB	=	NO	T2G	=	0.1
FDOP	=	IN	Z3P	=	7.0
FDOG	=	IN	T3P	=	BLK
DIRU	=	ZSEQ	Z3GF	=	7.0
IOM	=	0.5	Z3GR	=	0.01
TOG	=	BLK	T3G	=	BLK

Phase to Ground Units

To calculate the fault impedance seen by the relay system the following formula applies:

$$Z\text{ fault} = \frac{Vxg}{I_{Xg}\left|\dfrac{2 + ZR\angle\text{GANG-PANG}}{3}\right|}$$

Where x is either phase a,b, or c.

The above formula is rigorous and general. However, if a quick approximation of the minimum trip current required at different angles (θ) is desired, the following formula applies:

$$Ixg = \frac{V_{XG}}{Z2GF * \cos(PANG - \theta)\ [1 + (\text{ZR} - 1)/3]}$$

where x is either phase a, b, or c.

Zone 2 Phase-Ground Element Without Reverse Reach

1. Forward Internal Faults

For forward Zone 2 Phase-Ground Internal Faults use Table 5-1 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. Compare the relay system trip target data to the applied fault values. The target data should be within +/- 10% on magnitude and +/- 3 degrees on phase. Trip time should fall within 100-132 milliseconds.

Table 5-1. Zone 2 Phase-Ground Forward Internal Faults: Z2GF = 4.5 Ohms Z2GR = 0.01 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AG at MTA 90% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 4.4 ∠ -75 (285) Ib = 0 Ic = 0	4.05 ∠ 75	Z2T Trip Fault type AG Z2G Unit Trip time 100-132 ms
AG at MTA –45° 90% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 6.23 ∠ -30 (330) Ib = 0 Ic = 0	2.86 ∠ 30	Z2T Trip Fault type AG Z2G Unit Trip time 100-132 ms
AG at MTA +45° 90% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 6.23 ∠ -120 (240) Ib = 0 Ic = 0	2.86 ∠ 120	Z2T Trip Fault type AG Z2G Unit Trip time 100-132 ms
BG at MTA 90% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 4.4 ∠ -195 (165) Ic = 0	4.05 ∠ 75	Z2T Trip Fault type BG Z2G Unit Trip time 100-132 ms
BG at MTA –45° 90% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 6.23 ∠ -150 (210) Ic = 0	2.86 ∠ 30	Z2T Trip Fault type BG Z2G Unit Trip time 100-132 ms
BG at MTA +45° 90% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 6.23 ∠ -240 (120) Ic = 0	2.86 ∠ 120	Z2T Trip Fault type BG Z2G Unit Trip time 100-132 ms
CG at MTA 90% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 4.4 ∠ -315 (45)	4.05 ∠ 75	Z2T Trip Fault type CG Z2G Unit Trip time 100-132 ms
CG at MTA –45° 90% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 6.23 ∠ -270 (90)	2.86 ∠ 30	Z2T Trip Fault type CG Z2G Unit Trip time 100-132 ms
CG at MTA +45° 90% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 6.23 ∠ 0	2.86 ∠ 120	Z2T Trip Fault type CG Z2G Unit Trip time 100-132 ms

2. Forward External Faults

For forward Zone 2 Phase-Ground External faults use the Table 5-2 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. In each case the relay system should not trip as these faults are beyond the reach of the Zone 2 ground units.

Table 5-2. Zone 2 Phase-Ground Forward External Faults: Z2GF = 4.5 Ohms Z2GR = 0.01 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AG at MTA 110% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 3.6 ∠ -75 (285) Ib = 0 Ic = 0	4.95 ∠ 75	No Trips
AG at MTA –45° 110% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 5.09 ∠ -30 (330) Ib = 0 Ic = 0	3.5 ∠ 30	No Trips
AG at MTA +45° 110% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 5.09 ∠ -120 (240) Ib = 0 Ic = 0	3.5 ∠ 120	No Trips
BG at MTA 110% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 5.09 ∠ -195 (165) Ic = 0	4.95 ∠ 75	No Trips
BG at MTA –45° 110% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 5.09 ∠ -150 (210) Ic = 0	3.5 ∠ 30	No Trips
BG at MTA +45° 110% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 5.09 ∠ -240 (120) Ic = 0	3.5 ∠ 120	No Trips
CG at MTA 110% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 3.6 ∠ -315 (45)	4.95 ∠ 75	No Trips
CG at MTA –45° 110% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 5.09 ∠ -270 (90)	3.5 ∠ 30	No Trips
CG at MTA +45° 110% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 5.09 ∠ 0	3.5 ∠ 120	No Trips

3. Reverse External Faults

For reverse Zone 2 Phase-Ground External faults use the Table 5-3 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. In each case the relay system should not trip as these faults are reverse direction fron the GANG setting.

Table 5-3. Zone 2 Phase-Ground Reverse External Faults: Z2GF = 4.5 Ohms Z2GR = 0.01 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AG at MTA -180˚ 50% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 8 ∠ -255 (105) Ib = 0 Ic = 0	2.25 ∠ -105	No trips
BG at MTA –180˚ 50% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 8 ∠ -15 (345) Ic = 0	2.25 ∠ -105	No trips
CG at MTA –180˚ 50% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 8 ∠ -135 (225)	2.25 ∠ -105	No trips

Zone 2 Phase-Ground Element With Reverse Reach

NOTE: Change the “Z2GR” distance setting to 4.5 ohms before applying the following faults in Tables 5-4, 5-5, and 5-6 to the relay system.

4. Forward Internal Faults

For forward Zone 2 Phase-Ground Internal faults use the following Table 5-4 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. Compare the relay system trip target data to the applied fault values. The target data should be within +/- 10% on magnitude and +/- 3 degrees on phase. Trip time should fall within 100-132 milliseconds.

Table 5-4. Zone 2 Phase-Ground Forward Internal Faults: Z2GF = 4.5 Ohms Z2GR = 4.5 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AG at MTA 90% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 4.4 ∠ -75 (285) Ib = 0 Ic = 0	4.05 ∠ 75	Z2T Trip Fault type AG Z2G Unit Trip time 100-132 ms
AG at MTA –45° 90% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 4.4 ∠ -30 (330) Ib = 0 Ic = 0	4.05 ∠ 30	Z2T Trip Fault type BG Z2G Unit Trip time 100-132 ms
AG at MTA +45° 90% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 4.4 ∠ -120 (240) Ib = 0 Ic = 0	4.05 ∠ 120	Z2T Trip Fault type CG Z2G Unit Trip time 100-132 ms
BG at MTA 90% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 4.4 ∠ -195 (165) Ic = 0	4.05 ∠ 75	Z2T Trip Fault type BG Z2G Unit Trip time 100-132 ms
BG at MTA –45° 90% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 4.4 ∠ -150 (210) Ic = 0	4.05 ∠ 30	Z2T Trip Fault type BG Z2G Unit Trip time 100-132 ms
BG at MTA +45° 90% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 4.4 ∠ -240 (120) Ic = 0	4.05 ∠ 120	Z2T Trip Fault type BG Z2G Unit Trip time 100-132 ms
CG at MTA 90% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 4.4 ∠ -315 (45)	4.05 ∠ 75	Z2T Trip Fault type CG Z2G Unit Trip time 100-132 ms
CG at MTA –45° 90% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 4.4 ∠ -270 (90)	4.05 ∠ 30	Z2T Trip Fault type CG Z2G Unit Trip time 100-132 ms
CG at MTA +45° 90% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 4.4 ∠ 0	4.05 ∠ 120	Z2T Trip Fault type CG Z2G Unit Trip time 100-132 ms
The Zone 2 Ground unit (Z2G) should operate on all faults listed above. Trip time should be within times shown.			

5. Forward External Faults

For forward Zone 2 Phase-Ground External faults use the Table 5-5 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. The relay system should not trip as these faults are beyond the reach of the Zone 2 ground units.

Table 5-5. Zone 2 Phase-Ground Forward External Faults: Z2GF = 4.5 Ohms Z2GR = 4.5 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AG at MTA 110% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 3.6 ∠ -75 (285) Ib = 0 Ic = 0	4.95 ∠ 75	No trips
AG at MTA –45° 110% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 3.6 ∠ -30 (330) Ib = 0 Ic = 0	4.95 ∠ 30	No trips
AG at MTA +45° 110% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 3.6 ∠ -120 (240) Ib = 0 Ic = 0	4.95 ∠ 120	No trips
BG at MTA 110% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 3.6 ∠ -195 (165) Ic = 0	4.95 ∠ 75	No trips
BG at MTA –45° 110% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 3.6 ∠ -150 (210) Ic = 0	4.95 ∠ 30	No trips
BG at MTA +45° 110% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 3.6 ∠ -240 (120) Ic = 0	4.95 ∠ 120	No trips
CG at MTA 110% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 3.6 ∠ -315 (45)	4.95 ∠ 75	No trips
CG at MTA –45° 110% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 3.6 ∠ -270 (90)	4.95 ∠ 30	No trips
CG at MTA +45° 110% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 3.6 ∠ 0	4.95 ∠ 120	No trips

6. Reverse External Faults

For reverse Zone 2 Phase-Ground External faults use the Table 5-6 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. In each case the relay system should not trip as these faults are reverse direction from the GANG setting.

Table 5-6. Zone 2 Phase-Ground Reverse External Faults: Z2GF = 4.5 Ohms Z2GR = 4.5 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AG at MTA -180° 50% of reach fault			
Va = 30 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 8 ∠ -255 (105) Ib = 0 Ic = 0	2.25 ∠ -105	No trips
BG at MTA –180° 50% of reach fault			
Va = 69 ∠ 0 Vb = 30 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 8 ∠ -15 (345) Ic = 0	2.25 ∠ -105	No trips
CG at MTA –180° 50% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 30 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 8 ∠ -135 (225)	2.25 ∠ -105	No trips

Zone 3 Phase-Ground Element Without Reverse Reach

NOTE: Change the "T3G" timer setting to 1.0 seconds before applying the faults in Tables 5-7, 5-8, and 5-9.

7. Forward Internal Faults

For forward Zone 3 Phase-Ground Internal faults use the Table 5-7 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. Compare the relay system trip target data to the applied fault values. The target data should be within +/- 10% magnitude and +/- 3 degrees on phase. Trip time should fall within 1.00 - 1.05 seconds.

Table 5-7. Zone 3 Phase-Ground Forward Internal Faults: Z2GF = 7.0 Ohms Z2GR = 0.01 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AG at MTA 90% of reach fault			
Va = 25 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 2.38 ∠ -75 (285) Ib = 0 Ic = 0	6.3 ∠ 75	Z3T Trip Fault trip AG Z3G Unit Trip time 1.0-1.05 S
BG at MTA 90% of reach fault			
Va = 69 ∠ 0 Vb = 25 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 2.38 ∠ -195 (165) Ic = 0	6.3 ∠ 75	Z3T Trip Fault trip BG Z3G Unit Trip time 1.0-1.05 S
CG at MTA 90% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 25 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 2.38 ∠ -315 (45)	6.3 ∠ 75	Z3T Trip Fault trip CG Z3G Unit Trip time 1.0-1.05 S

8. Forward External Faults

For forward Zone 2 Phase-Ground External faults use the Table 5-8 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. In each case the relay system should not trip as these faults are beyond the reach of the Zone 3 ground units.

Table 5-8. Zone 3 Phase-Ground Forward External Faults: Z2GF = 7.0 Ohms Z2GR = 0.01 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AG at MTA 110% of reach fault			
Va = 25 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 1.95 ∠ -75 (285) Ib = 0 Ic = 0	7.7 ∠ 75	No trips
BG at MTA 110% of reach fault			
Va = 69 ∠ 0 Vb = 25 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 1.95 ∠ -195 (165) Ic = 0	7.7 ∠ 75	No trips
CG at MTA 110% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 25 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 1.95 ∠ -315 (45)	7.7 ∠ 75	No trips

9. Reverse External Faults

For reverse Zone 3 Phase-Ground External faults use the Table 5-9 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. In each case the relay system should not trip as these faults are reverse direction fron the GANG setting.

Table 5-9. Zone 3 Phase-Ground Reverse External Faults: Z2GF = 7.0 Ohms Z2GR = 0.01 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AG at MTA -180° 50% of reach fault			
Va = 25 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 4.29 ∠ -255 (105) Ib = 0 Ic = 0	3.5 ∠ -105	No trips
BG at MTA –180° 50% of reach fault			
Va = 69 ∠ 0 Vb = 25 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 0 Ib = 4.29 ∠ -15 (345) Ic = 0	3.5 ∠ -105	No trips
CG at MTA –180° 50% of reach fault			
Va = 69 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 25 ∠ -240 (120)	Ia = 0 Ib = 0 Ic = 4.29 ∠ -135 (225)	3.5 ∠ -105	No trips

Phase to Phase Units

To calculate the fault impedance seen by the relay system the following formula applies:

$$Z\ \text{fault} = \frac{Vxy}{Ix - Iy}$$

where x is either phase a, b, or c and y is the next lagging phase.

The above formula is rigorous and general. However, if a quick approximation of the minimum trip current required at different angles (θ) is desired, the following formula applies:

$$Ixg = \frac{V_{XG}}{Z2P\ (\cos\,(PANG - \theta))}$$

where x is either phase a, b, or c and y is the next lagging phase.

Zone 2 Phase-Phase Element

10. Forward Internal Faults

For forward Zone 2 Phase-Phase Internal faults use the Table 5-10 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. Compare the relay system trip target data to the applied fault values. The target data should be within +/- 10% on magnitude and +/- 3 degrees on phase. Trip time should fall within 100-132 milliseconds.

Table 5-10. Zone 2 Phase-Phase Forward Internal Faults: Z2P = 4.5 Ohms

Volts	∠	Angle	I Amps	∠	Angle	Fault Z Ohms	∠	Angle	Relay System Operation
AB at MTA 90% of reach fault									
Va = 17.3 Vb = 17.3 Vc = 69	∠ ∠ ∠	0 -120 (240) -240 (120)	Ia = 3.7 Ib = 3.7 Ic = 0	∠ ∠	-75 (285) -225 (135)	4.05	∠	75	Z2T Trip Fault trip AB Z2G Unit Trip time 100-132 mS
BC at MTA 90% of reach fault									
Va = 69 Vb = 1.73 Vc = 1.73	∠ ∠ ∠	0 -120 (240) -240 (120)	Ia = 0 Ib = 3.7 Ic = 3.7	∠ ∠	-165 (195) -345 (15)	4.05	∠	75	Z2T Trip Fault trip BC Z2G Unit Trip time 100-132 mS
CA at MTA 90% of reach fault									
Va = 17.3 Vb = 69 Vc = 17.3	∠ ∠ ∠	0 -120 (240) -240 (120)	Ia = 3.7 Ib = 0 Ic = 3.7	∠ ∠	-105 (255) -285 (75)	4.05	∠	75	Z2T Trip Fault trip CA Z2G Unit Trip time 100-132 mS

11. Forward External Faults

For forward Zone 2 Phase-Phase External faults use the Table 5-11 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. In each case the relay system should not trip as these faults are beyond the reach of the Zone 2 ground units.

Table 5-11. Zone 2 Phase-Phase Forward External Faults: Z2P = 4.5 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AB at MTA 110% of reach fault			
Va = 17.3 ∠ 0 Vb = 17.3 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 3.03 ∠ -45 (315) Ib = 3.03 ∠ -225 (135) Ic = 0	4.95 ∠ 75	No Trips
BC at MTA 110% of reach fault			
Va = 69 ∠ 0 Vb = 1.73 ∠ -120 (240) Vc = 1.73 ∠ -240 (120)	Ia = 0 Ib = 3.03 ∠ -165 (195) Ic = 3.03 ∠ -345 (15)	4.95 ∠ 75	No Trips
CA at MTA 110% of reach fault			
Va = 17.3 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 17.3 ∠ -240 (120)	Ia = 3.03 ∠ -105 (255) Ib = 0 Ic = 3.03 ∠ -285 (75)	4.95 ∠ 75	No Trips

12. Reverse External Faults

For reverse Zone 2 Phase-Phase External faults use the Table 5-12 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. In each case the relay system should not trip as these faults are reverse direction from the PANG setting.

Table 5-12. Zone 2 Phase-Phase Reverse External Faults: Z2P = 4.5 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AB at MTA -180° 50% of reach fault			
Va = 17.3 ∠ 0 Vb = 17.3 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 6.66 ∠ -225 (135) Ib = 6.66 ∠ -45 (315) Ic = 0	2.25 ∠ -105	No Trips
BC at MTA -180° 50% of reach fault			
Va = 69 ∠ 0 Vb = 1.73 ∠ -120 (240) Vc = 1.73 ∠ -240 (120)	Ia = 0 Ib = 6.66 ∠ -345 (15) Ic = 6.66 ∠ -165 (195)	2.25 ∠ -105	No Trips
CA at MTA -180° 50% of reach fault			
Va = 17.3 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 17.3 ∠ -240 (120)	Ia = 6.66 ∠ -285 (75) Ib = 0 Ic = 6.66 ∠ -105 (255)	2.25 ∠ -105	No Trips

Zone 3 Phase-Phase Element

NOTE: Change the “T3P” timer setting to 1.0 seconds before applying the faults in Tables 5-13, 5-14, and 5-15.

13. Forward Internal Faults

For forward Zone 3 Phase-Ground Internal faults use the Table 5-13 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. Compare the relay system trip target data to the applied fault values. The target data should be within +/- 10% magnitude and +/- 3 degrees on phase. Trip time should fall within 1.00 - 1.05 seconds.

Table 5-13. Zone 3 Phase-Phase Forward Internal Faults: Z3P = 7.0 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AB at MTA 90% of reach fault			
Va = 17.3 ∠ 0 Vb = 17.3 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 2.38 ∠ -45 (315) Ib = 2.38 ∠ -225 (135) Ic = 0	6.3 ∠ 75	Z3T Trip Fault type AB Z3P Unit Trip time 1.0-1.05 mS
BC at MTA 90% of reach fault			
Va = 69 ∠ 0 Vb = 1.73 ∠ -120 (240) Vc = 1.73 ∠ -240 (120)	Ia = 0 Ib = 2.38 ∠ -165 (195) Ic = 2.38 ∠ -345 (15)	6.3 ∠ 75	Z3T Trip Fault type BC Z3P Unit Trip time 1.0-1.05 mS
CA at MTA 90% of reach fault			
Va = 17.3 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 17.3 ∠ -240 (120)	Ia = 2.38 ∠ -105 (255) Ib = 0 Ic = 2.38 ∠ -285 (75)	6.3 ∠ 75	Z3T Trip Fault type CA Z3P Unit Trip time 1.0-1.05 mS

14. Forward External Faults

For forward Zone 3 Phase-Phase External faults use the Table 5-14 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. The relay system should not trip as these faults are beyond the reach of the Zone 3 Phase units.

Table 5-14. Zone 3 Phase-Phase Forward External Faults: Z3P = 7.0 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AB at MTA 110% of reach fault			
Va = 17.3 ∠ 0 Vb = 17.3 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 1.95 ∠ -45 (315) Ib = 1.95 ∠ -225 (135) Ic = 0	7.7 ∠ 75	No Trips
BC at MTA 110% of reach fault			
Va = 69 ∠ 0 Vb = 1.73 ∠ -120 (240) Vc = 1.73 ∠ -240 (120)	Ia = 0 Ib = 1.95 ∠ -165 (195) Ic = 1.95 ∠ -345 (15)	7.7 ∠ 75	No Trips
CA at MTA 110% of reach fault			
Va = 17.3 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 17.3 ∠ -240 (120)	Ia = 1.95 ∠ -105 (255) Ib = 0 Ic = 1.95 ∠ -285 (75)	7.7 ∠ 75	No Trips

15. Reverse External Faults

For reverse Zone 3 Phase-Phase External faults use the Table 5-15 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. In each case the relay system should not trip as these faults are reverse direction from the PANG setting.

Table 5-15. Zone 3 Phase-Phase Reverse External Faults: Z3P = 7.0 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
AB at MTA -180° 50% of reach fault			
Va = 17.3 ∠ 0 Vb = 17.3 ∠ -120 (240) Vc = 69 ∠ -240 (120)	Ia = 4.28 ∠ -225 (135) Ib = 4.28 ∠ -45 (315) Ic = 0	3.5 ∠ -105	No Trips
BC at MTA -180° 50% of reach fault			
Va = 69 ∠ 0 Vb = 1.73 ∠ -120 (240) Vc = 1.73 ∠ -240 (120)	Ia = 0 Ib = 4.28 ∠ -345 (15) Ic = 4.28 ∠ -165 (195)	3.5 ∠ -105	No Trips
CA at MTA -180° 50% of reach fault			
Va = 17.3 ∠ 0 Vb = 69 ∠ -120 (240) Vc = 17.3 ∠ -240 (120)	Ia = 4.28 ∠ -285 (75) Ib = 0 Ic = 4.28 ∠ -105 (255)	3.55 ∠ -105	No Trips

3-Phase Units

To calculate the fault impedance seen by the relay system the following formula applies:

$$Z\ \text{fault} = \frac{Vxg}{Ixg}$$

where x is either phase a, b, and c phases.

The above formula is rigorous and general. However, if a quick approximation of the minimum trip current required at different angles (θ) is desired, the following formula applies:

$$Ixg = \frac{V_{XG}}{\mathrm{Z2P}\ (\cos\ (PANG - \theta))}$$

where x is either phase a, b, and c phases.

Zone 2 3-Phase Units

NOTE: Set the "T3P" timer setting to "BLK" before applying the faults in Tables 5-16, 5-17, and 5-18.

16. Forward Internal Faults

For forward Zone 2 Three-Phase Internal faults use the Table 5-16 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. Compare the relay system trip target data to the applied fault values. The target data should be within +/- 10% magnitude and +/- 3 degrees on phase. Trip time should fall within 100 - 132 milliseconds.

Table 5-16. Zone 2 Three-Phase Forward Internal Faults: Z2P = 4.5 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
BC at MTA 90% of reach fault			
Va = 20 ∠ 0 Vb = 20 ∠ -120 (240) Vc = 20 ∠ -240 (120)	Ia = 4.93 ∠ -75 (285) Ib = 4.93 ∠ -195 (165) Ic = 4.93 ∠ -315 (45)	4.05 ∠ 75	Z2T Trip Fault type ABC Z2P Unit Trip time 100-132 mS

17. Forward External Faults

For forward Zone 2 Three-Phase External faults use the Table 5-17 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. The relay system should not trip as these faults are beyond the reach of the Zone 2 Three-Phase units.

Table 5-17. Zone 2 Three-Phase Forward External Faults: Z2P = 4.5 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
BC at MTA 110% of reach fault			
Va = 20 ∠ 0 Vb = 20 ∠ -120 (240) Vc = 20 ∠ -240 (120)	Ia = 4.04 ∠ -75 (285) Ib = 4.04 ∠ -195 (165) Ic = 4.04 ∠ -315 (45)	4.95 ∠ 75	No Trips

18. Reverse External Faults

For reverse Zone 2 Three-Phase External faults use the Table 5-18 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. In each case the relay system should not trip as these faults are reverse direction from the PANG setting.

Table 5-18. Zone 2 Three-Phase Reverse External Faults: Z2P = 4.5 Ohms

Volts ∠ Angle	I Amps ∠ Angle	Fault Z Ohms ∠ Angle	Relay System Operation
Va = 20 ∠ 0 Vb = 20 ∠ -120 (240) Vc = 20 ∠ -240 (120)	Ia = 8.89 ∠ -255 (105) Ib = 8.89 ∠ -15 (345) Ic = 8.89 ∠ -135 (225)	2.25 ∠ -105	No Trips

Zone 3 3-Phase Units

NOTE: Set the “T3P” timer setting to 1.0 seconds before applying the faults in Tables 5-19, 5-20, and 5-21.

19. Forward Internal Faults

For forward Zone 3 Threehase Internal faults use the Table 5-19 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. Compare the relay system trip target data to the applied fault values. The target data should be within +/- 10% magnitude and +/- 3 degrees on phase. Trip time should fall within 1.00 - 1.05 seconds.

Table 5-19. Zone 3 Three-Phase Forward Internal Faults: Z3P = 7.0 Ohms

Volts	∠	Angle	I Amps	∠	Angle	Fault Z Ohms	∠	Angle	Relay System Operation
BC at MTA 90% of reach fault									
Va = 20	∠	0	Ia = 3.17	∠	-75 (285)	6.3	∠	75	Z3T Trip
Vb = 20	∠	-120 (240)	Ib = 3.17	∠	-195 (165)				Fault type ABC
Vc = 20	∠	-240 (120)	Ic = 3.17	∠	-315 (45)				Z3P Unit
									Trip time 1.0-1.05 mS

20. Forward External Faults

For forward Zone 3 Three-Phase External faults use the Table 5-20 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. The relay system should not trip as these faults are beyond the reach of the Zone 3 Three-Phase units.

Table 5-20. Zone 3 Three-Phase Forward External Faults: Z3P = 7.0 Ohms

Volts	∠	Angle	I Amps	∠	Angle	Fault Z Ohms	∠	Angle	Relay System Operation
BC at MTA 110% of reach fault									
Va = 20	∠	0	Ia = 2.6	∠	-75 (285)	7.7	∠	75	No Trips
Vb = 20	∠	-120 (240)	Ib = 2.6	∠	-195 (165)				
Vc = 20	∠	-240 (120)	Ic = 2.6	∠	-315 (45)				

21. Reverse External Faults

For reverse Zone 3 Three-Phase External faults use the Table 5-21 of voltages and currents. In each case apply the 3-phase voltage to the relay system first then suddenly apply the currents listed. In each case the relay system should not trip as these faults are reverse direction from the PANG setting.

Table 5-21. Zone 3 Three-Phase Reverse External Faults: Z3P = 7.0 Ohms

Volts	∠	Angle	I Amps	∠	Angle	Fault Z Ohms	∠	Angle	Relay System Operation
ABC at MTA -180° 50% of reach fault									
Va = 20	∠	0	Ia = 5.71	∠	-255 (105)	3.5	∠	-105	No Trips
Vb = 20	∠	-120 (240)	Ib = 5.71	∠	-15 (345)				
Vc = 20	∠	-240 (120)	Ic = 5.71	∠	-135 (225)				

WARNING: The user should verify that Standing Relay Trip SRT = NO in the Test Mode Function prior to putting the REL 356 in service.

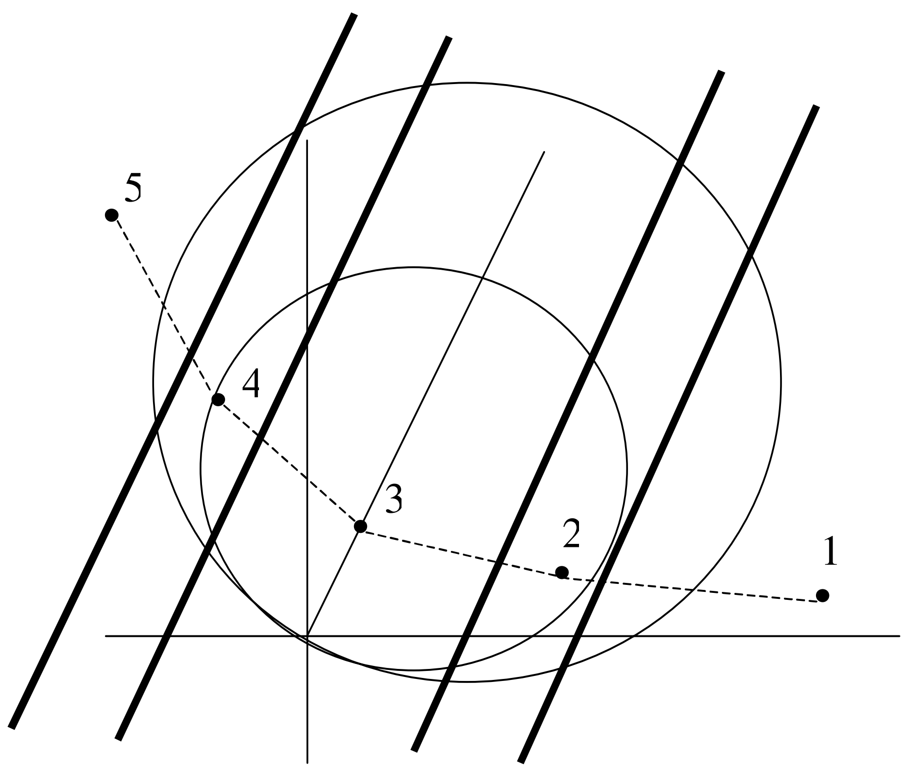
Out Of Step System Functional Tests

For systems equipped with OST logic the following settings may be used to check the OST logic in REL 356:

PANG	=	65	T2G	=	0.1
GANG	=	65	Z3P	=	11.0
ZR	=	3.0	T3P	=	.2
BKUP	=	OUT	Z3GF	=	11.0
LOPB	=	NO	Z3GR	=	0.01
FDOP	=	IN	T3G	=	.2
FDOG	=	IN	OST	=	WAYO
DIRU	=	ZSEQ	OSB	=	BOTH
IOM	=	0.5	RT	=	2.0
TOG	=	BLK	RU	=	4.0
Z2P	=	8.5	OST1	=	2
T2P	=	0.1	OST2	=	3
Z2GF	=	6.5	OST3	=	3
Z2GR	=	0.01	OSOT	=	100

NOTE: These tests are optional and require programing Computer Aided, Multi-amp or Doble test equipment.

In the R-X diagram, the positions shown correspond to the following quantities:



	V (Volts)	I (Amps)
1	Va = 69 ∠0 Vb = 69 ∠-120 Vc = 69 ∠+120	Ia = 5 ∠-5 Ib = 5∠-125 Ic = 5∠+115
2	Va = 20 ∠0 Vb = 20 ∠-120 Vc = 20 ∠+120	Ia = 4.5 ∠-25 Ib = 4.5∠-145 Ic = 4.5∠+95
3	Va = 20 ∠0 Vb = 20 ∠-120 Vc = 20 ∠+120	Ia = 6 ∠-65 Ib = 6∠+175 Ic = 6∠+55
4	Va = 20 ∠0 Vb = 20 ∠-120 Vc = 20 ∠+120	Ia = 4 ∠-100 Ib = 4∠+140 Ic = 4∠+20
5	Va = 69 ∠0 Vb = 69 ∠-120 Vc = 69 ∠+120	Ia = 6.5 ∠-105 Ib = 6.5∠+135 Ic = 6.5∠+15

The apparent impedances seen by the relay in each of the above positions and the expected operation of the inner (21 BI) and outer (21 BO) blinders are the following:

POS	Z app	21 BI	41 BO
1	13.8 ∠5	No	No
2	4.47 ∠25	No	Yes
3	3.33 ∠65	Yes	Yes
4	5.00 ∠100	No	Yes
5	10.6 ∠105	No	No

Test #1 indicates the sequence of positions in the RX diagram to be applied and the time in cycles to hold the position and the action of the relay.

The fault impedance measured should be 10.6 ∠ 105 ohms.

TEST #1 Trip OST on the Way Out		
Pos	Time	Trip Action
A		
1	60	
2	5	
3	20	
4	5	
5	60	50-67 ms after 2

In-Service Checks

This section will guide you through the In-Service checks that should be performed to insure that the relay is connected properly to the system and phasing is correct at both ends of the protected line. The first section verifies the proper connection of the CT & PT circuits along with their respective ratio. This section is dependent on connections to the PT circuits. The second section deals with phasing of the overall relay system.

Potential and Current Circuits:

STEP 1

Before putting the relay into service, first recheck all the settings to the setting sheet and verify all values are correct.

STEP 2

Open all trip circuits via the built in FT switches or block the trips coming from this relay at any convenient point. Leave the trip circuits intact for any backup system that is being used.

STEP 3

Close the breaker at one end of the line only and heat up the line.

STEP 4

Verify that the voltages and angles displayed in the metering display correspond to what exists on the system. The voltages displayed are Line to Neutral voltage so a multiplication factor of 1.73 must be used to determine the Line to Line voltage. A∅ Voltage will always have a phase reference of 0°. B∅ will appear as -120° and C∅ will appear as +120°. Looking at the metering menu in the RCP (Remote Communication Program), all of the potential should appear as Positive Sequence or V1. Small quantities of V2 & V0 are acceptable and are a result of small phase unbalalnces in the system and or variations in the PT's themselves. Verify at both ends and record the data.

STEP 5

Close the breaker in at the remote end.

STEP 6

Verify that the current levels and angles displayed in the metering display correspond to what is actually flowing in the system. This is more easily done in the metering menu of RCP. Verify with the Load dispatcher current levels and power flow. Verify that the relay sees the same direction and same relative value of power flow as the Load Dispatcher. If not the Ct's may be hooked up backwards or the CT ratio entered in the settings is incorrect. Whenpower is flowing out of Station "A", it will appear as (+) watts in the metering menu. Station "B" will see this same power flow coming in, and it will appear as (-) watts. The current angles at Station "B" wil also be 180° out of phase with the angles at Station "A".

STEP 7

Record and compe the current levels and angles with the levels and angles at the other end of the line. Verify that the angles in all three phase are 180° different from one end to the other. Also verify in the RCP metering menu that the Current appears as mainly I1 or positive sequence current. This will verify that the phase rotation is correct at both ends.

STEP 8

After all checks of Voltage & Current are completed and everything corresponds with what the Load Dispatcher is reporting, you are ready to move on to the current differential section of the test. If problems exist, they must be corrected before moving on to the current differential checks.

Current Differential Checks

The current differential checks will utilize load current to verify proper phase relationship at both ends of the line. The OSCAR and RCP programs should be used to process and view the oscillographic records.

STEP 1

Use the actual settings or
C1 = 0.1
C2 = 0.7
C0 = 0.0

Make sure that LPBK = NO and ALDT = YES and that the relay displays CHRX = NORM.

STEP 2

Use the Display Select button to scroll down the Test Menu on the front of the REL 356. Use the RAISE button to scroll to move through the functions until TEST appears in the window. With the tip of a pen, trigger an oscillographic record by depressing the ENTER key on the front of the relay. Make sure you get a green VALUE ACCEPTED led indication.

STEP 3

In the RCP relay menu, go to Oscillographic Data <enter>. Select Analog and Digital data <enter>. Select record 0 (most recent) <enter>. Wait for the program to download the record and save it to a file in a subdirectory of your choice.

STEP 4

Open the OSCAR program. Select Osc Data File <enter>. Select REL 356 <enter>. Find the .os6 file you saved in step 3 <enter>. Wait for the OSCAR program to calculate the analog and digital data in the saved file. Select Graph Osc Data <enter>.

STEP 5

Now you will see the analog and digital data associated with this record.
Press F1 ANA MENU.
Press F3 SELECT MOVE DN.
Press F8 REMOVE TRACE and repeat until OP and RES are the two top traces on the screen.
Press F9 RETURN
Press F9 MAIN MENU

STEP 6

Repeat Step 4.
Read off the magnitudes for OP and RES displayed on the right side of the traces. OP should be close to zero while RES should be two times the load current multiplied by the C1 setting.
(RES = $|IL| + |IR| = 2 \times I_{load} \times C1$)

If the load current is low, this test can be performed with a temporarily higher C1 setting so that the RES waveform will show in OSCAR, e.g. set C1 = 1.0 when taking the oscillographic record.

STEP 7

Verify at both line ends.

STEP 8

If the C1 setting was changed, return it back to actual setting.

STEP 9

Scroll the TEST menu on the front of the REL 356. Next scroll through the functions until the SRT function is displayed. Verify that SRT = NO. This function stands for standing relay trip. If this is YES, it means that as soon as you close the trip circuits, you will trip the breaker.

Computer Communications

Communication Port(s) Use

Introduction

REL 356 can be communicated with for target data, settings, etc., through the man-machine interface (MMI), The relay can also be communicated with via the communication (comm) ports. Comm port communications, provides the user with more information than is available with the MMI. For example, all 16 targets are available and a more friendly user interface for settings can be accessed (all settings are displayed on a single screen on the user's PC). This section will provide the details of the comm port options, personal computer requirements, connecting cables and all information necessary to communicate with and extract data from the relay. Additional communications details are contained in IL 40-603, (RCP) Remote Communication Program.

Communication Port Options

REL 356 is supplied with a rear communications port. If the network interface is not specified, a RS-232C (hardware standard) communications port is supplied. Network interface comm port option allows the connection of the relay with many other devices to a 2-wire network. A detailed discussion of networking capabilities can be found in AD 40-600, Substation Control and Communications Application Guide.

RS-232C, rear comm port is of the removable, Product Operated Network Interface (PONI) type and is available in three styles. One is identified by a 25 pin (DB-25S) female connector, it is usually black and has a single data comm. rate of 1200 bps. The second style is identified by a 9 pin (DB-9P) male connector and externally accessible dip switches (next to the connector) for setting the communication data rate. This port option is always black in color, can be set for speeds of 300, 1200, 2400, 4800, 9600, or 19200 bps and offers an option for IRIG-B time clock, synchronization input.

The third style is a PONI-M Modbus RS485 Product Operated Network Interface for connecting the REL 356 system to a Modbus Host. Communication details for this option are given in IL 40-616.

Personal Computer Requirements

Communication with the relay requires the use of Remote Communication Program (RCP) regardless of the comm port option. RCP is supplied by ABB Relay Division and is run on a personal computer (PC).

To run the program requires an IBM AT, PC/2 PC or true compatible with a minimum of 640 kilobytes of RAM, 1 hard disk drive, a RS-232C comm port and a video graphics adapter card. The PC must be running Version 3.3, or higher, MS-DOS.

Connecting Cables

With each comm port option the connecting cable requirement can be different. Also, connecting directly to a PC or connecting to a modem, for remote communication, affects the connecting cable requirements. Table 6-1, provides a summary of a plug pin assignments, pins required and cable connectors.

Some terminology will be defined to aid the user in understanding cable requirements in Table 6-1. Reference, is often made to the "RS-232C" standard, for data communication. The RS-232C standard describes mechanical, electrical, and functional characteristics. This standard is published by the Electronics Industry Association (EIA) and use of the standard is voluntary but widely accepted for electronic data transfer. ABB relay communications follows the RS-232C standard for non-network data communication.

Although the RS-232C standard does not specify a connector shape, the most commonly used is the "D" shape connector. As stated in Section 1, all ABB relay communication connectors are of the "D" shape (such as DB-25S).

Data communication devices are categorized as either Data Terminal Equipment (DTE) or Data Communication Equipment (DCE). A DTE is any digital device that transmits and/or receives data and uses communications equipment for the data transfer. DCE's are connected to a communication line (usually a telephone line) for the purpose of transferring data from one point to another. In addition to transferring the data, DCE devices are designed to establish, maintain, and terminate the connection. As examples, a computer is a DTE device and a modem is a DCE device.

By definition the connector of a DCE is always female (usually DB-9S or 25S). Similarly, DTEs are always male (usually DB-9P or 25P). These definitions apply to the equipment being con-nected and to the connectors on the interconnecting cables.

One additional piece of hardware that is required, in some applications, is a "null" modem. Null modem's function is to connect the transmit line (TXD), pin 2 by RS-232C standard, to the receive line (RXD), pin 3. A null modem is required when connecting like devices. That is DTE to DTE or DCE to DCE. A DCE to DCE, example, where a null modem is required, is the connection of a 25 pin, PONI to a modem.

A null modem function can be accomplished in the connecting cable or by separate null modem package. That is, by using a conventional RS-232C cable plus a null modem. One type of null modem, available from electronics suppliers, is B & B Electronics Type 232MFNM.

Modem Communications

The REL 356 system can be connected to its configuration software, RCP, using a dial up configuration. The Application Note in Section 8 "Modem Communication to ABB Relays" provides a step-by-step guide for the remote communications setup.

Setting Change Permission and Relay Password

To gain access to certain communication port functions, the REL 356 must have the remote setting capability permission **SETR** set to **YES** and knowledge of the relay password is required. All communications port functions listed below require **SETR** set to **YES** before the actions can be performed:

Update/Change Settings
Enable Local Settings (capability)
Disable Local Settings (capability)
Activate Output Relays (contact testing function)

Access control, both setting permission and password knowledge is required for all communication port options.

Before attempting any of the above functions, the setting of **SETR** must be verified via the front panel MMI. Using the setting change procedure in Section 2, "Front Panel Operation", verify or change **SETR** such that it is set to **YES**.

Using comm. port communications, the ability to change settings from the MMI can be disabled. The RCP, Password Menu Choice "Disable Local Settings" when selected, will block setting changes via the MMI. Blocking the front panel setting changes, may be useful for situations in which the access to the relay cannot be secured from tampering by unauthorized persons.

Password:

When the REL 356 is received from the factory or if the user loses the relay password, a new password can be assigned with the following procedure:

Turn off the relay dc supply voltage for a few seconds, Restore the dc supply voltage and wait for the relay to complete the self check/start-up routine, Using RCP, perform the Password Menu choice "Set Relay Password", Use the word "password" when prompted for the "current relay password" and then enter a new password.

Password setting change procedure must be completed within 15 minutes of energizing relay or "password" will not be accepted as the "current" password.

Troubleshooting

In the event the communication remains unsuccessful, first make sure that the relay is powered, proper communication cable is used (Table 6-1), and the connection is good.

For further testing, check that the bit rate (Baud) on the RS-PONI (Table 6-2) is set to correspond to the one displayed at the bottom right of the RCP display.

If after these verifications the problem remains, try to remove the power from the relay and apply it again. If the communication still fails (several attempts), the communication equipment needs to be serviced.

Sixteen Fault Target Data

The REL 356 saves the latest 16 fault records, but only the latest two fault records can be accessed from the front panel. For complete 16 fault data, the computer communication is necessary.

Digital Fault Recording

Three digital fault records are stored in REL 356. Each set includes seven analog traces (V_a, V_b, V_c, I_a, I_b, I_c and I_n), with one cycle pre-fault and 7-cycle fault information, and 64 digital signals based on 12 samples per cycle.

NOTE: IF POWER IS INTERRUPTED TO RELAY ALL “OSCILLOGRAPHIC DATA” WILL BE LOST.

Table 6-1. Communications Cable Requirements

Connection Type	Cable (Straight = no null modem)	Pins Req'd (All pins not required)	Cable Connectors	Data Rate
DB-25S, RS-232C connected to PC*	Straight	2, 3, 7	To port: 25 pin DTE To PC: 9 or 25 pin DCE	1200 bps only
DB-25S, RS-232C connected to modem	Null Modem	2, 3, 7	To port: 25 pin DTE to Modem: 25 pin DTE	1200 bps only
DB-9P, RS-232C connected to PC*	Null Modem	2, 3, 5	To port: 9 pin DCE To PC: 9 or 25 pin DCE	See Table 6-2 For settings
DB-9P, RS-232C connected to modem*	Straight	2, 3, 5	To port: 9 pin DCE To Modem: 25 pin DTE	See Table 6-2 For settings

Table 6-2. RS-PONI Dip Switch Settings

Dip Switch Pole			Port Data Rate
1	2	3	bps
0	0	0	300
0	0	1	1200
0	1	0	2400
0	1	1	4800
1	0	0	9600
1	0	1	19200
1	1	0	1200
1	1	1	1200
Dip Switch Pole		**Auto Answer Rings**	
4	5		
0	0	none	
0	1	4	
1	0	8	
1	1	12	

NOTE: ***Turn the power OFF and ON, anytime Dip Switch changes are made.***

Fault Record Data Definitions

The Oscillographic and Recording Program (OSCAR) under selection: "Load Screen Layout File" of the main menu offers the following display files for REL 356.

Analog Signals

The following signals are displayed on the main OSCAR screen following a download of both analog and digital signals from the REL 356 relay:

Ia phase A current
Ib phase B current
Ic phase C current
-3I0 zero sequence current (note the negative sing)
Vag phase A to ground voltage
Vbg phase B to ground voltage
Vcg phase C to ground votlage
It local current after sequence filter
Vflr real part of local It current

These additional analog signals are displayed by F1 - ANA MENU:

Vfli imaginary part of local It current
Vfrr* real part of remote It current
Vfri* imaginary part of remote It current
Op operating value
Res restraint value

*Note that only every third sample is sent from the remote end. The local received value, Vfrr, and the computed, Vfri, are “padded” in OSCAR by repeating the same sample value three times. This results in a “stepped” waveform. This is of no concern for the measurement as only every third, true, sample is used for diifferential measurement. The display Vfrr and Vfri are delayed by the local delay time, LDT plus 3 frames values, i.e. LDT + 3 x 1.39 msec = LDT + 4.17 msec. The delay is due to data transfer time between the protection processor and the oscillographic processor and is of no importance for the protection function. For testing, however, it should be noted that when Vfri lags the local quantity, Vfli by 90 degrees + LDT they are actually in phase, i.e. an internal fault. When Vfri leads Vfli by LDT - 90 degrees they are actually 180 degrees out of phase, i.e. an external fault.

Digital Signals

A total of 64 digital signals are displayed in OSCAR. These signals are easiest identified by finding them in the SYSTEM LOGIC diagrams, at the back of this IL.

The first 20 digital signals are display in the OSCAR main screen after downloading the file from the REL 356 relay. The command F8 - DIG MENU displays 20 additional signals and the command F1 - SCROLL DIGI UP displays the remaining 24 signals, one by one.

Main Screen

PLT pilot trip
SBT stub bus trip
OBKT open breaker trip
ROBR remote open breaker
CT channel trouble
RDPD remote differential protection disabled
RNRM receive in normal mode
RDTT receive direct transfer trip
SCTB soft channel trouble (no delay measurement)
CHOK channel OK
TDIS transmit disable
TRNM transmit in normal mode
OBKR open breaker
LDTT local direct transfer trip input
LDPD differential protection disable input
DEMM DCE echo mismatch
DNOR DCE no response
DRST DCE in reset
DMMM DCE modem mismatch
BK1S breaker 1 trip contact seal

Extended Digital Screen

BK3S breaker 3 trip seal
BK4S breaker 4 trip seal
BK5S breaker 5 trip seal
BL6S breaker 6 trip seal
JMP7 jumper 7
TTRP direct transfer trip
STBB stub bus
DISA disable input
ERST external reset input
52B 52b contact input
TP12 trip relay 1 and 2
TL34 trip relay 3 and 4
TP56 trip relay 5 and 6

BFIA	breaker failure initiate A output
BFIB	breaker failure initiate B output
BFIC	breaker failure initiate C output
RI1	reclose initiate 1
RI2	reclose initiate 2
RB	reclose block
GS	general start

Additional Signals When Scrolling Up

ALMF	failure alarm
ALMT	trip alarm
ALMC	channel alarm
SEBR	enable backup system
RIFT	reclose into fault
PT	na
PTG	na
TG	FDOG timer
Z2P	zone 2 phase distance
Z2G	zone 2 ground distance
Z3P	zone 3 phase distance
Z3G	zone 3 ground distance
ECHO	na
IOM	medium set ground overcurrent element
LOP	loss of potential block
LOI	loss of current
21BI	inner blinder
OSB	out of step block
TGTP	time delayed ground trip
T2P	zone 2 phase timer
T2G	zone 2 ground timer
T3P	zone 3 phase timer
T3G	zone 3 ground timer
BK2S	breaker 2 trip seal

∠3I0	Zero sequence current angle	2-15
ΔI	Current change detector	3-5
ΔIΔV	Current and voltage change detectors	3-4
∠IA	Phase A current angle	2-15
∠IB	Phase B current angle	2-15
∠IC	Phase C current angle	2-15
∠VAG	Phase A voltage angle	2-15
∠VBG	Phase B voltage angle	2-15
∠VCG	Phase C voltage angle	2-15
21BI	Inner blinder	5-25
21BO	Outer blinder	5-25
3I0	Zero sequence current	2-15
3V0	Zero sequence voltage	2-17
AB	Fault type A-B	2-16
ABC	Fault type ABC	2-16
AG	Fault type A-G	4-1
ALDT	Automatic delay compensation	3-11
ALRB	Reclose block setting	3-22
BC	Fault type B-C	2-16
BFI	Breaker failure initiate	2-7
BG	Fault type B-G	2-16
BK1	Breaker current flowed	2-16
BK2	Breaker current flowed	2-16
BK3	Breaker current flowed	2-16
BK4	Breaker current flowed	2-16
BK5	Breaker current flowed	2-16
BK6	Breaker current flowed	2-16
BKUP	Back up setting	3-13
C0	Zero sequence setting parameter	3-9
C1	Positive sequence setting parameter	3-9
C2	Negative sequence setting parameter	3-9
CA	Fault type C-A	2-16
CD	Change detector	3-5
CG	Fault type C-G	2-16
CHRX	Channel receive status	2-15
CHTB	Channel trouble	2-18
CHTX	Transmitter status	2-15
CODEC	Coder/Decoder	2-5
CT	Current transformer	1-7
CTDD	Back up system setting	3-13
CTR	Current transformer ratio	3-4
CTYP	Current transformer type, 1A or 5A	3-4
DCER	Communication error	2-18
DCI	Digital communication interface	2-6
DFT	Discrete fourier transform	4-1
DIRU	Ground directional unit polarization	3-14
DKM	Fault distance in kilometers	2-17
DMI	Fault distance in miles	2-16

DSBL	Disable	2-16
DTT	Direct transfer trip	4-5
DTYP	Distance unit type	3-12
EEPROM	Electrically erasable, read-write non-volatile memory	2-3
EPROM	Ultraviolet erasable, read-only memory	2-3
FANG	Fault impedance angle	2-16
FDAT	Trigger for storing fault target data	3-5
FDOG	Ground directional unit	3-13
FDOP	Phase directional unit	3-13
FEPH	Bit error	2-15
FOLO	Follower mode	3-11
FREQ	Rated frequency	3-4
FTYP	Fault type	2-16
GANG	Line zero sequence impedance angle	3-13
I0	Zero sequence current component	4-9
IA	Phase A current	2-15
IAH	High set current phase A	2-16
IB	Phase B current	2-15
IBH	High set current phase B	2-16
IC	Phase C current	2-15
ICH	High set current phase C	2-16
IDER	Unit ID error	2-18
IE	Very low set overcurrent unit	3-7
IGH	High set ground overcurrent	3-7
IGL	Low set ground overcurrent unit	3-7
ILTS	IL trip supervision	3-6
IOM	Medium set ground overcurrent unit	3-14
IPH	High set phase overcurrent	3-7
IPL	Low set phase overcurrent unit	3-7
IT	Composite current	1-7
ITL	Local, filtered composite current	1-7
ITR	Remote composite current	1-7
KBPS	Communication speed	3-12
LDFL	Lead/follower mode	3-11
LDT	Local delay timer	3-11
LEAD	Lead mode	3-11
LED	Light emitting diode	2-4
LOC	Local	2-15
LOI	Loss of current	2-15
LOPB	Loss of potential block	3-13
LP	Pre-fault load angle	2-17
LPBK	Loopback	3-12
MLDT	Measured communication channel delay	2-15
NODM	No delay measurement	2-18
NORB	No reclose block	3-22
NORM	Normal, error free channel operation	2-18
OBKT	Open breaker trip	2-16
OP	Operate quantity	6-4

OPBR	Open breaker	3-6
OSB	Out of step block	2-15
OSC	Trigger for storing oscillographic data	3-4
OSCAR	Oscillographic and recording program	2-6
OSOT	Out of step override timer	3-16
OST	Out of step trip	3-16
OST1	Out of step detection timer	3-16
OST2	Out of step trip timer	3-16
OST3	Out of step timer, way out trip	3-16
OTH	Set operating threshold	3-8
PANG	Line positive sequence angle	3-13
PFLC	Pre-fault load current	2-17
PFLV	Pre-fault voltage	2-17
PLT	Pilot trip	2-16
PONI	Computer/network interface	2-13
RAM	Read-write random access volatile memory	2-3
RB	Reclose block contact	2-7
RBEN	Reclose block enable	3-6
RCP	Remote communication program	2-6
REM	Remote	2-15
RES	Restraint quantity	1-7
RIFT	Reclose into fault	2-16
RLSD	Receiver level signal detector	3-12
ROM	Read-only memory	2-3
RP	Enable readouts in primary values	3-4
RT	Inner blinder setting, load restriction	3-16
RU	Outer blinder setting	3-16
S/N ratio	Signal to noise ratio	2-17
SET	Setting access status	2-15
SETR	Remote setting	3-16
SLGF	Single line to ground fault	4-8
SNR	Signal to noise ratio	2-17
T2G	Zone 2 ground timer	3-15
T2P	Zone 2 phase timer	3-15
T3G	Zone 3 ground timer	3-15
T3P	Zone 3 phase timer	3-15
TDES	Trip desensitizing	3-8
TG	Time overcurrent ground trip	2-16
TOG	Ground overcurrent unit timer	3-14
TRGG	Ground current pickup timer	3-5
TRGP	Phase current pickup level	3-5
TTRP	Direct transfer trip	3-12
UNID	Unit ID	3-11
VAG	Phase A to ground voltage	6-4
VBG	Phase B to ground voltage	6-4
VCG	Phase C to ground voltage	6-4
VERS	Software version	3-4
VTR	Voltage transformer ratio	3-4

WAYI	Out of step trip, way in	3-16
WAYO	Out of step trip, way out	3-16
XCLK	Transmit clock source	3-12
XMTR	Transmitter output level	3-12
XPUD	Distance multiplier setting	3-12
Z	Fault impedance	2-16
Z0L	Zero sequence line impedance	4-9
Z1L	Positive sequence line impedance	4-9
Z2GF	Zone 2 ground forward	3-15
Z2GR	Zone 2 ground reverse	3-15
Z2P	Zone 2 phase	3-15
Z3G	Zone 3 ground	3-15
Z3GF	Zone 3 ground forward	3-15
Z3GR	Zone 3 ground reverse	3-15
Z3P	Zone 3 phase	3-15
ZFG	Forward zone reach setting	4-8
ZGF	Forward ground impedance reach	4-8
ZGR	Reverse ground impedance reach	3-14
ZP	Forward phase impedance setting	4-8
ZR	Zero sequence to positive sequence impedance ratio	3-13

Line Sectionalizing Using a PLC and ABB Protective Relays

Rev A.

***ABSTRACT**: With the advent of utility deregulation, uptime and minimal line restoration times are demanded. With the economics of off-the-shelf equipment usage for substation control and decision making, PLC, and ABB relay use is widely accepted as a restoration solution. This advanced application note explains a method to inexpensively implement advanced Line Sectionalizing techniques using a TPU2000R, DPU2000R, PCD2000, and a programmable logic controller. THE DISCUSSION AND LADDER LOGIC USED HEREIN IS TO BE USED AS A GUIDE TO PLC AND PROTECTIVE RELAY INTEGRATION.*

Typical Installation

Figure 1 illustrates a typical installation in which protective relays are installed within a substation providing for restoration schemes. Both the network architecture and sample modified one line is shown for clarity.

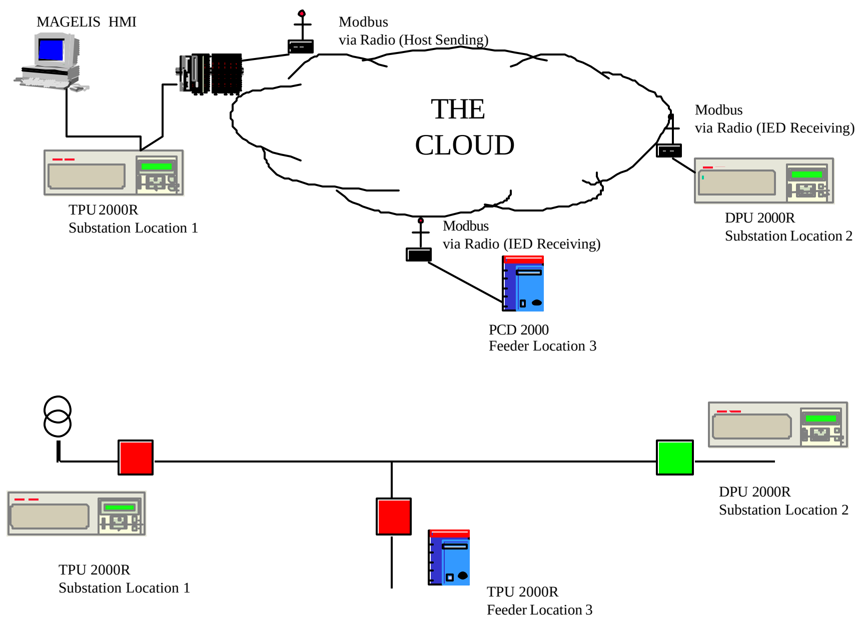


Figure 1. Typical PLC/Protective Relay Report by Exception Application

The scenario illustrated is indicative of a line sectionalizing (load shedding) installation. Using intelligent off the shelf IEDs such as protective relays and PC based HMI interfaces and programmable logic controllers to analyze and perform intelligent switching decisions is more commonplace given the advantages afforded by the economics and increased functionality of such a system. Using an ABB protective relay and a PLC is a logical decision because:

- All items are commercially available Off The Shelf units
- The installations use inexpensive radio modems.
- The software to perform the tasks is programmed in ladder logic, which can be easily written by either a system house or a utility engineer.
- The DPU2000R, TPU2000R, or PCD may be field retrofitted by the user, if the Modbus Plus or Modbus protocols are not presently installed in the units.
- No proprietary protocols or equipment is utilized in this installation.
- An inexpensive operation interface allowing for visualization of local and remote status/operation is available.

- Real Time Switching is based on instantaneous decisions made by the microprocessor based IEDs.

As illustrated in Figure 1, the feeder and substation 2 are located a great distance away from the main PLC. Inexpensive radio scatter modems are used to allow communication between the PLC which has the RTU based functionality and logic imbedded within it and the remote IEDs.

Line Sectionalizing Explained

This application note is intended to illustrate the method of obtaining information from the IED's through the Modbus and Modbus Plus interfaces. Each one of the nodes, PLC, IED and HMI operate in concert as follows:

1. The PLC reads/writes/calculates information obtained from the TPU2000R via the Modbus Plus network. Data gathered from the TPU2000R is:
    - Breaker Status (52a, 52b) is read
    - Cumulative Watts, Vars, 3 Phase Power, Amps, Volts, Watts, Var values are read.
    - Calculation of the combined loading is performed when the Substation Location 1 is feeding the lines at Location 3 (PCD2000).
2. The PLC reads/writes information between itself and the DPU2000R. Data gathered by the PLC is:
    - Breaker Status (52a, 52b) is read.
    - Cumulative Watts (per phase and 3 phase), Vars (per phase and 3 phase), Amps, Volts, frequency values are read.
    - Calculation of the combined loading is performed when the Substation Location 2 is feeding the lines at Location 3 (PCD2000).
    - Control Operation capabilities such as breaker trip and breaker close can be completed automatically (via logical decisions made by the PLC) or manually (via an operator at the HMI station).
3. The PLC reads/ writes information between itself and the PCD2000. Data gathered by the PLC is:
    - Breaker Status (52a, 52b) is read.
    - Cumulative Watts (per phase and 3 phase), Vars (per phase and 3 phase), Amps, Volts, frequency values are read.
    - Control Operation capabilities such as breaker trip and breaker close can be completed automatically (via logical decisions made by the PLC) or manually (via an operator at the HMI station).
4. The MAGELIS HMI displays the data values held in the PLC. In this installation, the PLC acts as a data concentrator and arbitrator for the logic operations. The MAGELIS HMI can disable the automatic restoration functions preprogrammed in the PLC. With the PLC placed in manual control mode, the operator viewing the data on the MAGELIS screen can perform manual restoration since visualization of each breaker and all feeder metering values are displayed on the screen.

There are two modes of operation, MANUAL and AUTOMATIC restoration. With the system in AUTOMATIC mode, line restoration is performed by the PLC without any operator intervention. AUTOMATIC MODE operation occurs as such:

1. The breakers at Substation Location 1 and Feeder Location 3 are closed. The breaker at Substation Location 2 is open. In this example, the feed from the TPU2000R is providing supply to the feeder at location 3. The PLC is constantly reading metering values and calculating the average load required by Feeder Location 3.
2. On the event of a fault, the TPU2000R trips the breaker. The PLC recognizes the trip immediately (under 10 mS in this case) and immediately determines if sufficient reserve is available at Substation Location 2 to supply Feeder Location 3.

3. The PLC immediately opens the breaker at Feeder Location 3. The PLC verifies that reading the status of the breaker opens the breaker. The MAGELIS system immediately displays the metering values and breaker status on its screen and may also generate alarms to alert the operator or attached SCADA system.
4. If Substation Location 2 has sufficient reserve to supply the feeder at location 3, the PLC wait 3 seconds to ensure that the TPU at Substation Location 1's breaker is open, AND that the Breaker at Substation Location is also open.
5. The PLC shall Close the breaker at Substation Location 2 and read the metering values and breaker status reported by the DPU2000R.
6. The PLC still calculates the load on the line and determines if there is still sufficient reserve to add additional feeder lines, the PLC shall wait another 1 second and send a close command to the breaker controlled by the PCD2000.
7. The PLC shall read the metering values and breaker statuses at each of the 3 IED locations and report them to the MAGELIS system via the internal network at the substation.
8. At each of the above steps, a message is generated as to the step being performed by the PLC. The status of each step (along with any error) messages is displayed and archived by MAGELIS operator interface. The PLC will place the restoration scheme in MANUAL mode, so that an operator may place the system in the same state that it was in prior to the TPU2000R trip.

If any one of the steps fails to execute, the MAGELIS HMI will display an error message as to the cause of failure in the restoration process.

MANUAL MODE disables the PLC's capability to trip/close the breaker. The PLC still computes the loading values and alerts the operator as to alarms. The PLC also communicates with MAGELIS MMI and displays messages/ breaker status information/metering data informing the operator if adequate load is available to supply the feeder. This gives the operator additional information if a manual restoration is to be performed via the operator interface. Additionally, the operator commands may be sent directly to the PLC to perform manual trips and close commands.

Method of Implementation

Two Ladder Logic instructions within the Modicon PLC allows line sectionalizing to occur:

- MSTR obtains the data from the TPU relay. Once the data is obtained, the PLC determines the field conditions and decides upon the control to be performed.
- XMIT instructions when executed by the PLC, initializes the COM port resident on the unit. The PLC can then act as an Remote Terminal Unit (RTU). The PLC then interrogates the DPU2000R and PCD2000 to determine if the units are available to be switched.

The remainder of this application note explains the programming process and ladder logic required to implement the application pictured in Figure 1.

Obtaining Relay Information Via Modbus Plus and Modbus

The PLC is programmed using four ladder logic segments. The logic within each segment is as follows (for this example).

SEGMENT 1: READ TPU2000R VALUES VIA MODBUS PLUS. PROVIDE MANUAL TPU CONTROL OPERATIONS VIA MODBUS PLUS.

SEGMENT 2: READ DPU2000R AND PCD2000 VALUES VIA THE RADIO MODEMS USING MODBUS PROTOCOL. PROVIDE MANUAL AND AUTOMATED CONTROL OPERATIONS VIA MODBUS.

SEGMENT 3: LOGIC REQUIRED FOR EACH STEP IN THE RESTORATION SEQUENCE FOR CALCULATION AND CONTROL. HMI LOGIC FOR TRIGGERNG MESSAGES AND ALARMS IN THE MAGELIS SYSTEM.

SEGMENT 4: ANCILLARY SUBROUTINES providing 32 bit number conversion since the Compact 984 does not easily allow for mathematics on a double register number or single register number containing a value of 9999 or greater. The ABB products allow numbers to be reported in a single register interpreted as 0 to 65535 (Unipolar) or –32767 to 32768 (Bipolar). If a number is a 32 bit representation, PLC logic must be added to the specific vendor's PLC allow computations to occur.

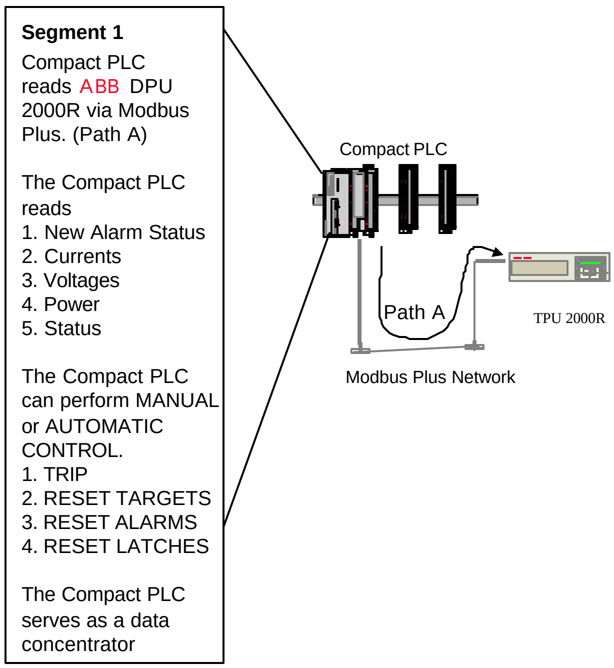


Figure 2. Modbus Plus Ladder Logic Implementation Strategy

The Ladder Logic is Segment 1 is very straight forward. Figure 3 illustrates the method of obtaining the data from the TPU2000R via Modbus Plus.

The data requested includes logical element status which includes breaker trip information for phases A, B, and C. The phase information is latched, and its status must be reset by the operator to annunciate the alarm which is decoded by the PLC.

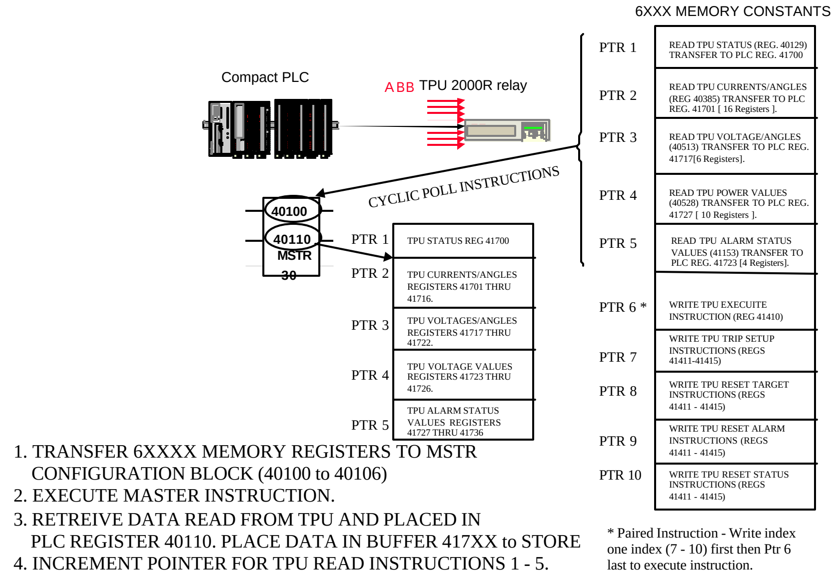


Figure 3. Data Map Request from the Compact PLC and TPU2000R via Modbus Plus

The MSTR block logic follows.

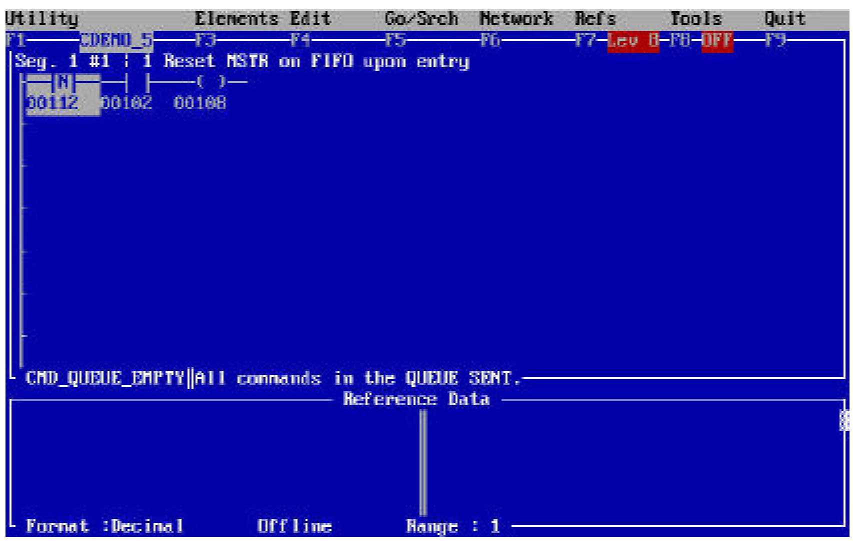


Figure 4. Network 1 Ladder Logic (MSTR Modbus Plus Logic)

NETWORK 1 – Figure 4:

The logic is written with cyclic polling occurring to gather the data and place it in a 4X memory space as illustrated in Figure 3. If a command is to be initiated via the ladder logic program (AUTOMATIC RESTORATION) or via the operator interface (MAGELIS), a specific request pointer is placed into a FIFO buffer for immediate execution once the present command is executed by the MSTR block.

Network 1 senses that a pending command is to be executed in the FIFO block and the current command is terminated in the cyclic polling sequence for the MSTR block.

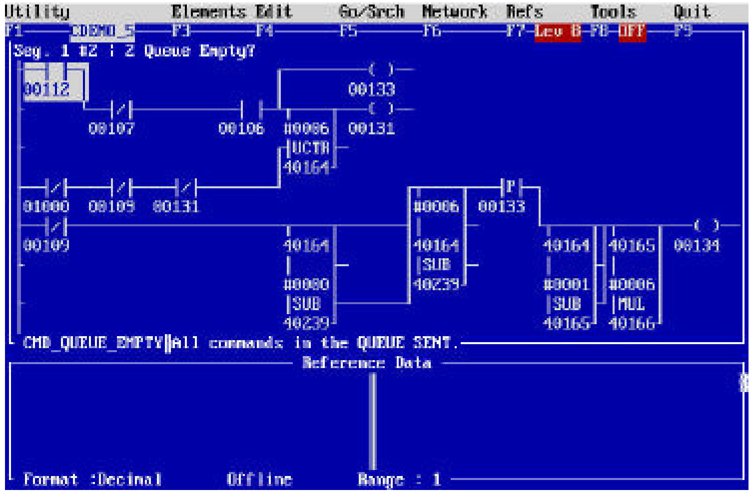


Figure 5. Network 2 Segment 1 – Cyclic Poll Logic Block

NETWORK 2 – Figure 5:

There are 6 cyclic poll read instructions (illustrated by Figure 3 above). This network actuates the time to send each of the six instructions to the MSTR block to read the information from the TPU. If an instruction must be executed (such as a TPU TRIP, RESET TARGET LED Instruction) which is not part of the cyclic instruction sequence, this drum sequence is halted until all the commands in the buffer are executed by the MSTR instruction. When the FIFO is emptied, then cyclic polling resumes and this logic construct is energized.

NETWORK 3 – Figure 6:

As illustrated in Figure 3, all instruction parameterization registers for the MSTR instruction is stored in the compact 6X memory registers. This network instruction (upon a change of the CTR instruction's cyclic poll) reads the block in 6X memory and places it in 4X memory. The contents are then moved into the MSTR block. Register 40100 = a 2 (read instruction) or a 1 (write instruction) based upon the data being read or written to the TPU. Registers 40102 through 40107 contain the MSTR parameters for the routing address (in this case the TPU is Address 1 Path 1) and such information as the number of registers to be transferred/read and the address in the TPU (to be read or written).

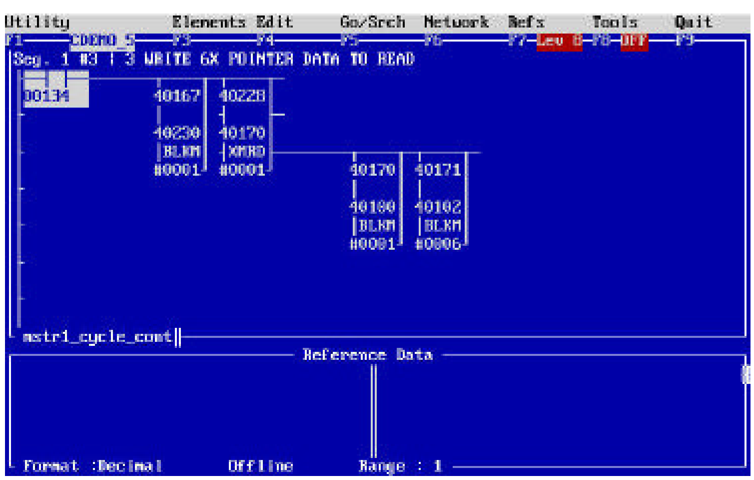


Figure 6. Network 3 Figure 6 – 6X Pointer Data

NETWORK 4 – FIGURE 7:

This is the MSTR send instruction which is parameterized for read and write commands. The upcounter in the logic counts the number of good network transactions (00104 energizes on a GOOD communication and 00103 energizes on a bad communication, 00102 is the instruction active indication). It should be noted that although 125 registers may be read/written at any one time, the program has been limited to Modbus Plus data accesses of 30 registers (to conserve PLC memory). The data is stored in 4X memory 40110 through 40149.

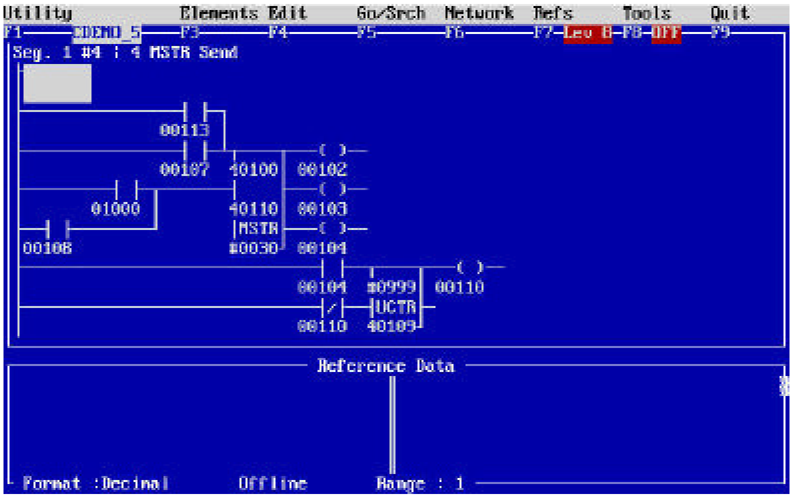


Figure 7. Segment 1 Network 4 – Master Polling Block

NETWORK 5 – Figure 8:

The UCTR in this network counts the BAD Modbus Plus network transfers (an excellent indicator for network troubleshooting and program troubleshooting). This network also determines when an network access has finished executing. The TMR in this network construct places a dwell time of 200 mS between each Modbus Plus network transaction.

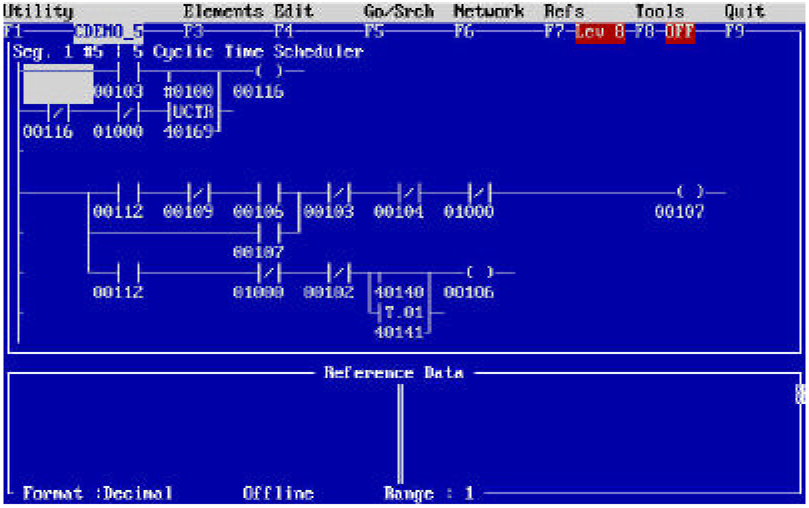


Figure 8. Ladder Logic Dwell Timer and Bad Transaction Network

NETWORK 6 – Figure 9:

This network determines if the FIFO has an entry. If the FIFO is empty Coil 00112 is energized. If the FIFO is full Coil 00111 is energized. The FIFO can contain 19 pending commands for execution in the TPU. As illustrated in Figure 3, the commands are numbered 1 through 10. 40142 and 40143 respectively are the data pointed to in the queue and the FIFO queue pointer.

Coil 00109 is the indicator for the program that the FIFO has an entry and the master should be halted.

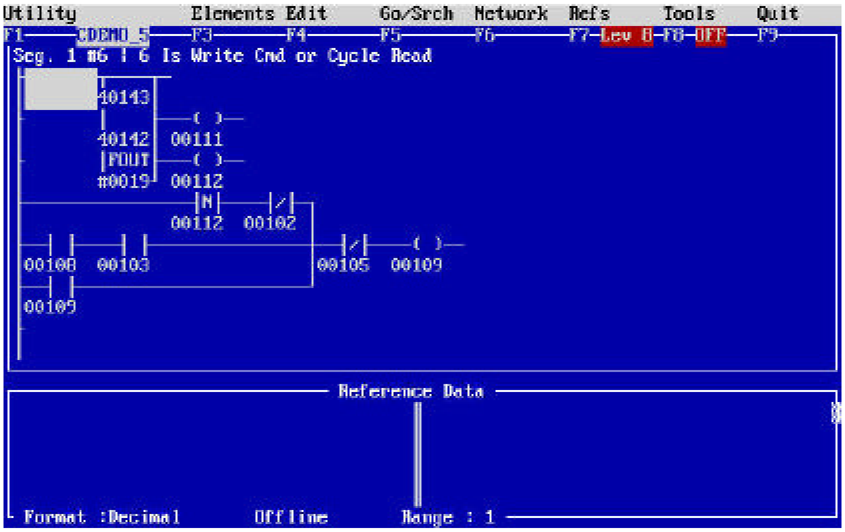


Figure 9. FIFO MSTR Halt Logic

NETWORK 7- Figure 10:

This network delays the initiation of the MSTR block send instructions when a FIFO command has been sensed in the buffer. The pointer to this command is in the 40163 pointer register. The delay is 100 mS. As can be seen in the ladder logic, the FOUT (FIFO out stack) is popped and the parameters corresponding to the FIFO pointer are transferred to the logic to transfer the 6X MSTR pointers from the 6X registers pointed (in FILE 1 6X memory) to the MSTR 40100 through 40109 register block.

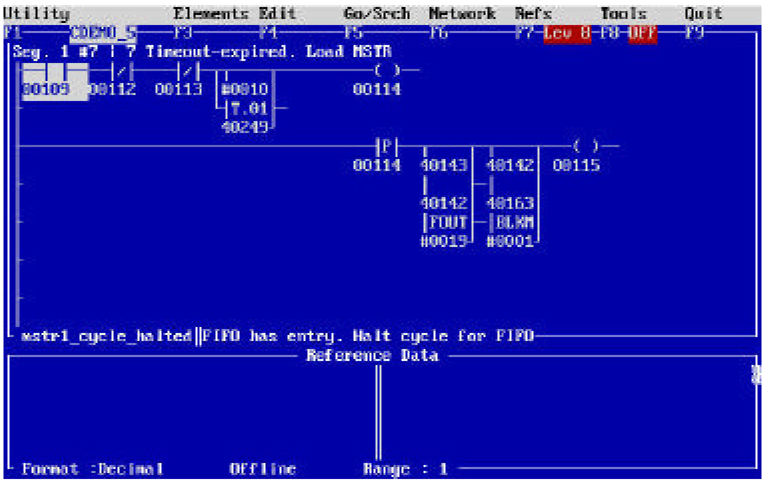


Figure 10. Network 7 Segment 1 - FIFO Scheduling Halt Logic

NETWORK 8 – Figure 11

This is the 6X transfer instructions as illustrated in Figure 11

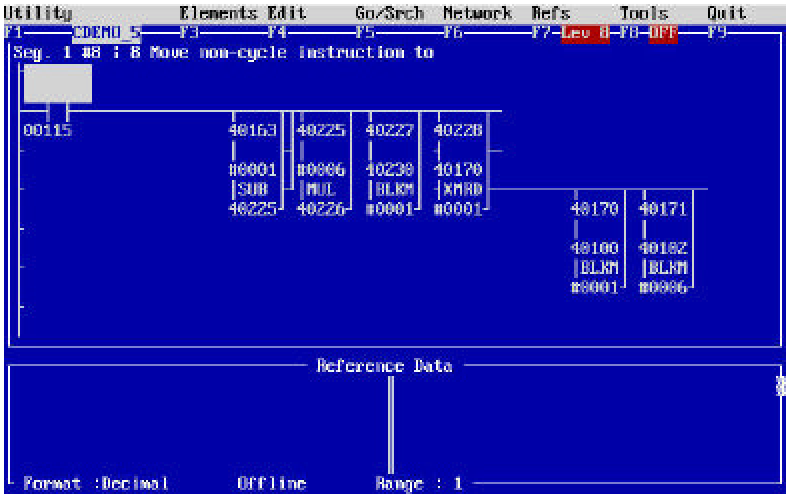


Figure 11. Ladder Logic 6X Transfer Instructions

The method to transfer the logic and the file layout in 6X memory is as such:

File 1 – Registers 60000 to 604999 contain the MSTR 1 instruction command parameterization. The commands are in a block of 6 register formats.
60XXXX+0 = MSTR Command 1 = read 2 = write
60XXXX+1 = Number of registers read/written
60XXXX+2 = Address in TPU to be read/written
60XXXX+3 = Node Route 1 Address
60XXXX+4 = Node Route 2 Address
60XXXX+5 = Node Route 3 Address

Routing address Paths 5 and 4 are a value of 0.

FILE 2 6X registers are the data written to the TPU. Each command is in a block of 10. If the command in the corresponding block is 1 (read) then the file 2 block of registers is a don't care. If the command in the corresponding block is 2, then the data in FILE 2 with the corresponding configuration data in FILE 1 is sent to the MSTR configuration registers. FILE 2 data is transferred to 40110 (MSTR data field). The grouping of the data in file 2 is always:

61XXXX + 0 to 61XXX + 9 = Block data.

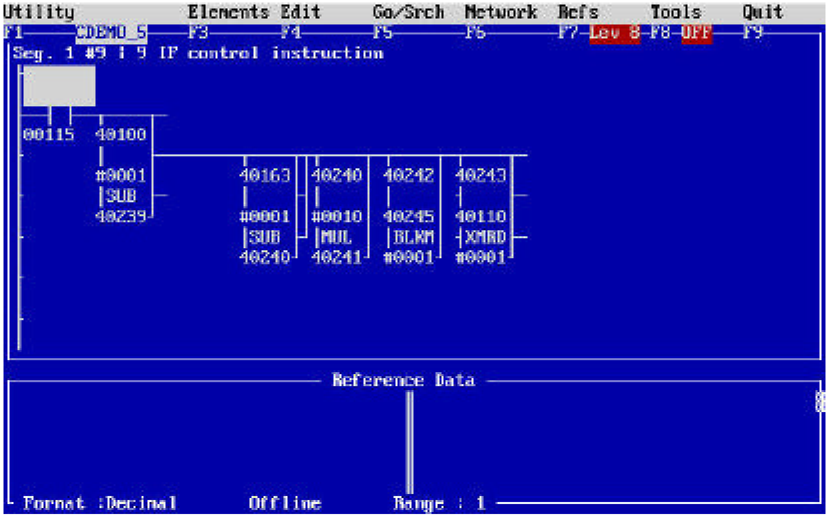


Figure 12. Transfer Logic for Control Instruction Parameterization

NETWORK 9- Figure 12:

As explained above, if the pointer in the FIFO vectors to a control instruction, then the FILE 2 data corresponding to that pointer must be transferred to 40110 in the MSTR instruction. This network does just that. The 6X address is calculated by the MULT instruction and then passed as an argument to the XMRD instruction. Upon execution of the XMRD instruction, the data is transferred into the MSTR block.
If the FIFO instruction in the buffer is a WRITE instruction, then the pointer placed in the buffer is multiplied by 10 to get the block of data to transfer to the MSTR data register buffer 40110. The multiplier for instructions are:

PTR = 1 Block 0 Add 0 to pointer for FILE 2 60000
PTR = 2 Block 1 Add 10 o pointer for FILE 2 60010
PTR = 3 Block 2 Add 20 pointer for FILE 2 60020
PTR = 4 Block 3 Add 30 to pointer for FILE 2 60030
PTR = 5 Block 4 Add 40 to pointer for FILE 2 60040
PTR = 6 Block 5 Add 50 to pointer for FILE 2 60050
PTR = 7 Block 6 Add 60 to pointer for FILE 2 60060
PTR = 8 Block 7 Add 70 to pointer for FILE 2 60070

… and so on, and so on ….

NOTE – The data is transferred if the function code in 40100 = 2 (write), else the data is meaningless.

NETWORK 10 – FIGURE 13

This network is only a latch in which once the buffer FIFO contains an entry.

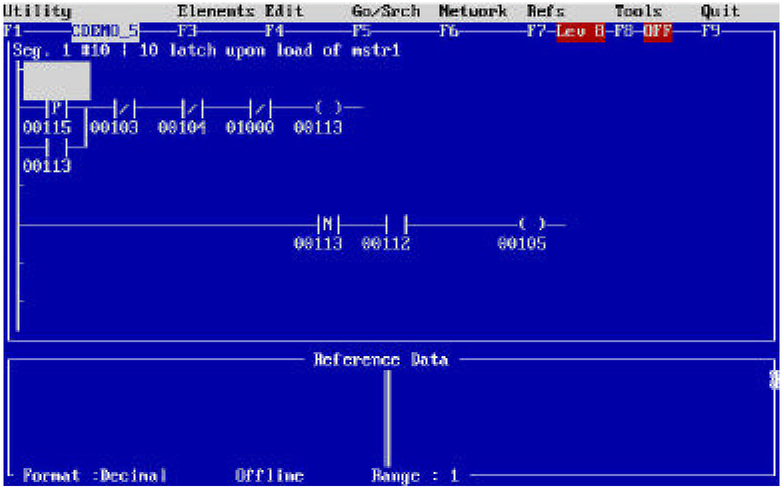


Figure 13. Segment 1 Network 10 – Start Polling Sequence

NETWORK 11 to 19 – Figures 14 to 22.

The commands 1 through 5 are the cyclic ladder logic commands which read

- REG 40129 TPU STATUS
- REG 40385 – 40401 CURRENT ANGLE DATA
- REG 40513 – 40518 VOLTAGE ANGLE DATA
- REG 40528 – 40533 POWER VALUES
- REG 41153 –41156 ALARM STATUS VALUES

The Command 6 is the trigger command for all the WRITE commands which include

- TRIP COMMAND – Write 41411 – 41415 and WRITE 41410
- RESET TARGETS – Write 41411 – 41415 and WRITE 41410
- RESET ALARMS – Write 41411 – 41415 and WRITE 41410
- RESET LATCHED DATA – Write 41411 – 41415 and WRITE 41410

The commands as illustrated in Figure 3 of this document.

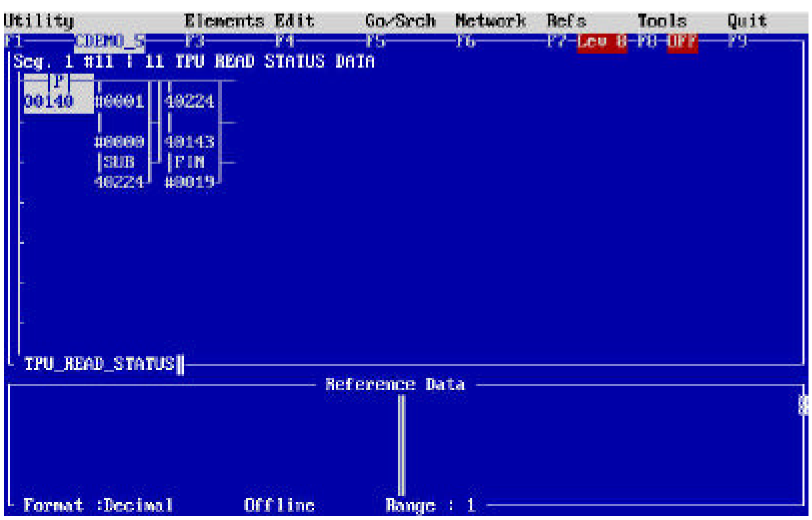


Figure 14. TPU Read Status FIFO Pointer Load Logic

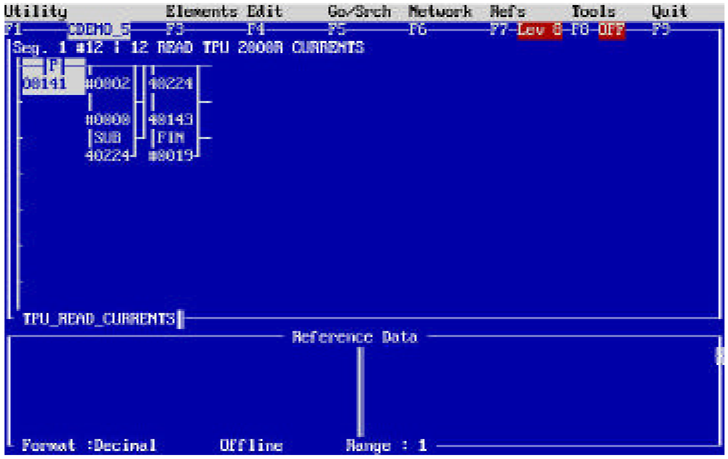


Figure 15. TPU Read Currents FIFO Pointer Load Logic

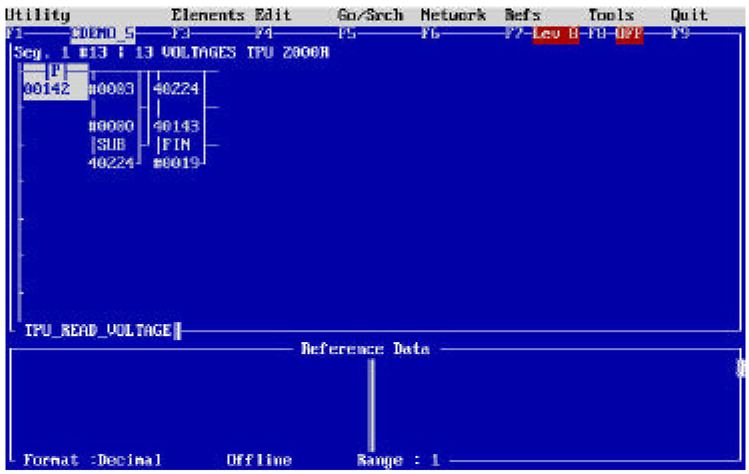


Figure 16. TPU Read Voltage FIFO Pointer Load Logic

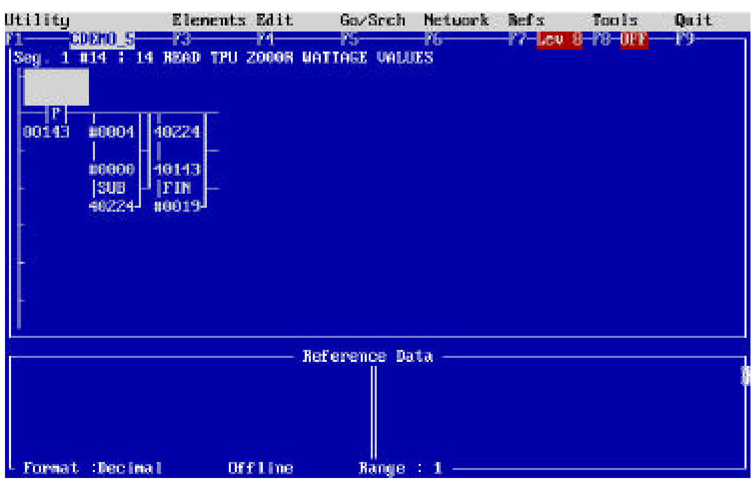


Figure 17. TPU Read Wattage FIFO Pointer Load Logic

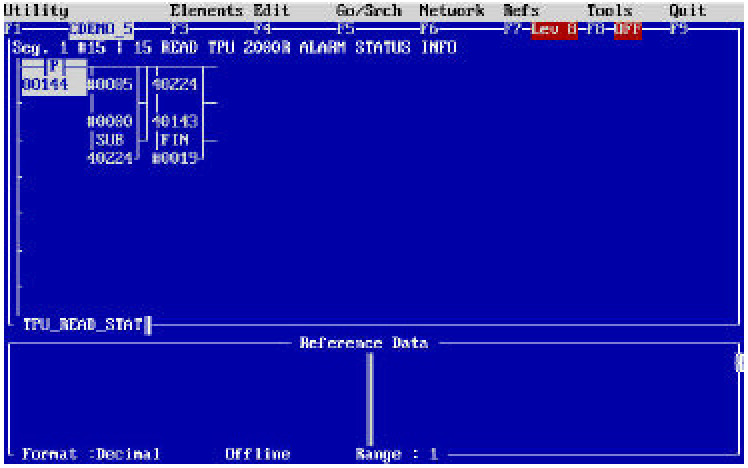


Figure 18. TPU Read Alarm Status FIFO Pointer Load Logic

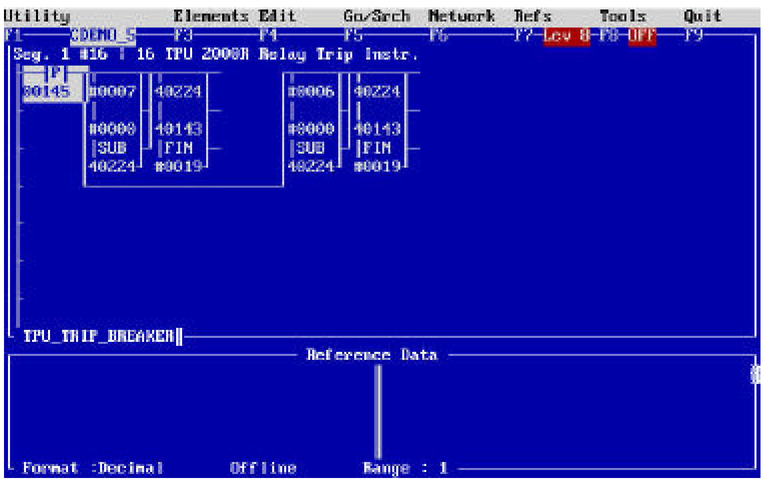


Figure 19. TPU Trip Breaker FIFO Pointers Load Logic

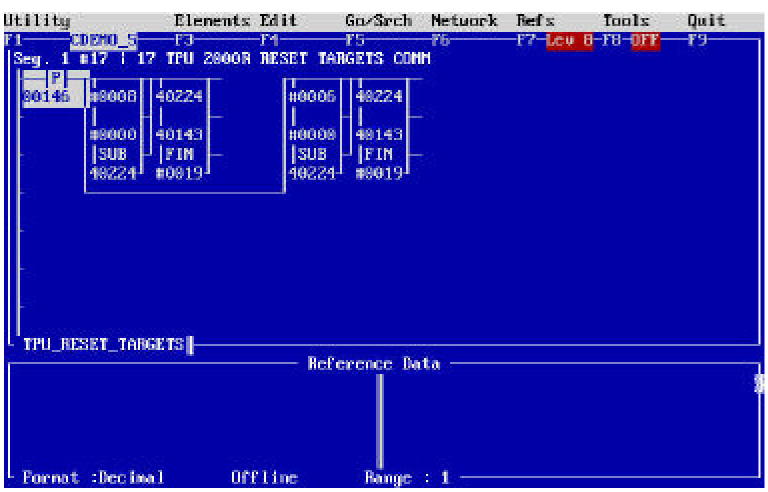


Figure 20. Reset Targets FIFO Pointers Load Logic

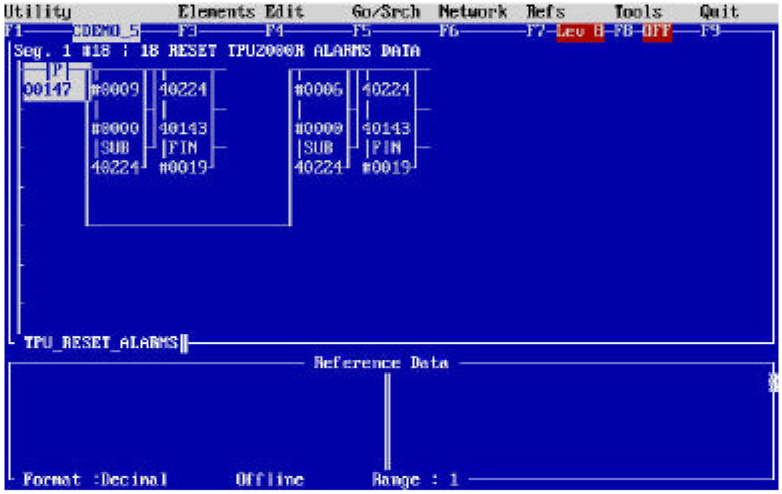


Figure 21. Reset Alarms FIFO Pointers Load Logic

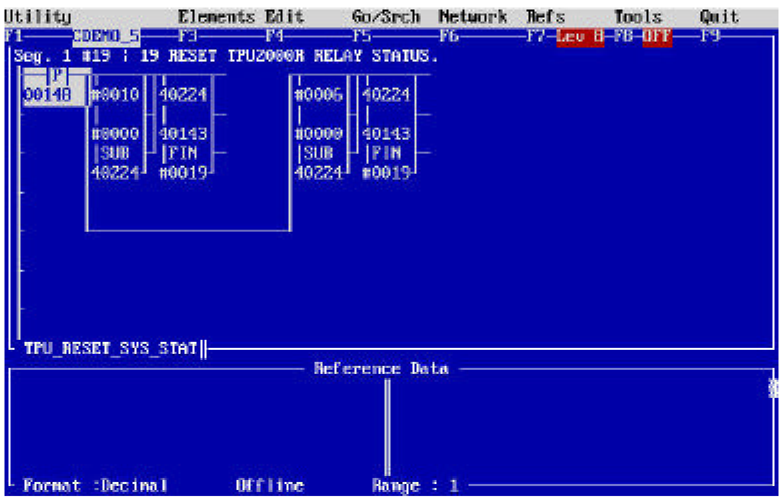


Figure 22. Reset Latched Points FIFO Pointers Load Logic

NETWORKS 20 to 24 – Figures 22 to 26

Once the data is read from the relay using the cyclic reads (pointers 1 through 5) or via the FIFO commands, the data read must be transferred from the MSTR read buffer to a general buffer for retrieval from the PLC. The PLC then serves as a data concentrator. The TPU data registers are contained in 41700 through 41726. The ladder logic networks in this construct are triggered when the MSTR instruction has obtained the information from the relay. The instruction then transfers the appropriate quantity to the appropriate registers (as illustrated by Figure 3 above).

The SUB instruction determines the MSTR command executed and the BLKM command instruction block moves the information from the MSTR data buffer (40110) to the appropriate register location from 41700 through 41726 resident in the PLC.

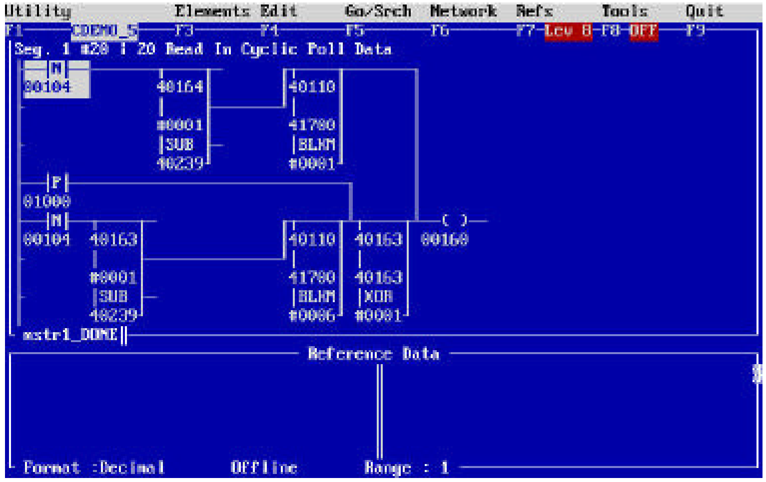


Figure 23. Read in Reply to Status Data Request and Store in PLC Registers

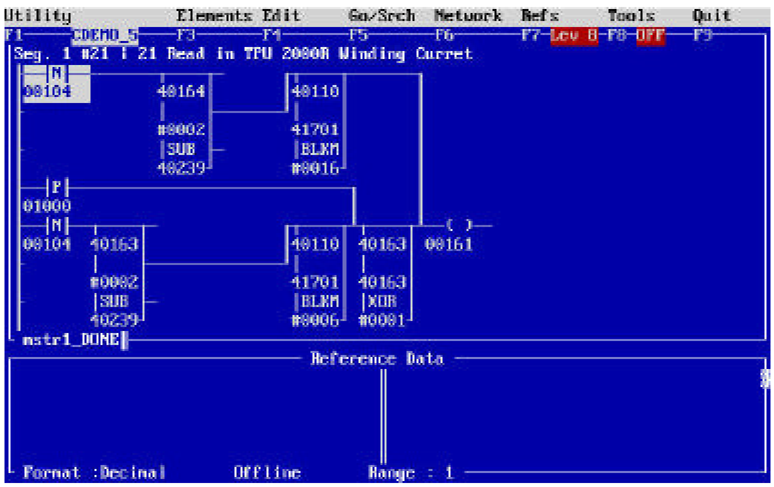


Figure 24. Read in Reply to Phase Current Data Request and Store in PLC Registers

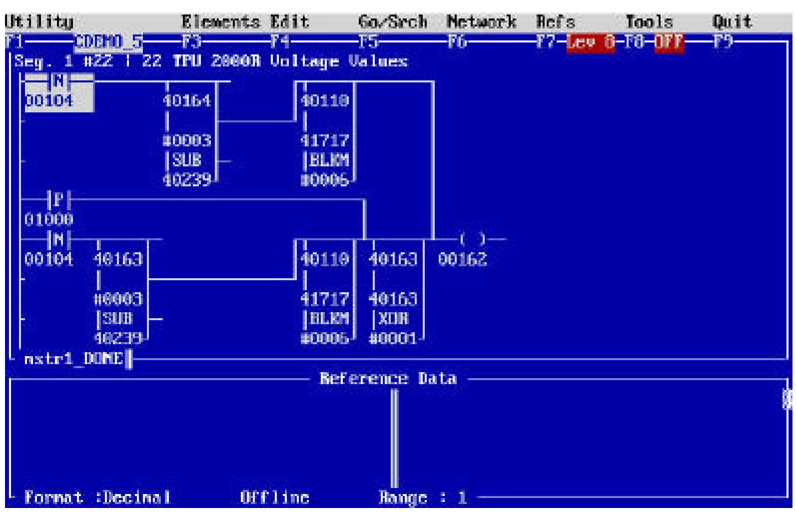


Figure 25. Read in Reply to Phase Voltage Data Request and Store in PLC Registers

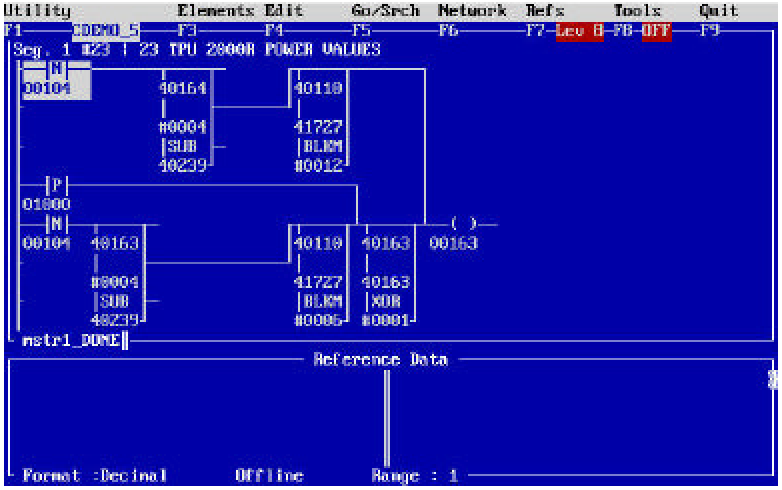


Figure 26. Read in Reply to Wattage Data Request and Store in PLC Registers

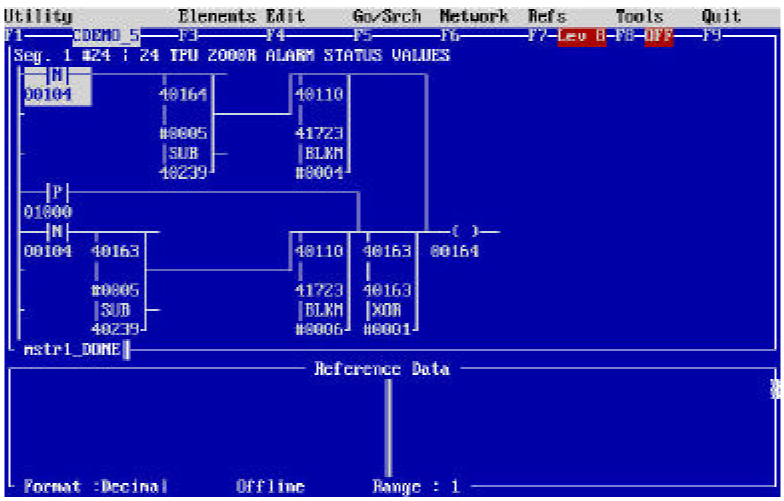


Figure 27. Read in Reply to Alarm Data Request and Store in PLC Registers

Segment 2 – Data Gathering from the PCD2000 and DPU2000R

The DPU2000R and the PCD2000 are both located some distance from the PLC. Attachment to these relays is accomplished using simple SCATTER RADIO MODEMS. The radio modems are able to communicate over a distance of 15 miles and retrieve information from them via a 10 bit protocol. The SCATTER RADIO MODEMS have the advantage that no special licensing is required for connection to the devices.

The ladder logic required for data retrieval is located in the ladder logic segment 2 and is based upon the XMIT instruction which turns the PLC's RS232 port into a MODBUS master. This enables the PLC to query attached devices and poll for data. In this way the PLC is able to determine the loading of the remote feeder and breaker status of the feeders being monitored and protected by the DPU2000R and the PCD2000.

The PLC queries both the PCD and DPU via the command parameterization of the XMIT instruction. The topology of the installation is illustrated in Figure 28 as follows in this discussion.

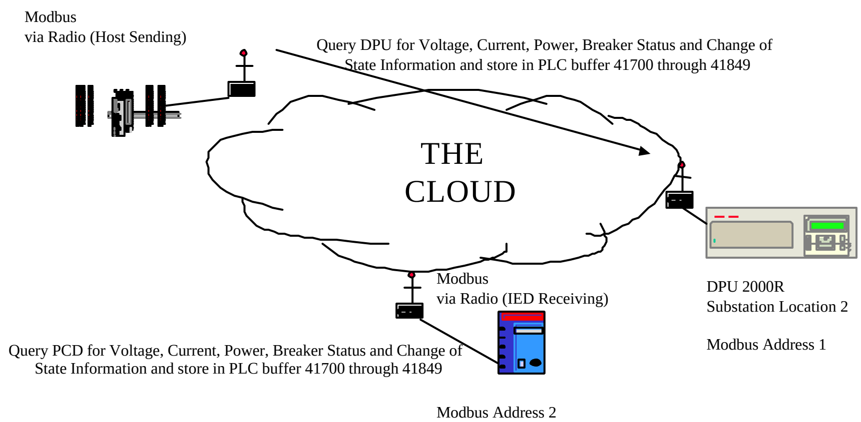


Figure 28. Network Topology for Nodes Remote to the PLC and Polled Via Modbus Command Responses

The ladder logic shall be reviewed for the method to complete the data exchange between the PLC and the IED's

SEGMENT 3 NETWORK 1:

The FIFO used to gather the information from the IED's is reset whenever data is transferred into the FIFO for polled queue. This is a standard instruction construct which is similar to that used for the MSTR instruction.

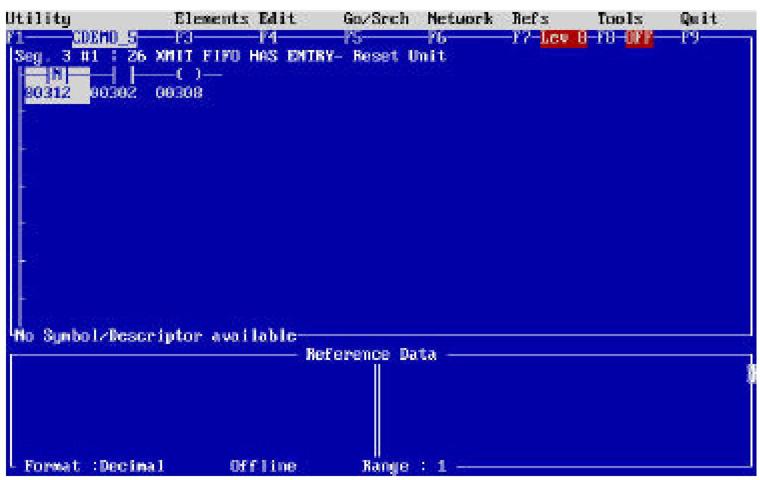


Figure 29. Segment 3 Network 1 – FIFO Entry for XMIT Instruction Notification

SEGMENT 3 NETWORK 2:

The network is a cyclical poll which pages the 10 instructions to the XMIT to gather data from the two IED's (PCD2000 and the DPU2000R). The UCTR instruction increments between 1 and 10. The Pointer is then multiplied by 10 (stored in 40333) which serves as the pointer to the 6X command buffer which parameterizes the XMIT instruction to retrieve the IED's data.

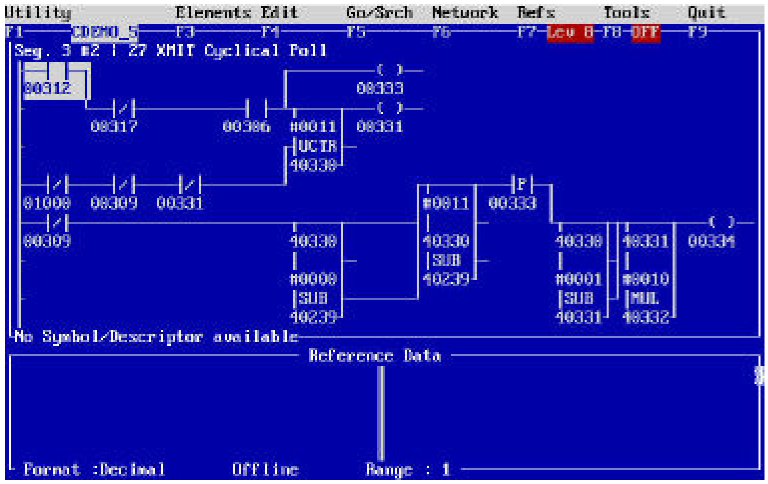


Figure 30. Segment 3 Network 2 – Cyclic Poll Pointer Setup Logic

SEGMENT 3 NETWORK 3:

This network seems to be rather complex, but it really is not. The XMIT block needs two types of parameterization 1) parameterization of the block for delay parameters, timeout parameters and definition of pointers for the MODBUS data gatheringwhich is in registers 40308 through 40315. 2) the parameterization of the Modbus commands which are pointed to by registers 40309 and 40310 (which is the address of the 5 registers for command parameterizations) and the length of the parameter block (which is 5 and its structure depends upon the instruction, please reference the MODICON XMIT BLOCK documentation for a more complete discussion of the data).

The XMIT instructions are stored in FILE 2 and FILE 1 of 6X memory beginning at addresses 600500 and 610500 respectively. File 1 parameterizes the XMIT block parameters and FILE 2 parameterizes the particular MODBUS request. The mathematics of this block calculates the data in the following way:

FILE 1 POINTER (Reg 40334) = Pointer (Reg 40331 * 10) + 500 offset.
FILE 2 POINTER (REG 30337) = Pointer (Reg 40331 * 30) + 500 offset.

The File 1 pointer is passed to the XMRD block which transfers 7 registers to the XMIT parameterization space 40308 to 40315. The File 2 Pointer is passed to the XMRD block which sends 30 registers from 6X memory to 40355 to 40384. Figure 31 illustrates the parameterization which must occur in order to allow the XMIT block to gather the data successfully. As is illustrated in Figure 31 the PLC stores the data in PLC register 41700 through 41849. The PLC program has been optimized for data storage and grouped register usage. This program may be expanded to perform other functions.

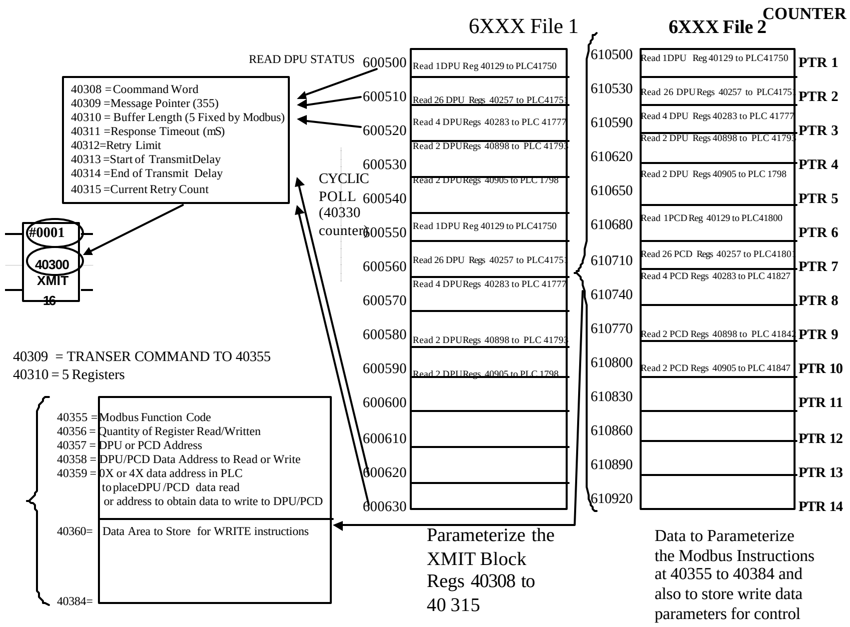


Figure 31. XMIT Parameterization Philosophy for Data Control

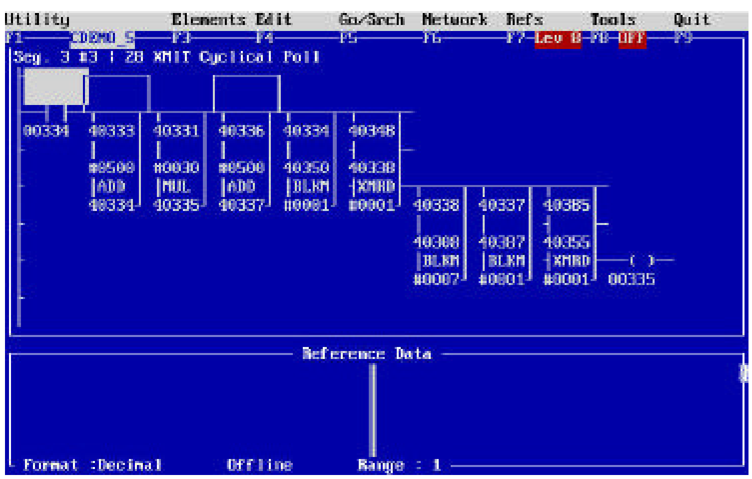


Figure 32. Segment 3 Network 3 – 6X Pointer Computation Logic for Loading XMIT Instruction

Segment 3 Network 4:

Network 4 is the base XMIT instruction. As illustrated above, the data table is filled when the drum timer of Segment 3 network 2 counts between 1 and 10 (which are the cyclic read instructions. An optional UPCTR counts the good transmissions (which is good for keeping track of communication percentage failures) over the radio network. This is used with the next network in the segment to keep track of the type of failures occurring during troubleshooting of the program. The Ladder Logic follows and is illustrated in Figure 33.

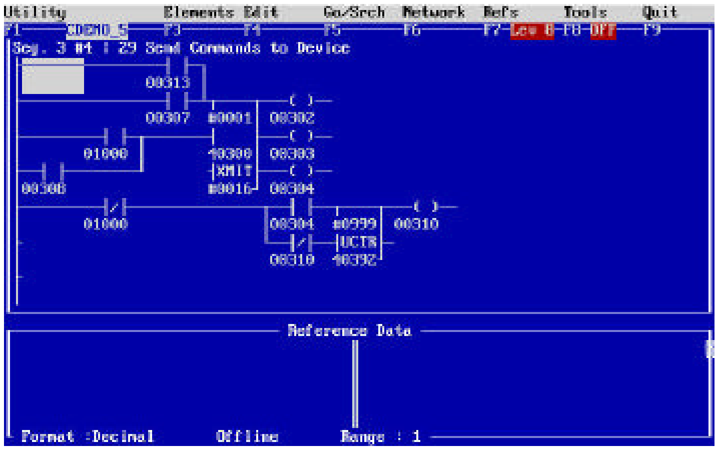


Figure 33. Segment 3 Network 4 – XMIT Instruction and Good Transaction Count

Segment 3 Network 5:

This network latches the last XMIT error in Register 40300. It is reset by pulsing coil 00888. This is additional logic added for the ease of troubleshooting the program. The logic is illustrated in Figure 34.

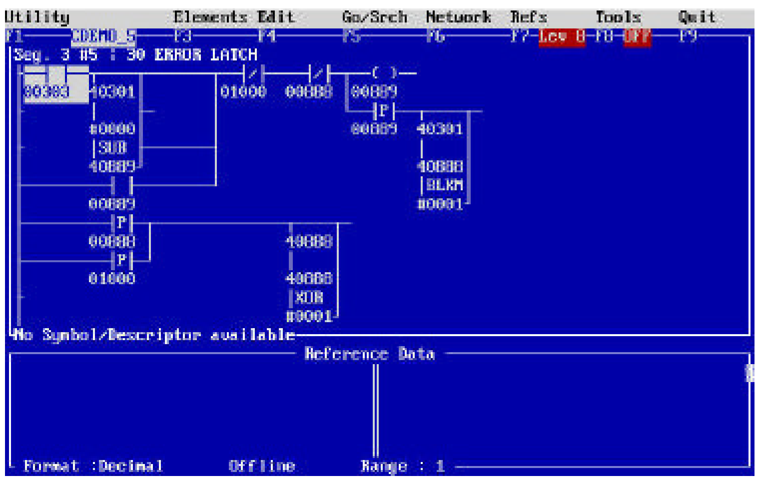


Figure 34. Segment 3 Network 5 – XMIT Error Bad Transaction Counter and XMIT Error Latch Clear Logic

Segment 3 Network 6:

The output of the XMIT block signals when an error occurs on a transmission. The UCTR instruction in this logic construct counts the number of transmission errors experienced by the XMIT BLOCK. This is instructional in determining the amount of errors occurring on the network.

The second logic construct (with the TMR) places a dwell time of 100 mS between MODBUS transmissions. The coil 00307 pulses the XMIT instruction when the FIFO buffer is empty and the XMIT instruction is able to transmit and instruction as part of its cyclical poll structure. The ladder logic is illustrated in Figure 35.

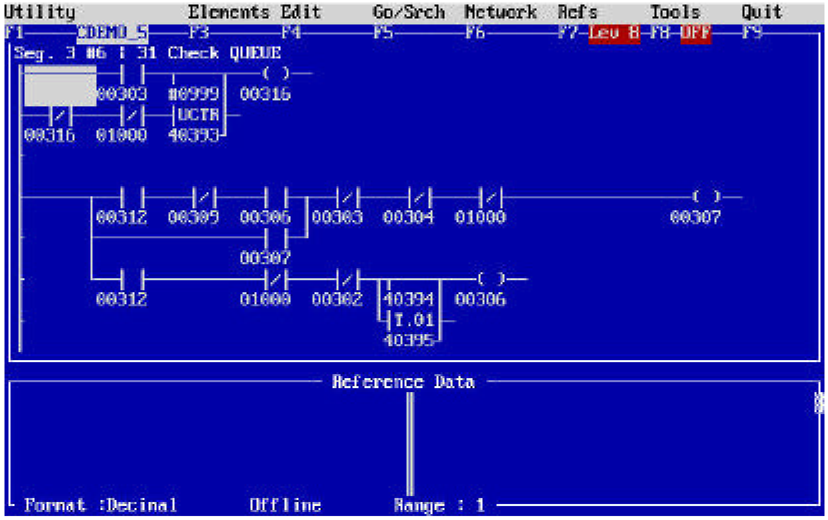


Figure 35. Segment 3 Network 6 - XMIT Dwell Timer and Bad Transmission Counter Logic

Segment 3 Network 7:

As with the Modbus Plus MSTR Logic, another FIFO has been constructed in which a manual control (or automated control instruction initiated by the ladder logic may be performed). Note the FIFO may contain up to 19 control instructions which may be queue'd for processing. Additionally, note the trigger construct for pending FIFO commands to be sent to the XMIT block (coil 00309) interrupting the cyclical poll. Using this philosophy ensures that control commands and operator initiated commands are immediately scheduled for operation by the XMIT block.

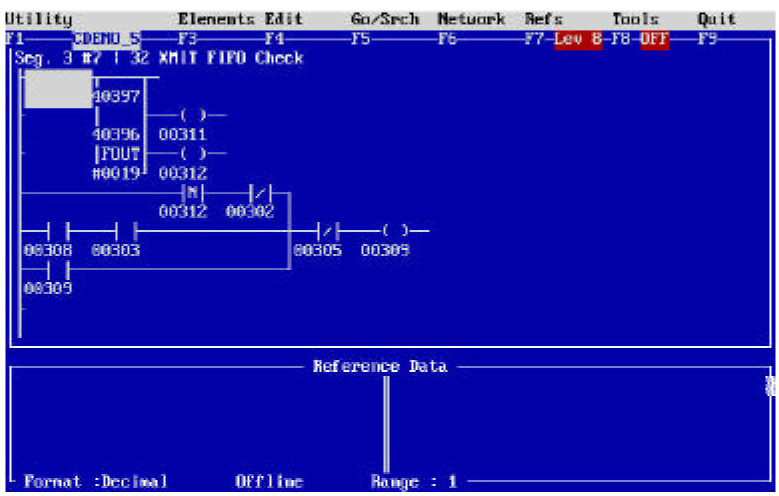


Figure 36. Segment 3 Network 7 – FIFO Empty/Full Notification Logic

Segment 3 Network 8:

If the FIFO has data, this logic construct interrupts the polling of the XMIT instructions and immediately parameterizes the block with the parameters pointed to within the FIFO queue. A dwell time of 100 mS creates a pause for the XMIT instruction to terminate. The logic in SEGMENT 3 NETWORK 9 creates the pointers for obtaining the 6X register data for passing to the appropriate 4X XMIT parameterization registers. Figure 37 illustrates the logic to accomplish this task.

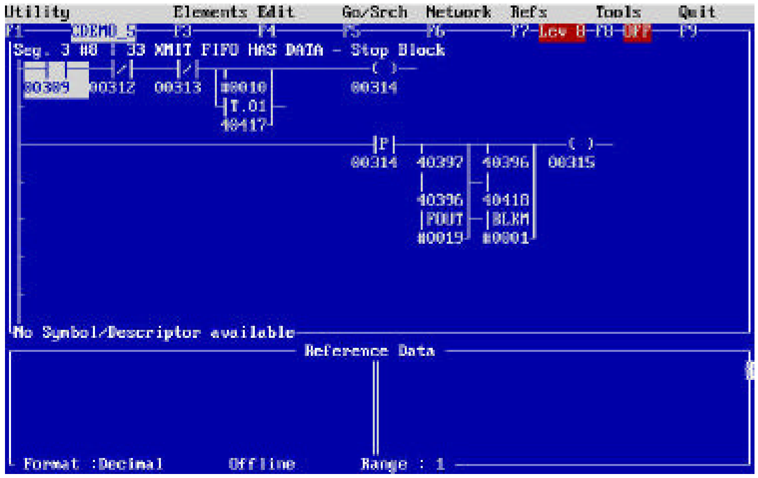


Figure 37. Segment 3 Network 8 – Cyclic Poll Cessation Logic

Segment 3 Network 9:

As illustrated, this is essentially a copy of Segment 3 Network 3 logic. It is copied here in order to keep the same philosophy for instruction parameter loading whether it is from a cyclic poll request or a FIFO task interruption. The logic is shown in Figure 38.

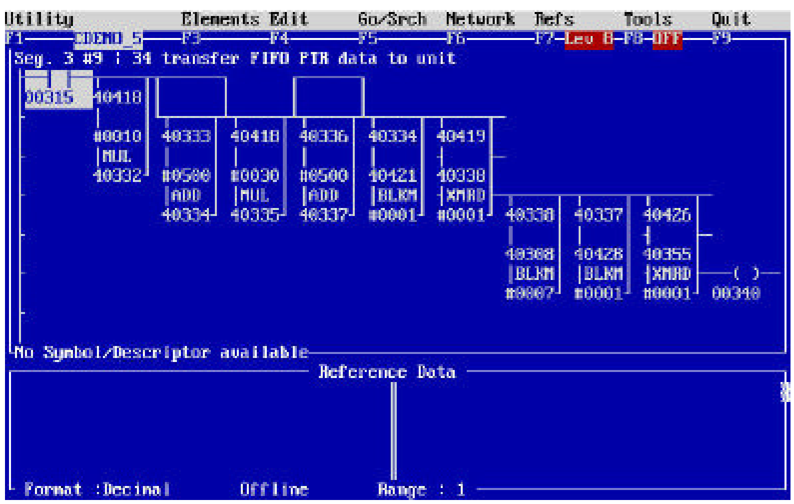


Figure 38. Segment 3 Network 9 – XMIT Pointer Computation Logic

Segment 3 Network10:

This network determines that the FIFO is empty and cyclic polling using the logic in Segment 3 Network 2 resumes. The Logic is illustrated in Figure 39.

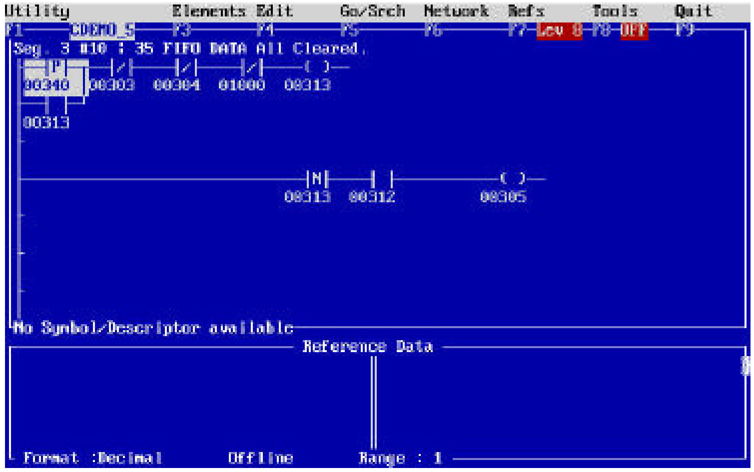


Figure 39. Segment 3 Network 10 – Resume Cyclic XMIT Poll Logic

Segment 3 Networks 11 through 20

As illustrated in Figure 31 – The first 10 instructions in the buffer are to read data from the Modbus registers in the DPU or PCD and stack them in the PLC for later data processing to perform the load shedding/load restoration (line sectionalizing). Figure 31 illustrates in the FILE 2 explanation, that whenever the POINTER from number 1 to 10 is placed in the FIFO (if an interrupt command is required) or if the UCTR instruction in Segment 3 Network2 changed within it's sequence, the data is transferred as illustrated. Networks 11 through 20 perform the following:

- If the SUB and FIN combination logic construct is energized by the preceding contact, the FIFO is filled with the queue'd command for processing by the XMIT block. This stops the cyclic polling (if occurring) and schedules the command for execution in the next 100 mS.
- When the XMIT block executes and receives the successful transmission, the data received is transferred from the XMIT block buffer and transmitted to the PLC data storage buffer 41750 through 41850. The data may be viewed by an operator interface such as MAGELIS, stored for further processing (decisions on whether to perform the line sectionalizing), or stored in other memory areas for data buffering/concentration for transfer to a host device at a later date.

The contact to the left of the rail (1st logic construct) are those which schedule the XMIT transmission.

Figures 40 through 49 illustrate the data FIFO instruction queue initiation and the data storage mechanism.

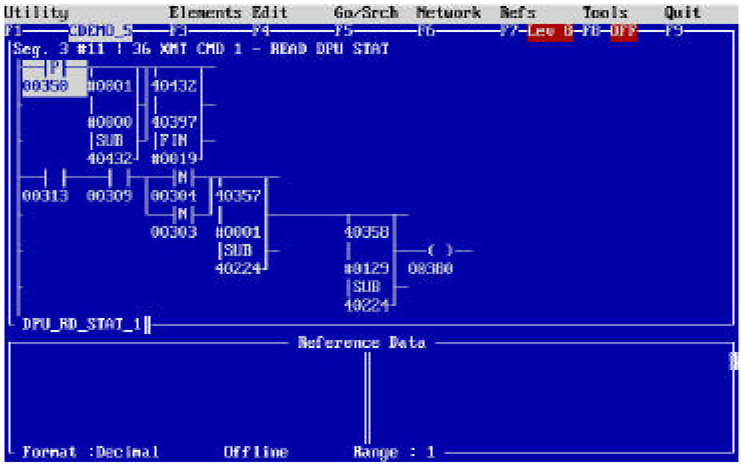


Figure 40. Segment 3 Network 11 – Read DPU Status Information or FIFO Instruction Load

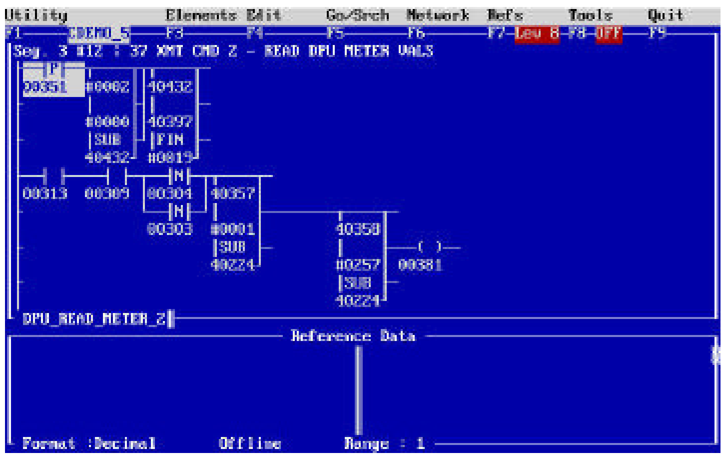


Figure 41. Segment 3 Network 12 – Read DPU Metering Information or FIFO Instruction Load

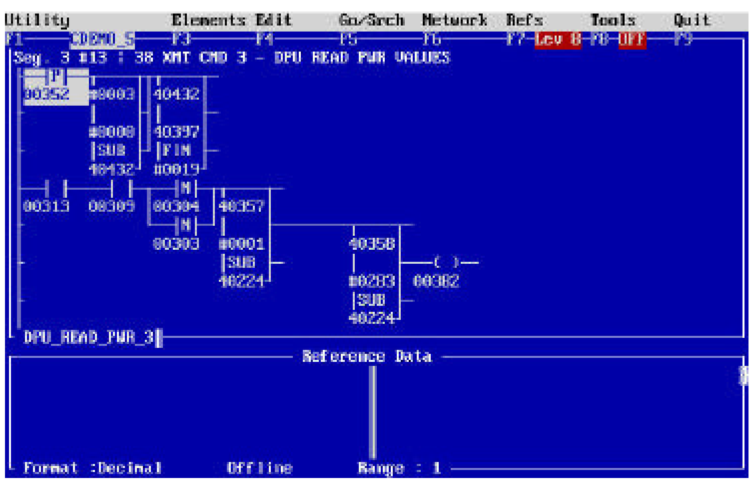


Figure 42. Segment 3 Network 13 – Read DPU Power Information or FIFO Instruction Load

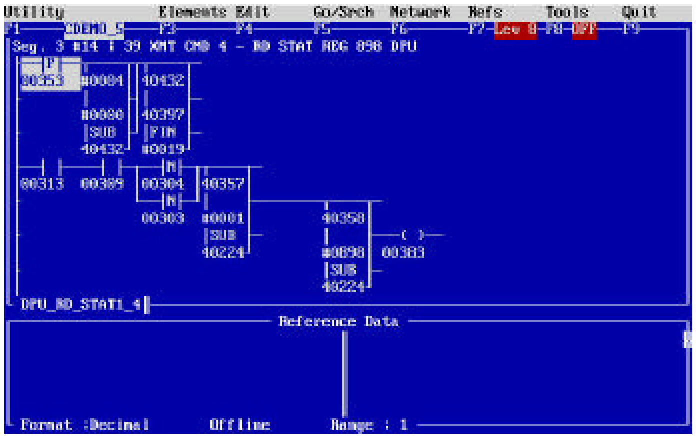


Figure 43. Segment 3 Network 14 – Read DPU Breaker Status Information or FIFO Instruction Load

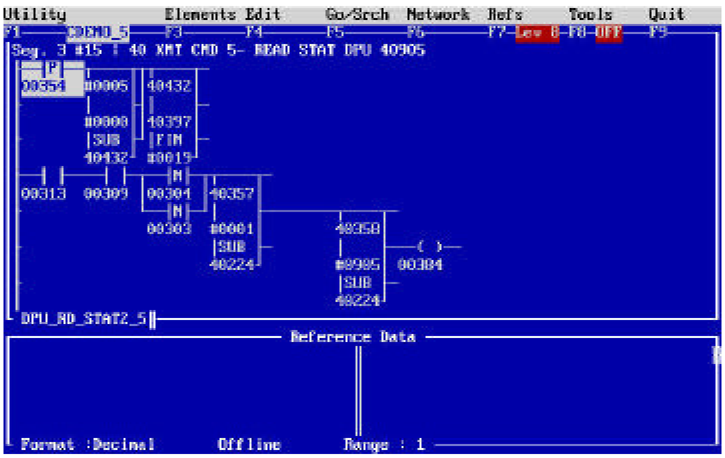


Figure 44. Segment 3 Network 15 – Read DPU Status Information or FIFO Instruction Load

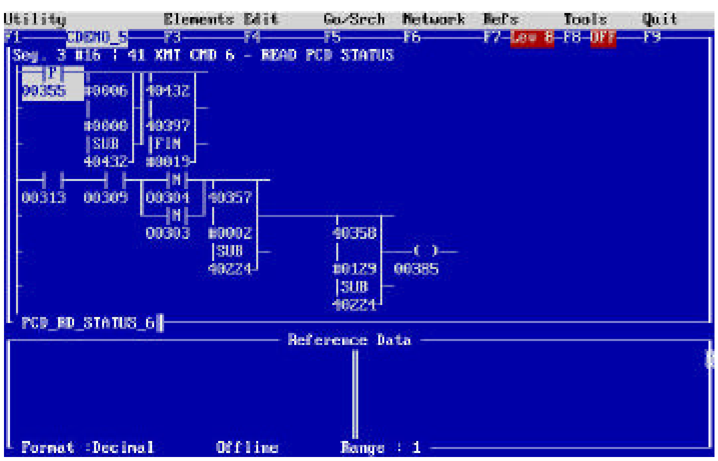


Figure 45. Segment 3 Network 16 – Read PCD Status Information or FIFO Instruction Load

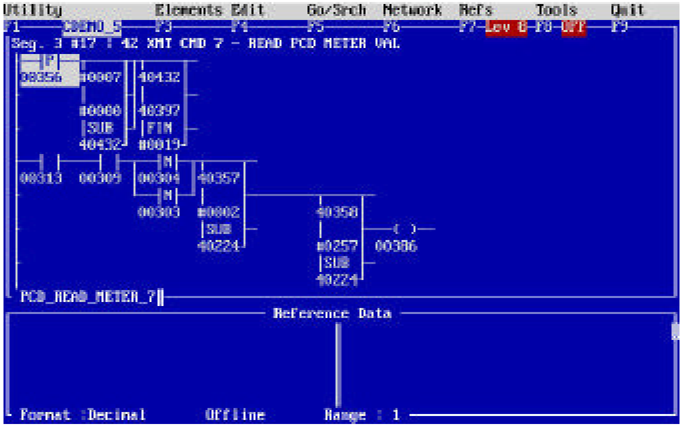


Figure 46. Segment 3 Network 11 – Read PCD Metering Information or FIFO Instruction Load

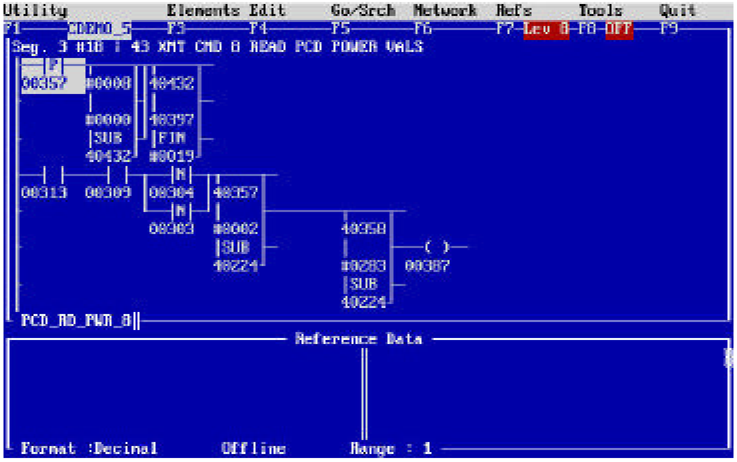


Figure 47. Segment 3 Network 18 – Read PCD Power Information or FIFO Instruction Load

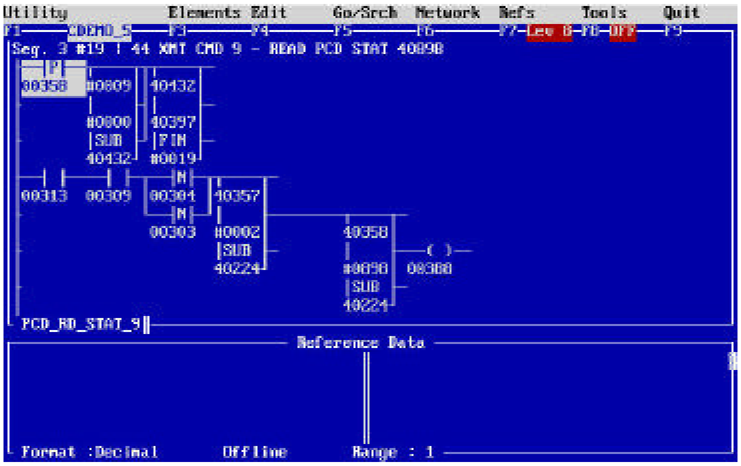


Figure 48. Segment 3 Network 19 – Read PCD Breaker Status Information or FIFO Instruction Load

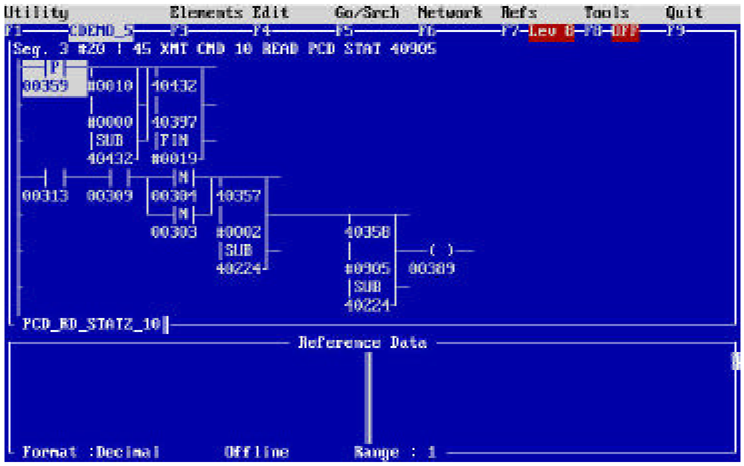


Figure 49. Segment 3 Network 20 – Read PCD Status Information or FIFO Instruction Load

Segment 3 Networks 21 through 30

As the previous networks 11 through 20 only data access instructions were programmed in the device. Networks 21 through 30 perform control instructions. As illustrated in the DPU2000R Automation Manual and the PCD2000 Modbus Protocol documents, the procedure for performing control is to write a group of registers parameterizing the control (usually writing 5 consecutive registers) and then writing one single register with the execute command (usually 1) and send it to the relay within 100 seconds of the parameterization commands. As illustrated in Figures 51 through 60, the procedure to do this is shown in Figure 50.

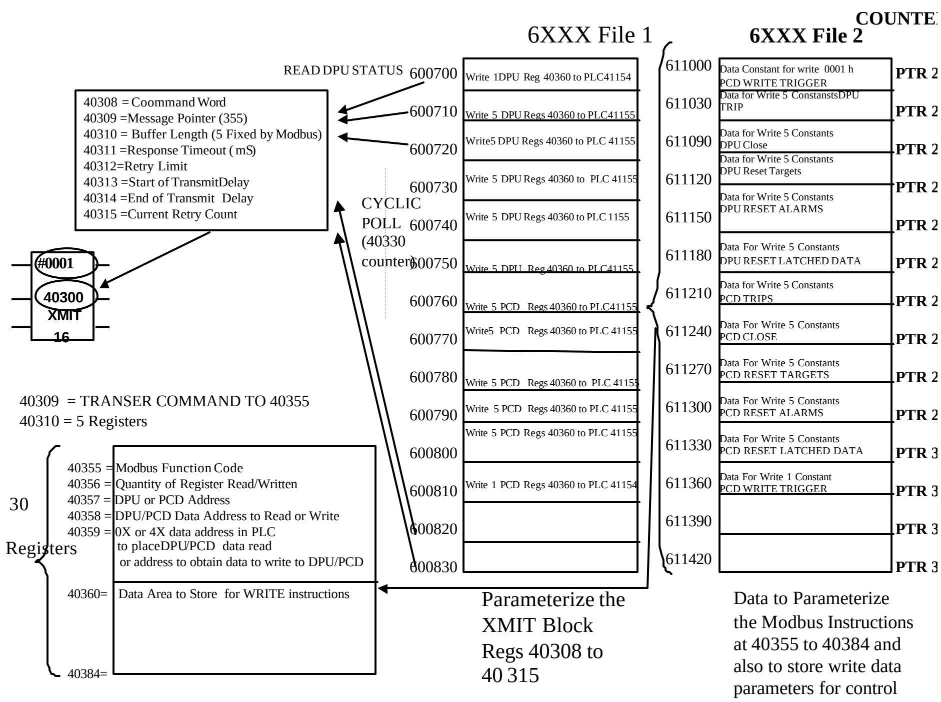


Figure 50. Write Ladder Logic Methodology

In order to do a write instruction for the DPU, the FIFO must be preloaded with an instruction between 21 through 25 and then the FIFO must be loaded with the trigger instruction (a Write of 1 to Register 41154) which is pointer 20. In order to do a write instruction for the DPU, the FIFO must be preloaded with an instruction between 26 through 30 and then the FIFO must be loaded with the trigger instruction (a Write of 1 to Register 41154) which is pointer 31. Figures 51 – 60 illustrates the ladder logic to perform the base relay control and read data structures by which this entire program is predicated upon.

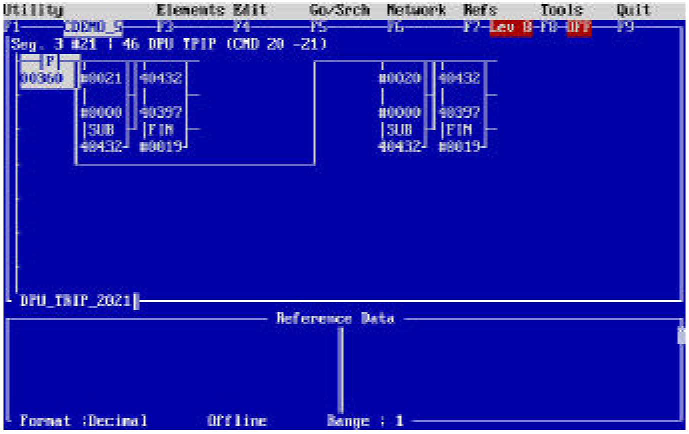


Figure 51. Segment 3 Network 21 - Place DPU Trip Command in FIFO

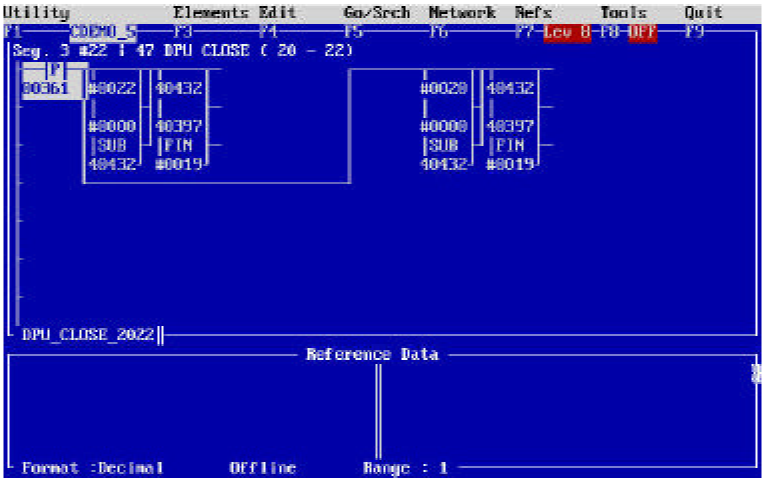


Figure 52. Segment 3 Network 22 - Place DPU Close Command in FIFO

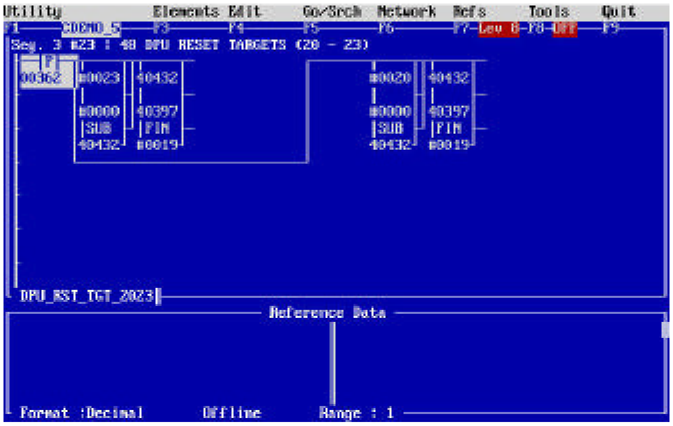


Figure 53. Segment 3 Network 23 - Place DPU Reset Targets Command in FIFO

Figure 54. Segment 3 Network 24 - Place DPU Reset Alarms Command in FIFO

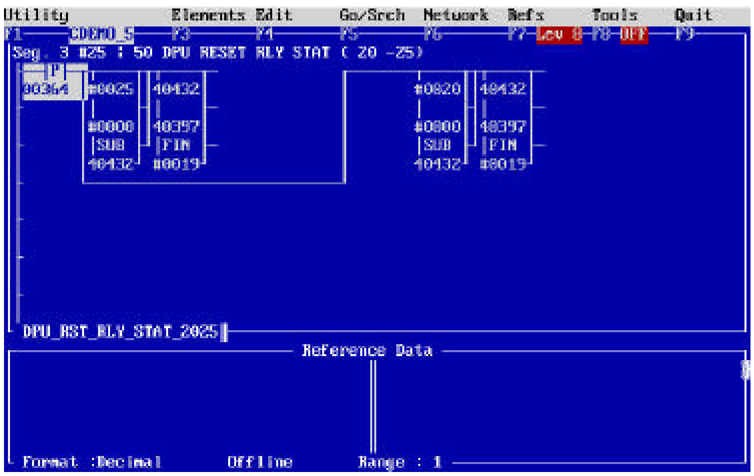


Figure 55. Segment 3 Network 25 - Place DPU Reset Status Command in FIFO

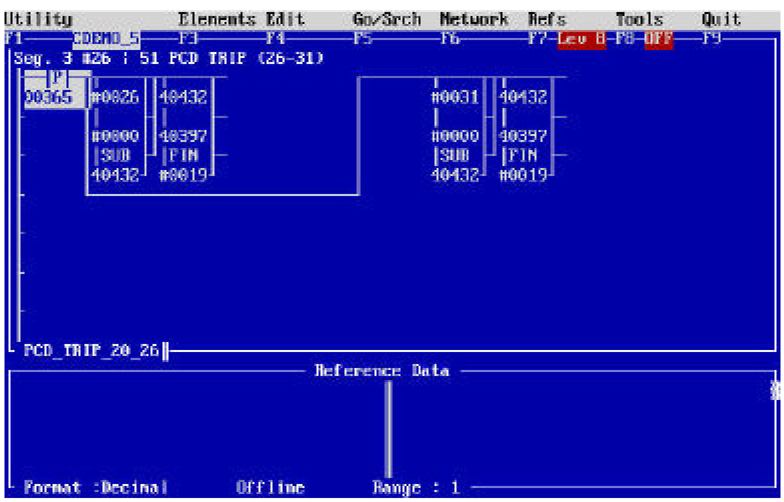


Figure 56. Segment 3 Network 26 – Place PCD Breaker Trip Command in FIFO

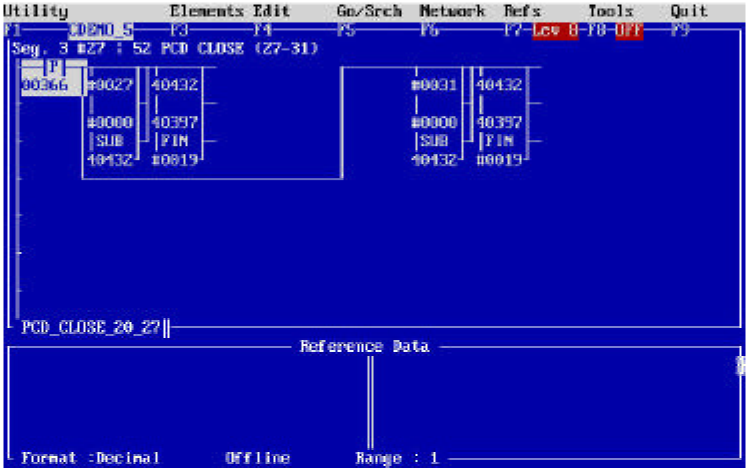


Figure 57. Segment 3 Network 27 - Place PCD Close Command in FIFO

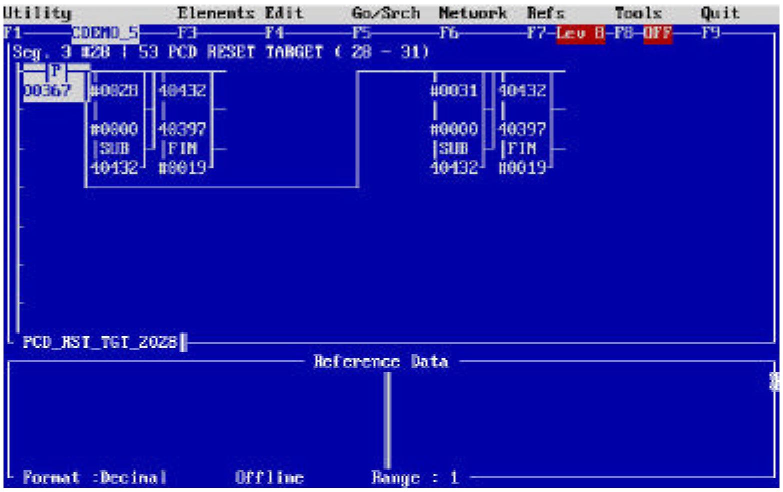


Figure 58. Segment 3 Network 28 - Place PCD Reset Targets Command in FIFO

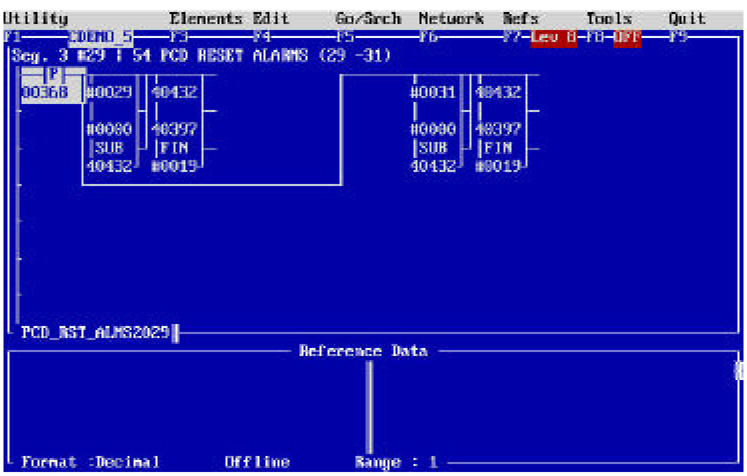


Figure 59. Segment 3 Network 29 - Place PCD Reset Alarms Command in FIFO

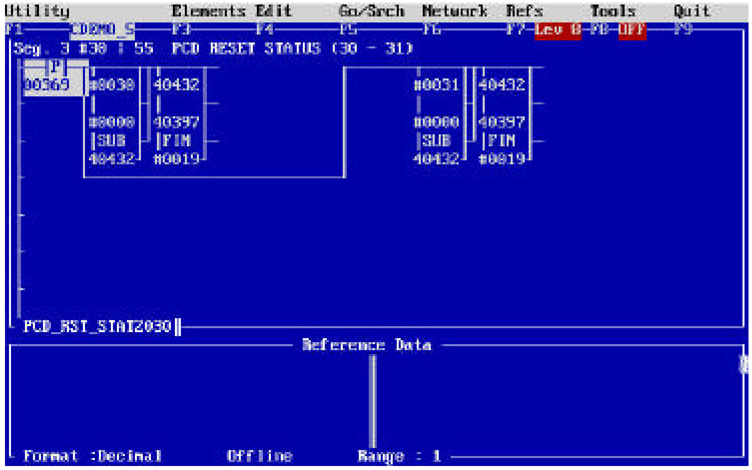


Figure 60. Segment 3 Network 30 - Place PCD Reset Status Command in FIFO

Segment 4 Network 1 – Operator Interface Control Screens

In this example, the PLC program exists as a central data concentrator. In this case, the program was developed to have a register be set in order to trigger the control instructions via an operator interface. The MMI control screens are described herein on a network to network basis.

Register 40051 is the input bit control register (the MAGELIS sets the bit momentarily) and the ladder logic fills the FIFO with the appropriate command for toggling the graphic. Bit 16 or 14 in the word is set to indicate that automatic or manual control for restoration is followed. Automatic restoration allows the logic for restoration to be enacted. If the Manual control is selected, the operator via the operator screen controls restoration.

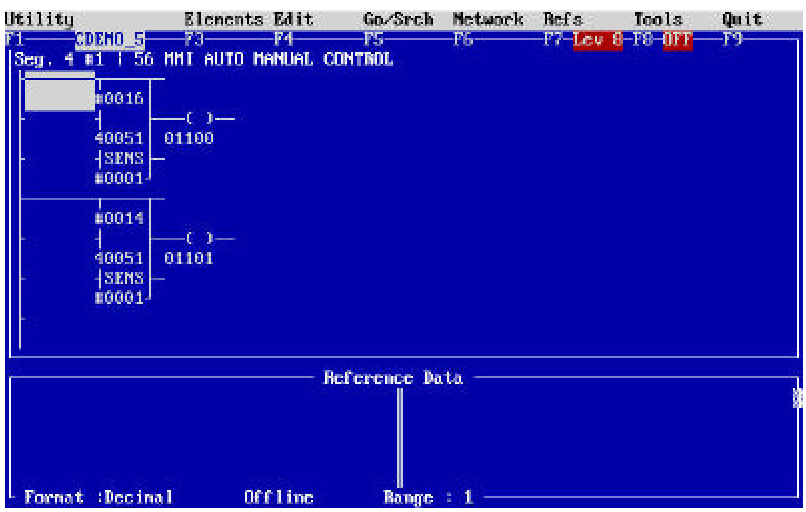


Figure 61. Segment 4 Network 1 - MAGELIS F1 and F2 Function Key Auto Manual Control Logic

Segment 4 Network 2

This is more MMI control logic required for the MAGELIS operator interface. NOTE the pushbuttons for trip, close and reset operations only operate when the system is in AUTOMATIC mode.

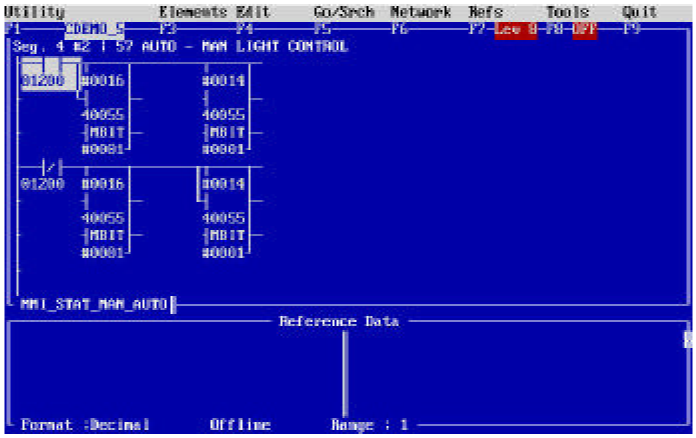


Figure 62. Segment 4 Network 2 - MAGELIS F1 and F2 Function Key LED Control Auto Manual Control Logic

Segment 4 Network 3

This network upon the MMI control screen being issues a system reset, the pending control operations, buffers and latched commands are reset to an initial state.

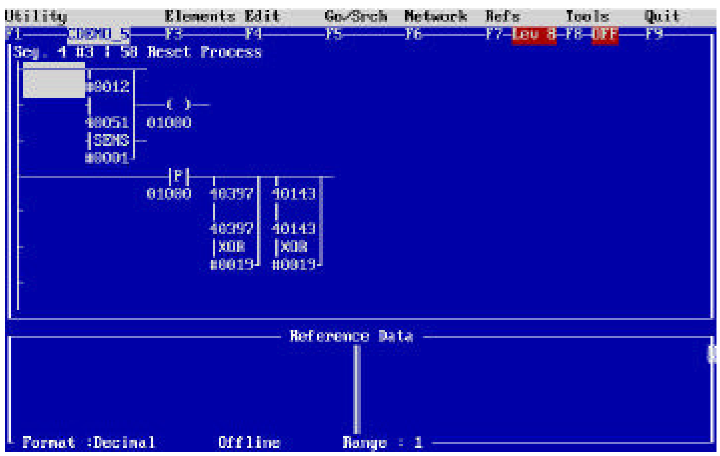


Figure 63. Segment 4 Network 3 – System Reset Logic

Segment 4 Network 4

If the control key for a MANUAL TRIP of the DPU is depressed on the MMI, this logic construct loads the FIFO with the XMIT pointer commands 21,20 to perform a breaker trip operation on the DPU2000R. Bit 15 of Register 40051 is set by the MMI to trigger this instruction (SENS). The ladder logic is illustrated in Figure 64.

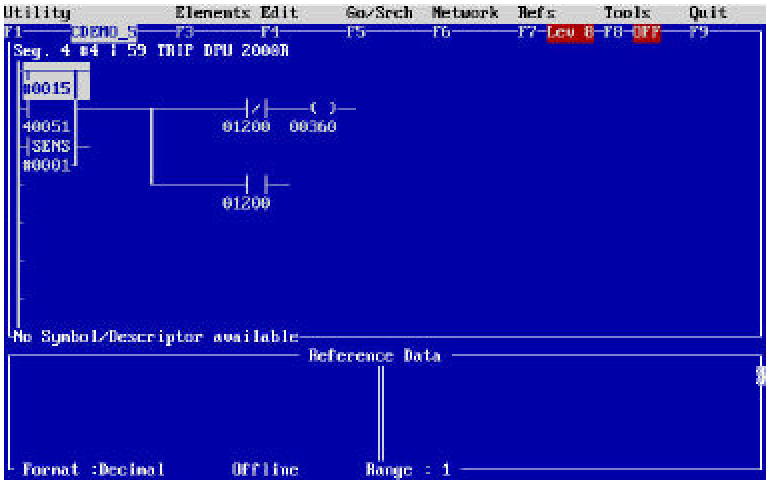


Figure 64. Segment 4 Network 4 - MAGELIS Pushbutton Manual Trip Logic

Segment 4 Network 5

If the control key for a MANUAL CLOSE of the DPU is depressed on the MMI, this logic construct loads the FIFO with the XMIT pointer commands 22,20 to perform a breaker trip operation on the DPU2000R. Bit 13 of Register 40051 is set by the MMI to trigger this instruction (SENS). The ladder Logic is illustrated in Figure 65.

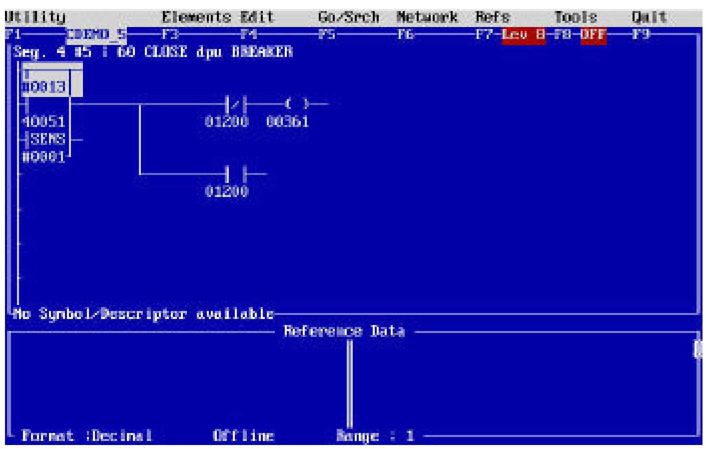


Figure 65. Segment 4 Network 5 - MAGELIS Manual Close Pushbutton Logic

Segment 4 Network 6

If the control key for a MANUAL TRIP of the PCD is depressed on the MMI, this logic construct loads the FIFO with the XMIT pointer commands 26,31 to perform a breaker trip operation on the DPU2000R. Bit 11 of Register 40051 is set by the MMI to trigger this instruction (SENS).

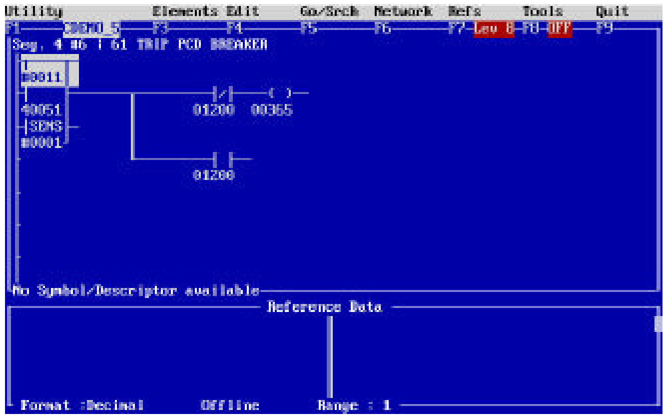


Figure 66. Segment 4 Network 6 - MAGELIS PCD Manual Trip Pushbutton Logic

Segment 4 Network 7

If the control key for a MANUAL CLOSE of the PCD is depressed on the MMI, this logic construct loads the FIFO with the XMIT pointer commands 27,31 to perform a breaker trip operation on the DPU2000R. Bit 5 of Register 40051 is set by the MMI to trigger this instruction (SENS).

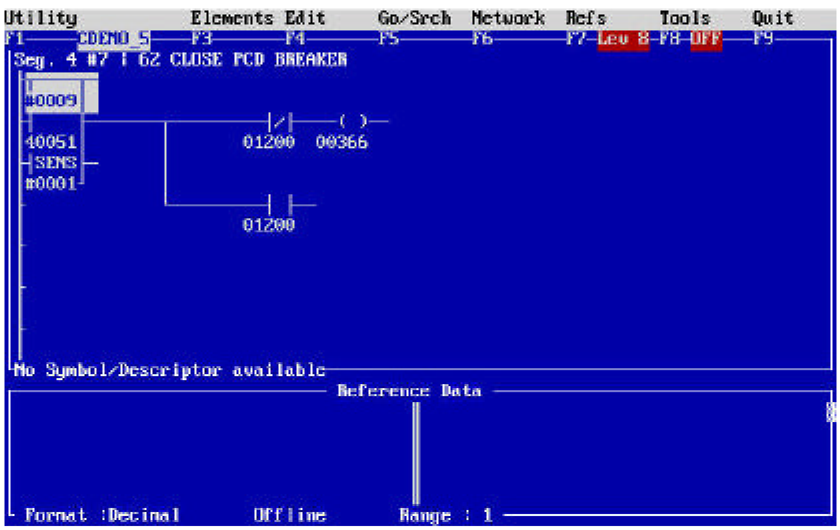


Figure 67. Segment 4 Network 7 - MAGELIS PCD Manual Close Pushbutton Logic

Segment 4 Network 8

If the control key for a MANUAL TRIP of the TPU is depressed on the MMI, this logic construct loads the FIFO with the MSTR pointer commands 7,6 to perform a breaker trip operation on the DPU2000R. Bit 11 of Register 40051 is set by the MMI to trigger this instruction (SENS). Note this operation sends a Modbus Plus command to the TPU.

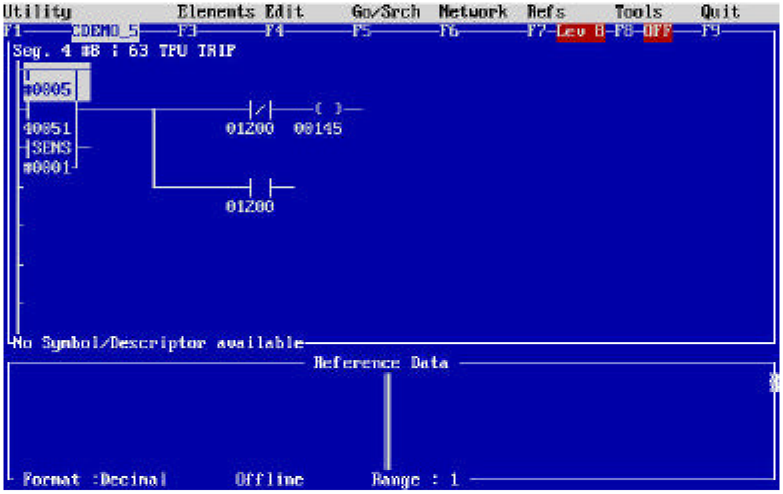


Figure 68. Segment 4 Network 8 - MAGELIS TPU Manual Trip Pushbutton Logic

Segment 4 Network 9

The MAGELIS operator interface does not display Floating Point Values. All the mathematics in this program is performed using floating point math. In order to display the information on the MMI display (MAGELIS), it must be converted from floating point to integer for display, Kwatts for phases A, B, C, and loading of the DPU prior to the TPU trip. These values are calculated using floating point math instructions.

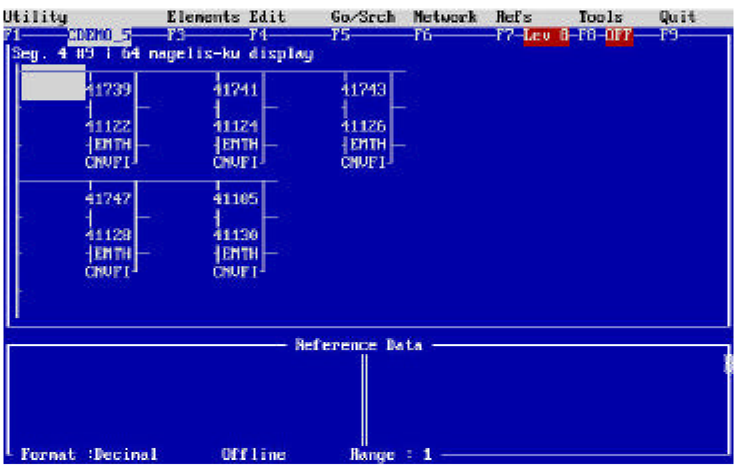


Figure 69. Segment 4 Network 9 - MAGELIS Watt Hour Display in Integer Units

Segment 4 Network 10,11,12

The operator is also able to reset the target information via the MAGELIS MMI. If the unit is in manual mode, the operator may depress the function key to reset the targets on the TPU (BIT 8 REGISTER 40051) DPU (BIT 10 REGISTER 40051) AND PCD (BIT 6 REGISTER 40051). The ladder logic for these constructs are listed in Figures 70 through 72.

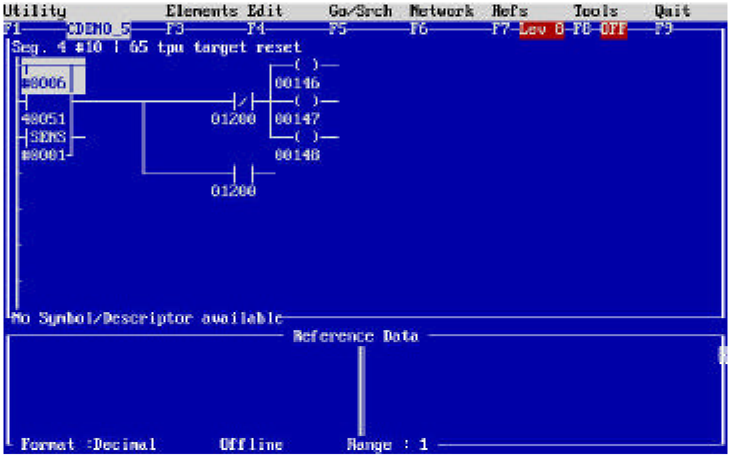


Figure 70. Segment 4 Network 10 - MAGELIS TPU Manual Trip Pushbutton Logic

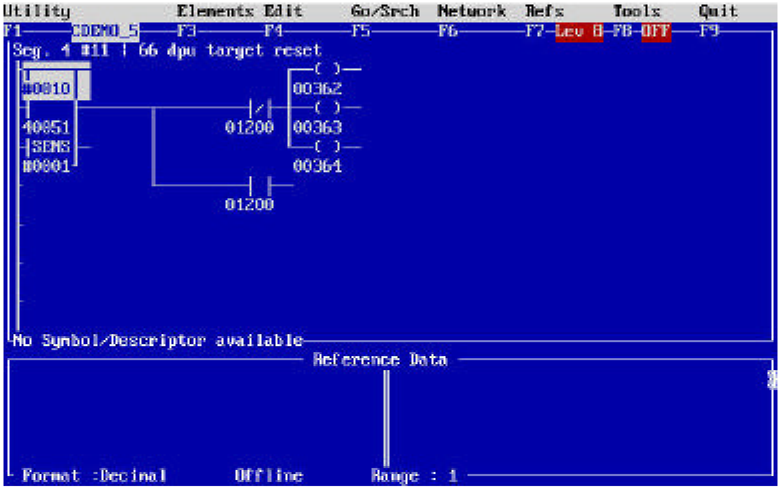


Figure 71. Segment 4 Network 11 - MAGELIS TPU Target Reset Pushbutton Logic

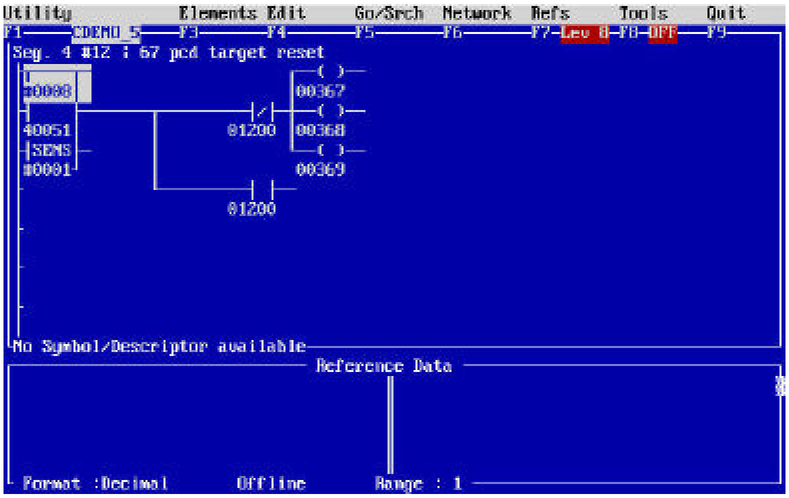


Figure 72. Segment 4 Network 12 - MAGELIS PCD Manual Target Reset Pushbutton Logic

Segment 4 Networks 13 AND 14

The MMI displays data via bit data which toggles the graphics. The logic constructs in Networks 13 and 14 illustrate the logic to indicate on the display the breaker status of the TPU as well as the AUTO/MANUAL PLC program control. The logic is illustrated in Figures 73 and 74.

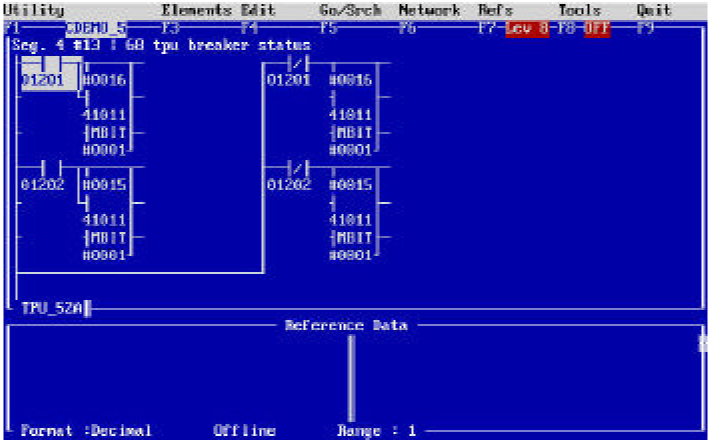


Figure 73. Segment 4 Network 13 - MAGELIS PCD Breaker Status Logic to Manipulate the Screen Graphics

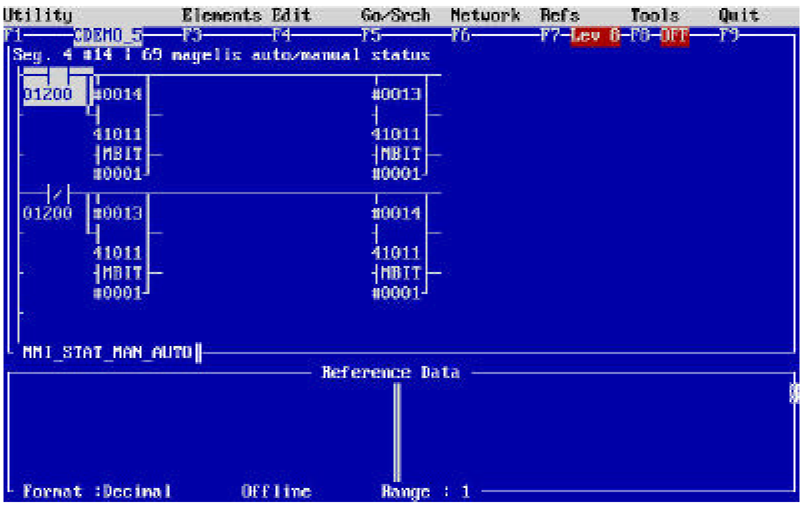


Figure 74. Segment 4 Network 12 - MAGELIS Auto Manual Screen Status Icon Logic

Segments 5 and 6 performs the logic which initiates the procedure upon a TPU monitored/protected feeder trip. The explanation of the logic follows.

Segment 5 Network 1

Since 52a and 52b are not direct points within the TPU, the PLC program reads WINDING currents for phase A (41702) , B (41704) , and C (41706) and if the currents are less than 2 amperes, the TPU denotes the relay as tripped and generated 52a (01201) and 52b (01202) internal status coils. Note that labels have been affixed to each of the registers contacts and coils. The logic is illustrated in Figure 75.

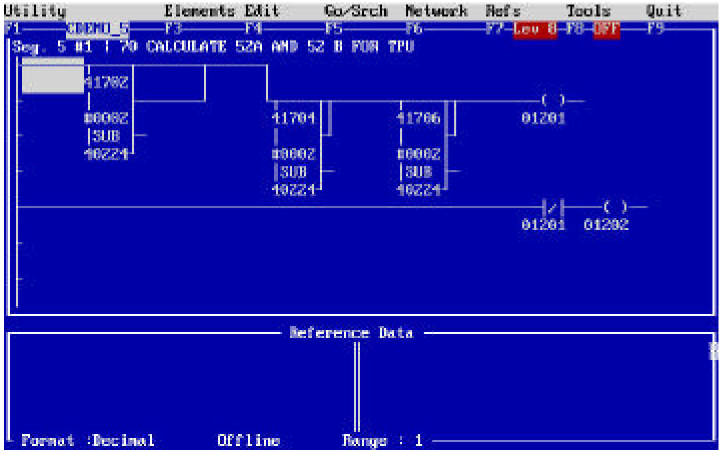


Figure 75. Segment 5 Network 1 - Calculate 52A and 52B on TPU Since Contacts are not Mapped

Segment 5 Networks 2, 3, 4, and 5

Segments 2, 3, 4, and 5 (for the sake of this program since it is a demonstration and illustration of the power of the relay and PLC's capabilties), convert the KW of Phase A, B, and C, which was read from the TPU and supplied to the feeder (controlled by the PCD). The Compact 984 PLC only performs integer math on numbers from 0000 to 9999. The PLC calls a subroutine to convert the number from a 32 bit number integer (which is obtained via the MSTR block and stored in Registers 41728 and 41729 [Phase A integer Units], 41730 and 41731 [Phase B Integer Units] and, 41732 and 41733 [Phase C Integer Units]) and converted into floating point numbers which enable easy mathematical conversion feeder load control. The floating point converted numbers are calculated in the subroutine segment (segment 7) and are labeled as JSR 2 and JSR 1. The floating point numbers are located in Registers 41739 and 41740 [Phase A Floating Point quantity]], 41741 and 41742 [Phase B Floating Point quantity], and 41743 and 41744 [Phase C Floating Point quantity]. Since this program was tested on a simulator, the values were made to be positive quantities for the sake of illustration in a demonstration environment.

Network 5 adds each of the quantities and stores it for comparison to a predefined feeder supply value which is compared when the line sectionalizing occurs.

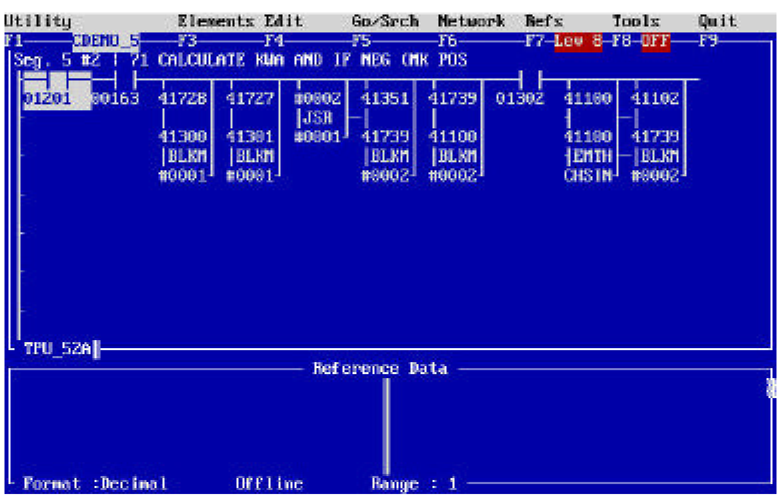


Figure 76. Segment 5 Network 2 - Calculate KW for Phase A

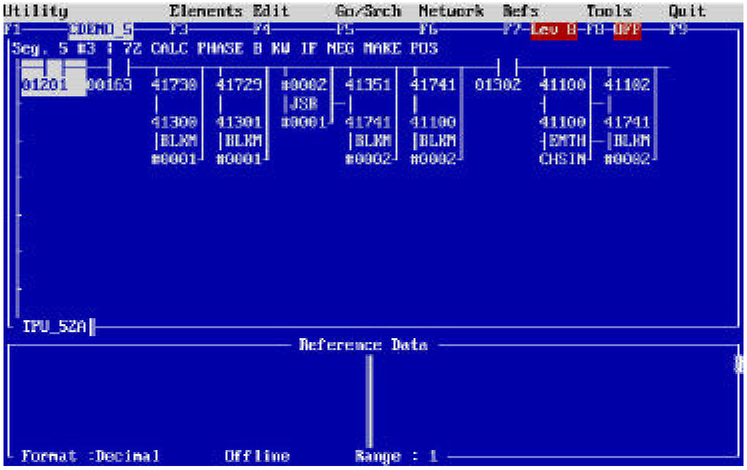


Figure 77. Segment 5 Network 3 - Calculate KW for Phase B

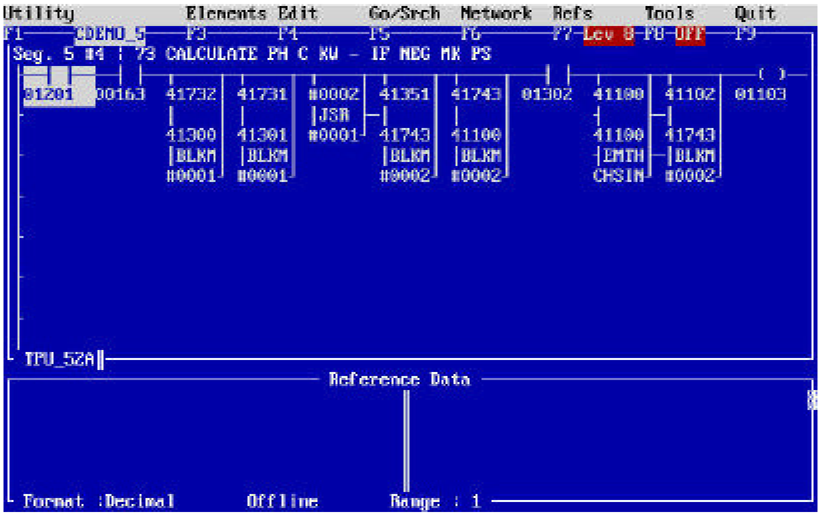


Figure 78. Segment 5 Network 4 - Calculate KW for Phase C

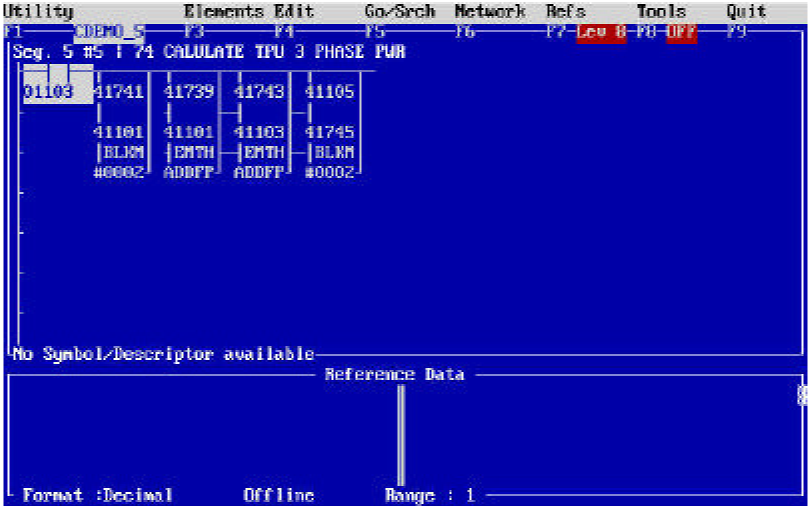


Figure 79. Segment 5 Network 5 - Calculate KW for All Three Phases

Segment 5 Network 6

Since the TPU does not have 52a and 52b reported for a trip condition (since it is not wired into the simulator in this example), if the current of each of the phases is a value less than 2 amps, the TPU is determined to be tripped. This instruction construct sends a trip command (via the commands 6 and 7) via the FIFO for the MSTR block. This trips the TPU to ensure the state of the unit. The network logic is illustrated as per Figure 3 of this note. This network performs the action in MANUAL mode.

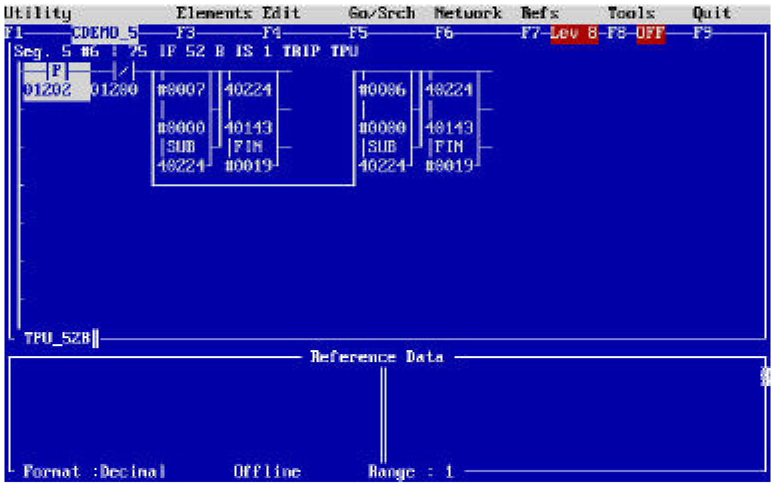


Figure 80. Segment 5 Network 6 – Trip TPU if Readings are Less Than 1 A Per Phase (Since 52A and B Contacts are not Wired into Demo Case)

Segment 6 Network 1

This network (although out of place in the scheme of things), takes a pushbutton input from the Magelis MMI and places the PLC program in the MANUAL or AUTOMATIC restoration status. If coil 01200 is a energized, the program is in AUTO mode. If the coil 01200 is de-energized, the program is in manual mode. The logic is illustrated in Figure 81.

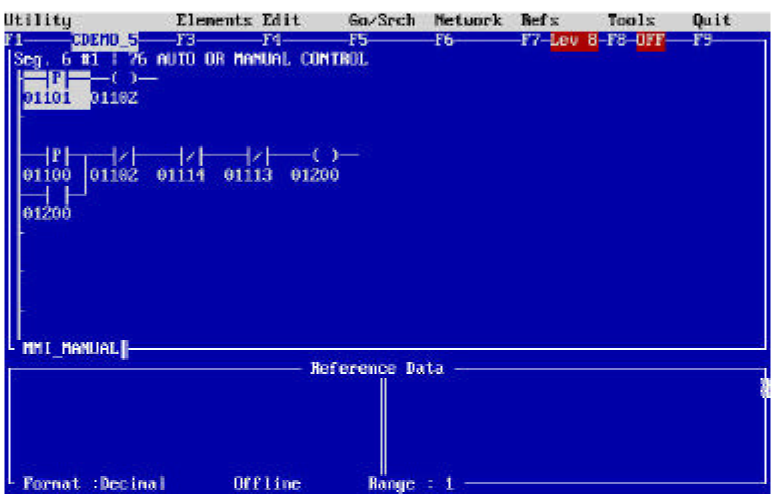


Figure 81. Segment 6 Network 1 – Upon MMI MAGELIS Action, Place the Program in Manual or Automatic Restoration Mode

Segment 6 Network 2

This network checks the TPU TARGET status which was stored in Register 41725. If a target is on the front panel interface, an indication is given by coil 001150 which is used in this program. The logic is illustrated in Figure 82.

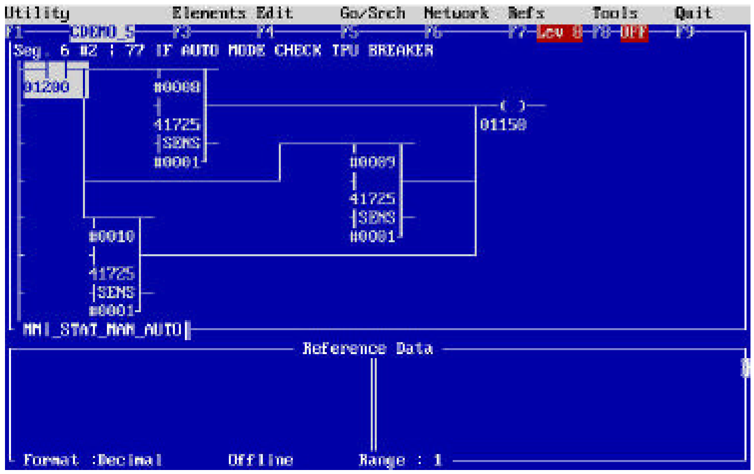


Figure 82. Segment 5 Network 6 - Trip TPU if Reading are Less Than 1 A Per Phase (Since 52A and B Contacts are not Wired into Demo Case)

Segment 6 Network 3

Since the TPU does not have 52a and 52b reported for a trip condition (since it is not wired into the simulator in this example), if the current of each of the phases is a value less than 2 amps, the TPU is determined to be tripped. This instruction construct sends a trip command (via the commands 6 and 7) via the FIFO for the MSTR block. This trips the TPU to ensure the state of the unit. The network logic is illustrated in Figure 83. This network performs the action in AUTOMATIC mode. The coil 01151 carries this action to the next instruction network.

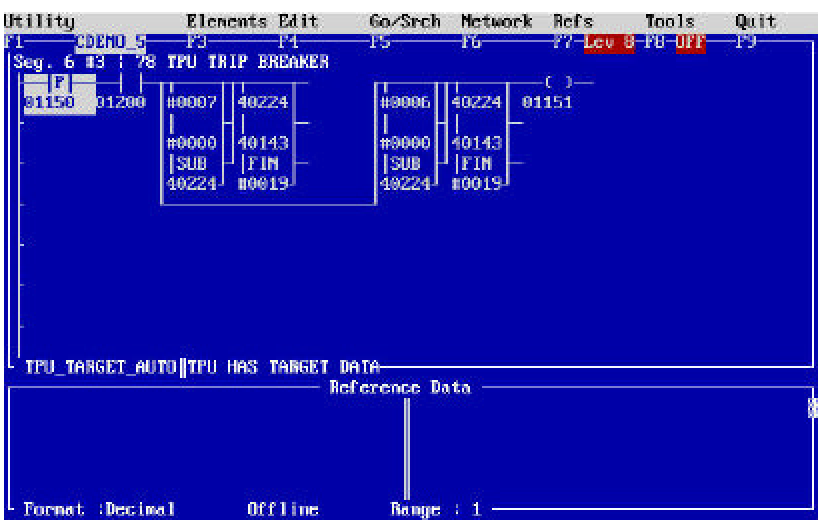


Figure 83. Segment 5 Network 6 - Trip TPU if Reading are Less Than 1 A Per Phase (Since 52A and B Contacts are not Wired into Demo Case)

Segment 6 Network 4

If there is no fault, calculate the loading prior to the trip of the TPU. This figure is used to determine if the DPU at the other end of the feeder has the capability to drive the load of the PCD2000. The ladder logic is illustrated in Figure 84 which follows.

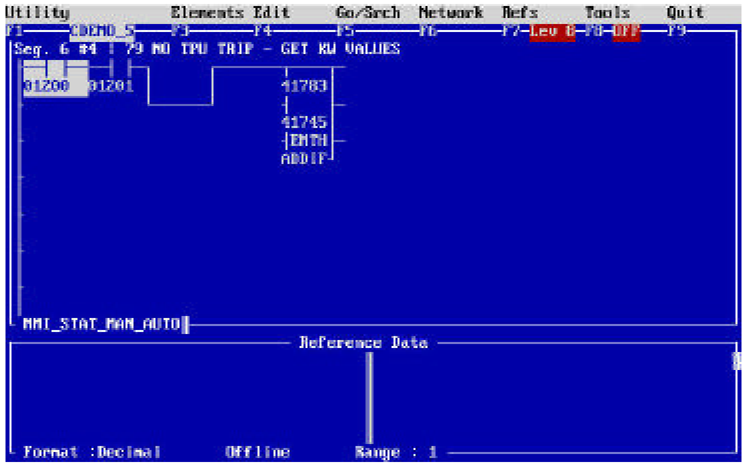


Figure 84. If No TPU Trip Calculate KW Values Prior to Trip for Later Loading Calculations for Bus Line Sectionalizing Calculations

Segment 6 Networks 5, 6, 7, 8, 9, and 10

If the loading is appropriate for the DPU to supply the PCD circuit in lieu of the TPU which tripped, the following sequence occurs.

The DPU status is checked and the breaker is closed as long as the TPU2000R breaker is tripped. The program is delayed by 3 seconds and the PCD2000 is then closed and the close is verified by the program.

The operator interface echo's the state of the restoration sequence on the operator interface as each of the steps is being performed.

The ladder logic networks are illustrated below as Figures 85 through 90.

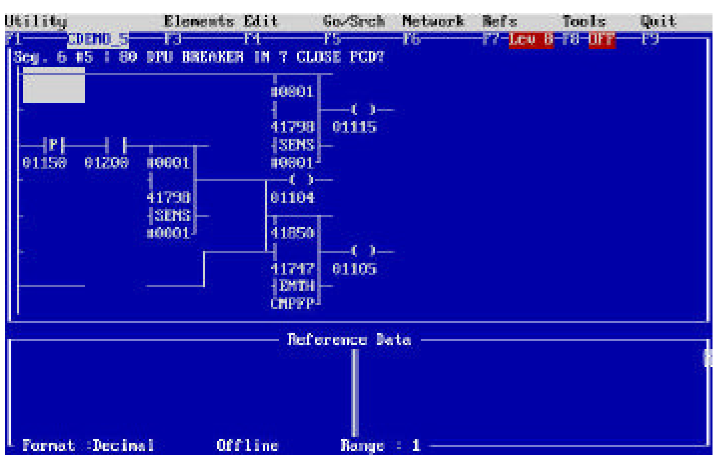


Figure 85. Segment 6 Network 5 – Check DPU Breaker Status

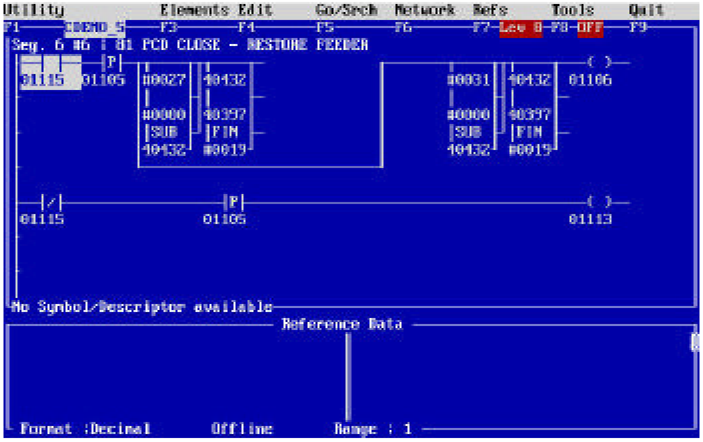


Figure 86. Segment 6 Network 6 – Close PCD in Anticipation of Feeder Restoration Upon TPU Trip

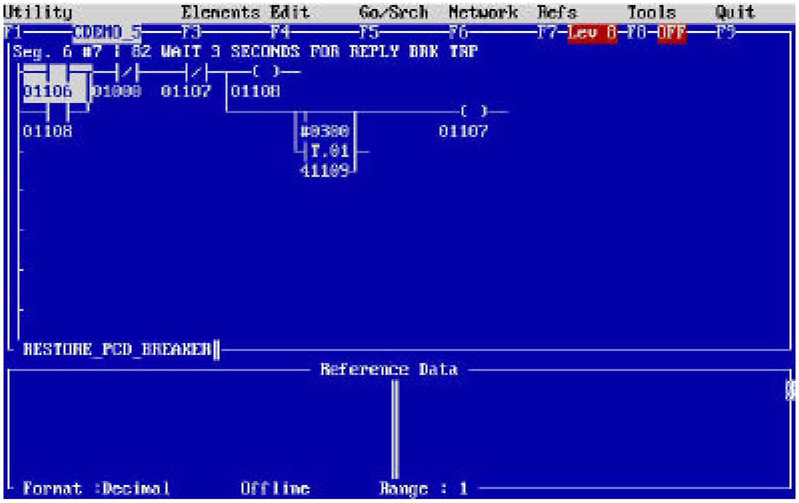


Figure 87. Segment 6 Network 7: Wait 3 Seconds for Breaker Action

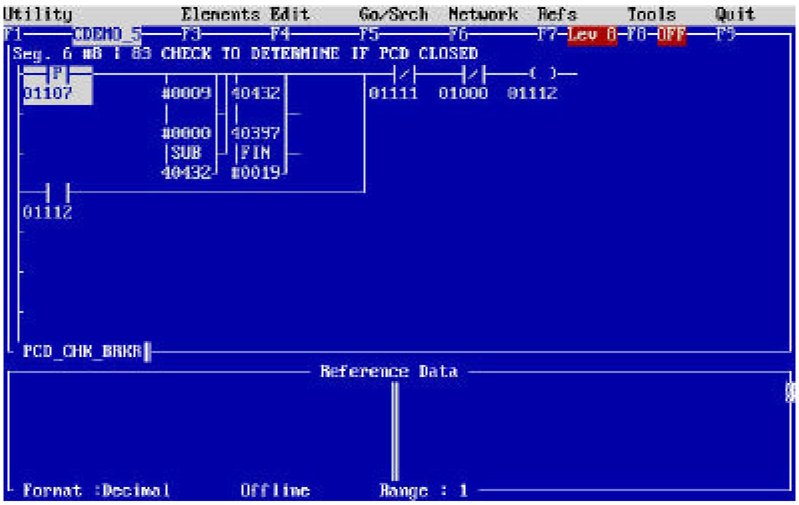


Figure 88. Segment 6 Network 8: Check to Determine if PCD is Closed

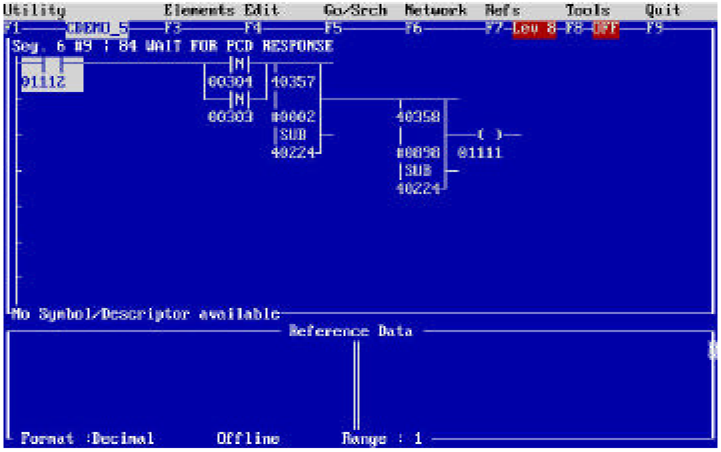


Figure 89. Segment 6 Network 9: Wait for PCD Response to Breaker Action

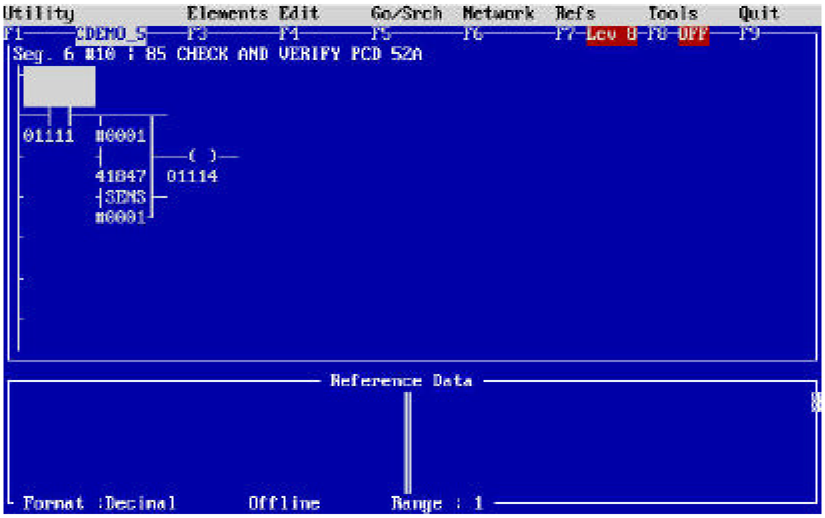


Figure 90. Segment 6 Network 10: Verify that Breaker is Closed

NOTE this program was developed for a demonstration of line restoration/sectionalizing applications. The TPU simulator used did not have breaker status, thus the need for the additional logic to calculate and maintain the correct status of the TPU breaker action (even if a manual trip command from the front panel was performed, the status of 52A and52B derived from this program is valid).

SUBROUTINES

Two subroutines are included in this program. The subroutines are called from within the main program located in Segments 1 through 6 (JSR 2) and from within the subroutine (JSR 1). The subroutines are:

SUBROUTINE 1 – Convert an UNSIGNED 32 bit double register integer into a floating point number.

INPUT INTEGER to be converted: 41300 and 41301

FLOATING POINT RESULT located in 41351 and 41352.

SUBROUTINE 2 – Convert a SIGNED 32 bit double register integer into an absolute value floating point number.

INPUT INTEGER 41300 and 41301

NORMALIZED FLOATING POINT NUMBER 41330 and 40331.

These subroutines require constants to be placed in specific registers as illustrated in the constant screen windows listed at the end of this document. The constant values are used in allowing the subroutine to calculate the numbers correctly. NOTE: these subroutines are required for three reasons:

- The TPU, DPU and PCD use true integer numbers and the PLC only calculates numbers using integer math for a range of 0000 to 9999 (Compact 984 limitation).
- The COMPACT 984 PLC can perform mathematics calculations in IEEE Floating POINT, thus a calculation must be made from the PLC numbers (0000 to 9999 or 00000000 to 99999999 [double precision integer]) to floating point numbers.
- The MAGELIS MMI cannot display IEEE floating point numbers, so the results of the floating point number must be changed to the integer format required by the MMI.

SEGMENT 7, the last segment in the program, is not set up in the ladder logic segment scheduler (as is necessary for ladder logic subroutines). As illustrated in the ladder logic segments, 1 through 9 (Figures 91 through 96), the subroutine starts with a LAB instruction and ends at the RET command. The ladder logic segments are listed with the constants required for operation.

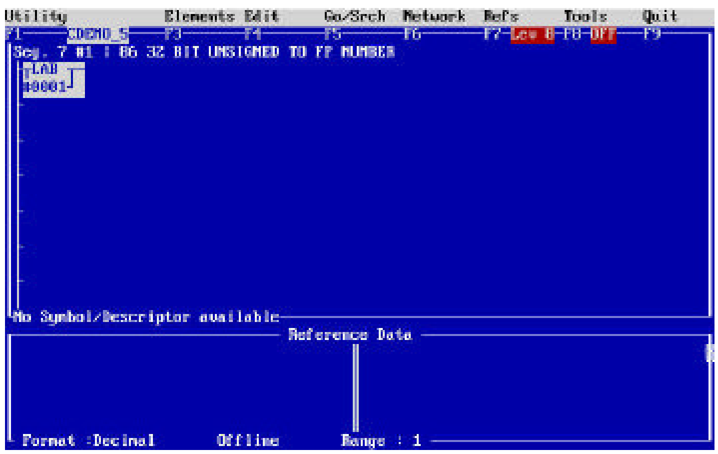


Figure 91. Segment 7 Network 1:32 Bit Integer to Floating Point Number, Subroutine 1

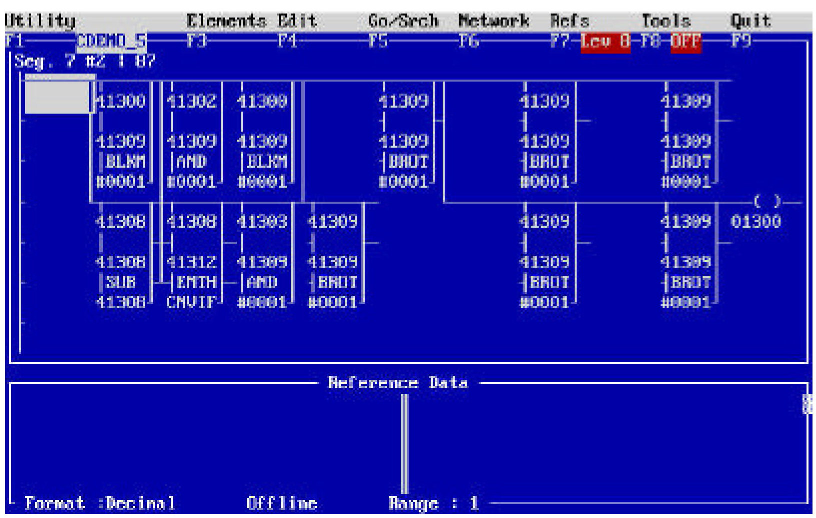


Figure 92. Segment 7 Network 2: 32 Bit Integer to Floating Point Number, Subroutine 1

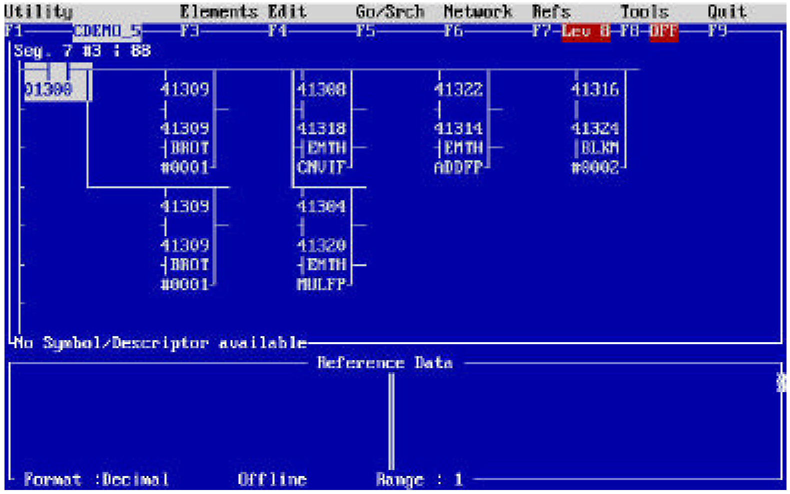


Figure 93. Segment 7 Network 3: 32 Bit Integer to Floating Point Number, Subroutine 1

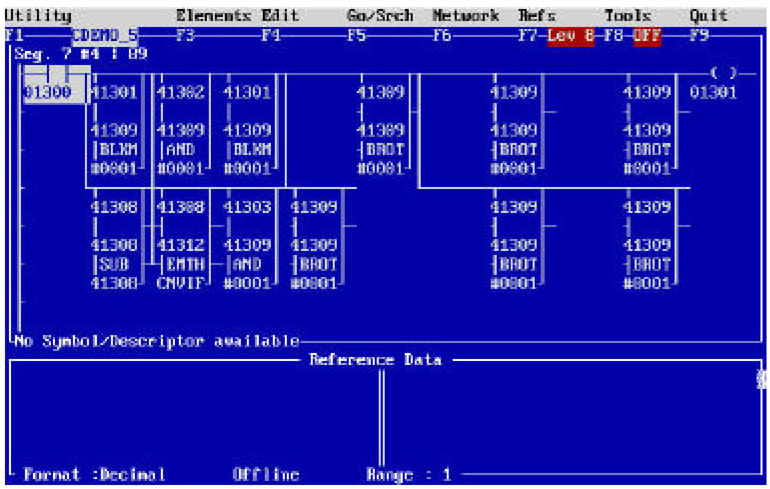


Figure 94. Segment 7 Network 4: 32 Bit Integer to Floating Point Number, Subroutine 1

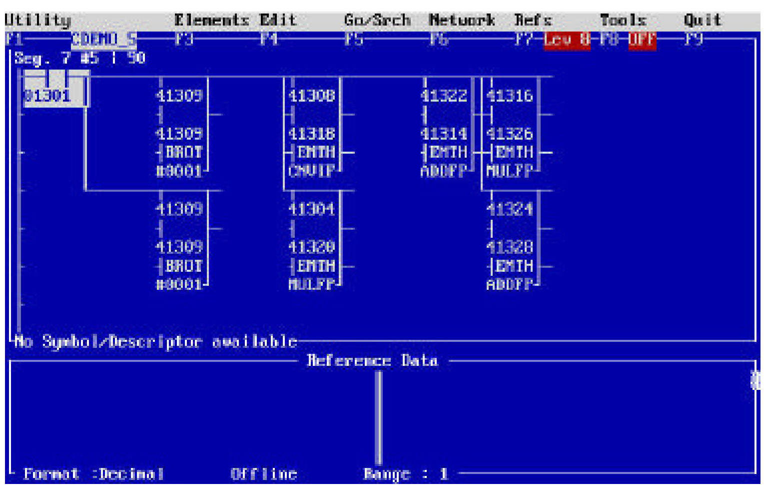


Figure 95. Segment 7 Network 5: 32 Bit Integer to Floating Point Number, Subroutine 1

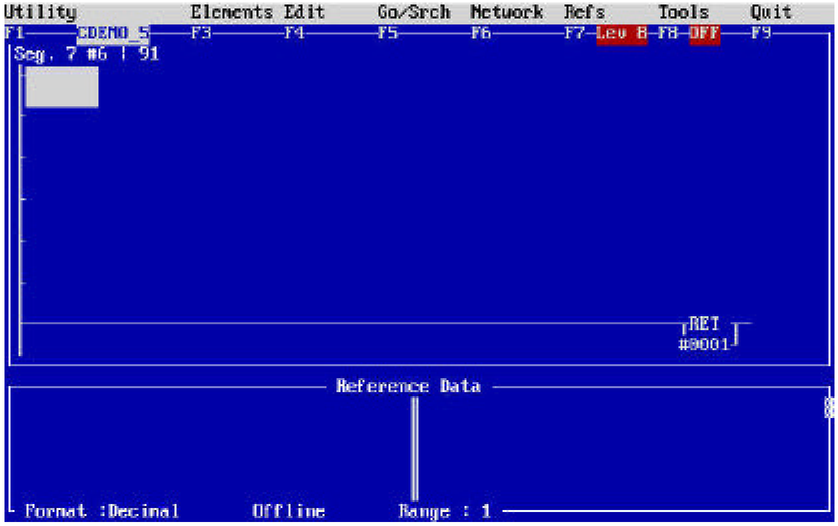


Figure 96. Segment 7 Network 6: 32 Bit Integer to Floating Point Number, Subroutine 1

Subroutine 2 uses subroutine 1 and it takes a negative number and converts it to a positive number (used for the sake of this demo to vary the KW readings using those from the simulator). This is used because the simulators use a single phase source and makes KW readings appear negative on some of the phases.

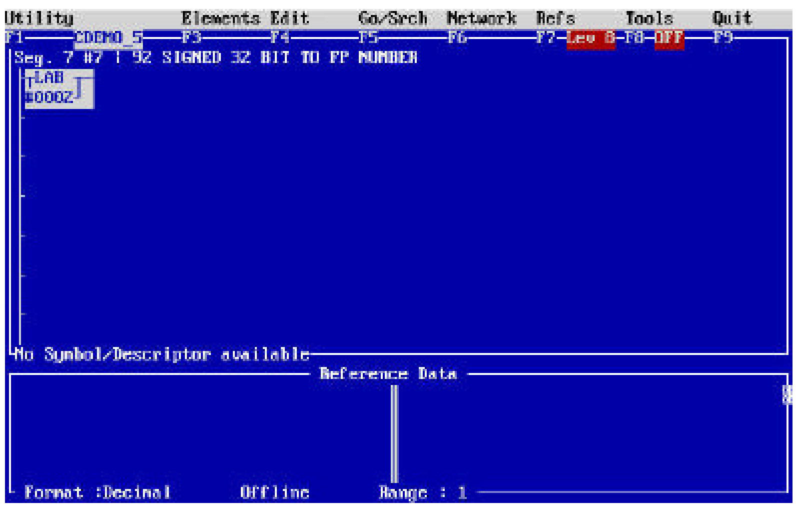


Figure 97. Segment 7 Network 7: 32 Bit Signed Integer to Floating Point Number, Subroutine 2

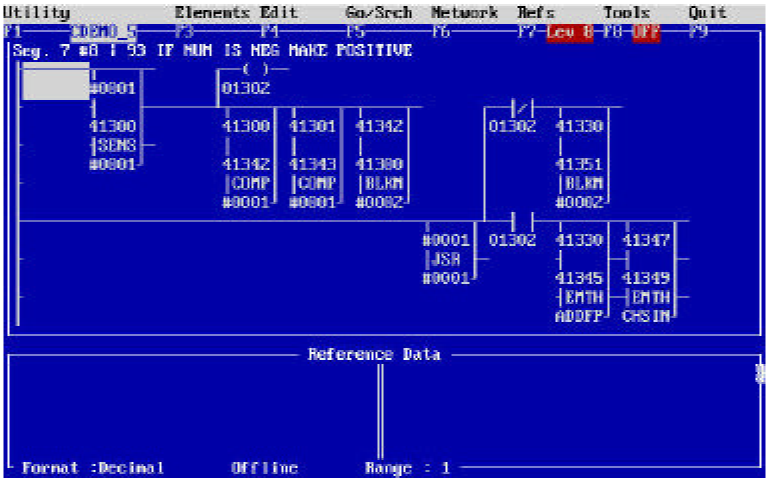


Figure 98. Segment 7 Network 8: 32 Bit Signed Integer to Floating Point Number, Subroutine 2

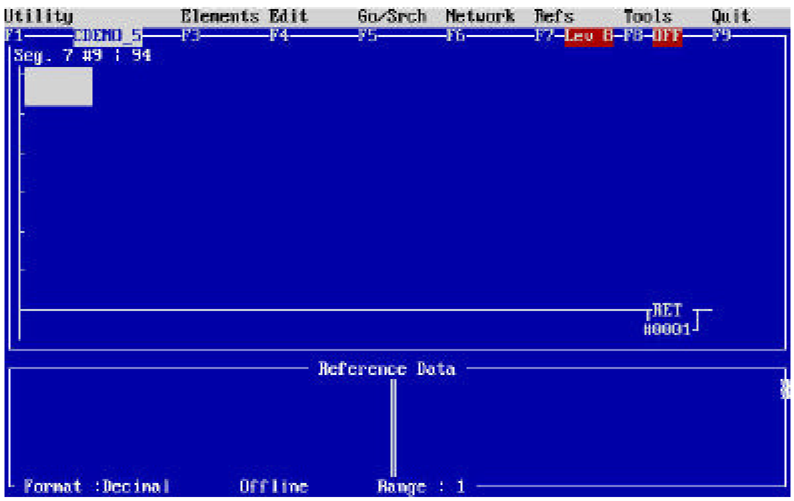
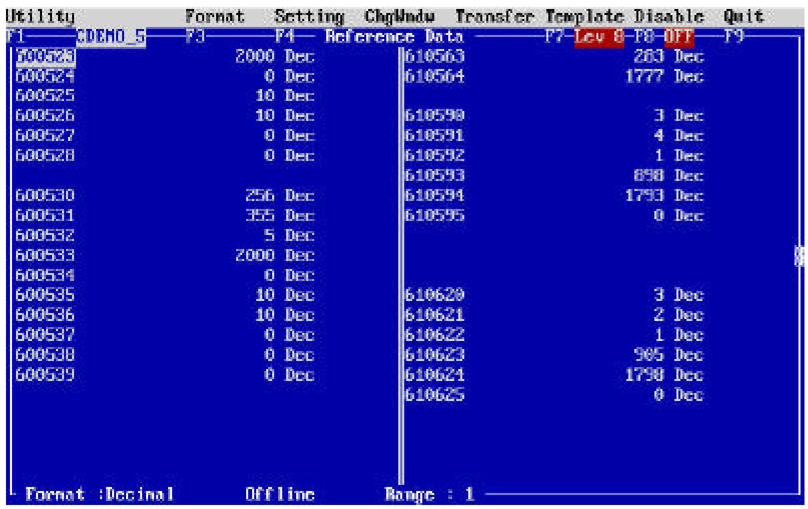


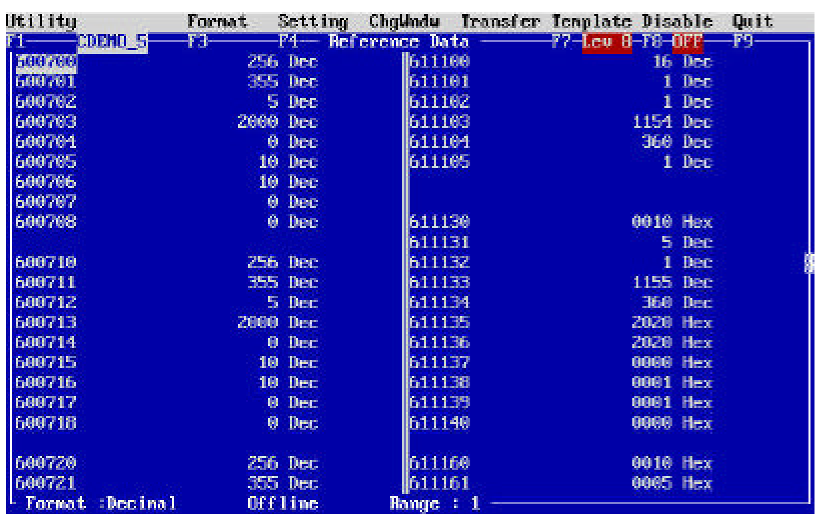
Figure 99. Segment 7 Network 9: 32 Bit Signed Integer to Floating Point Number, Subroutine 2

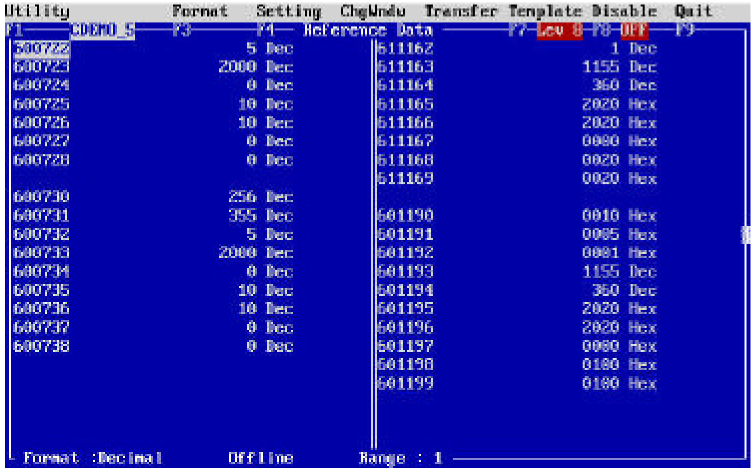
PLC Program Constants

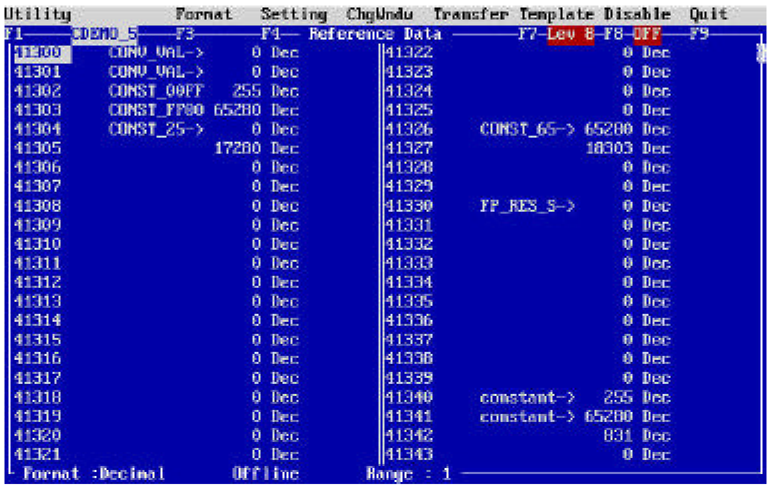
As illustrated previously, there are certain constants in 4x memory and 6x memory which must be preloaded into PLC memory for this program to function properly. The screens which follow illustrate the contents of each of the registers which are needed for this program's proper operation.


Utility Format Setting ChgWndw Transfer Template Disable Quit
F1 CDEMO_5 F3 F4 Reference Data F7 Lev 0 F8 OFF F9
600500 256 Dec 610500 3 Dec
600501 355 Dec 610501 1 Dec
600502 5 Dec 610502 1 Dec
600503 2000 Dec 610503 129 Dec
600504 0 Dec 610504 1750 Dec
600505 10 Dec
600506 10 Dec
600507 0 Dec
600510 256 Dec 610530 3 Dec
600511 355 Dec 610531 26 Dec
600512 5 Dec 610532 1 Dec
600513 2000 Dec 610533 257 Dec
600514 0 Dec 610534 1751 Dec
600515 10 Dec
600516 10 Dec
600517 0 Dec
600518 0 Dec
600520 256 Dec 610560 3 Dec
600521 355 Dec 610561 16 Dec
600522 5 Dec 610562 1 Dec
Format :Decimal Offline Range : 1


Utility Format Setting ChgWndw Transfer Template Disable Quit
F1 CDEMO_5 F3 F4 Reference Data F7 Lev 0 F8 OFF F9
600523 2000 Dec 610563 283 Dec
600524 0 Dec 610564 1777 Dec
600525 10 Dec
600526 10 Dec 610590 3 Dec
600527 0 Dec 610591 4 Dec
600528 0 Dec 610592 1 Dec
610593 898 Dec
600530 256 Dec 610594 1793 Dec
600531 355 Dec 610595 0 Dec
600532 5 Dec
600533 2000 Dec
600534 0 Dec
600535 10 Dec 610620 3 Dec
600536 10 Dec 610621 2 Dec
600537 0 Dec 610622 1 Dec
600538 0 Dec 610623 905 Dec
600539 0 Dec 610624 1798 Dec
610625 0 Dec
Format :Decimal Offline Range : 1


Utility Format Setting ChgWndw Transfer Template Disable Quit
F1 CDEMO_5 F3 F4 Reference Data F7 Lev 0 F8 OFF F9
600700 256 Dec 611100 16 Dec
600701 355 Dec 611101 1 Dec
600702 5 Dec 611102 1 Dec
600703 2000 Dec 611103 1154 Dec
600704 0 Dec 611104 360 Dec
600705 10 Dec 611105 1 Dec
600706 10 Dec
600707 0 Dec
600708 0 Dec 611130 0010 Hex
611131 5 Dec
600710 256 Dec 611132 1 Dec
600711 355 Dec 611133 1155 Dec
600712 5 Dec 611134 360 Dec
600713 2000 Dec 611135 2020 Hex
600714 0 Dec 611136 2020 Hex
600715 10 Dec 611137 0000 Hex
600716 10 Dec 611138 0001 Hex
600717 0 Dec 611139 0001 Hex
600718 0 Dec 611140 0000 Hex
600720 256 Dec 611160 0010 Hex
600721 355 Dec 611161 0005 Hex
Format :Decimal Offline Range : 1


Utility Format Setting ChgWndw Transfer Template Disable Quit
F1 CDEMO_5 F3 F4 Reference Data F7 Lev 8 F8 OFF F9
600722 5 Dec 611162 1 Dec
600723 2000 Dec 611163 1155 Dec
600724 0 Dec 611164 360 Dec
600725 10 Dec 611165 2020 Hex
600726 10 Dec 611166 2020 Hex
600727 0 Dec 611167 0000 Hex
600728 0 Dec 611168 0020 Hex
611169 0020 Hex
600730 256 Dec
600731 355 Dec 601190 0010 Hex
600732 5 Dec 601191 0005 Hex
600733 2000 Dec 601192 0001 Hex
600734 0 Dec 601193 1155 Dec
600735 10 Dec 601194 360 Dec
600736 10 Dec 601195 2020 Hex
600737 0 Dec 601196 2020 Hex
600738 0 Dec 601197 0000 Hex
601198 0100 Hex
601199 0100 Hex
Format :Decimal Offline Range : 1


Utility Format Setting ChgWndw Transfer Template Disable Quit
F1 CDEMO_5 F3 F4 Reference Data F7 Lev 8 F8 OFF F9
41300 CONV_VAL-> 0 Dec 41322 0 Dec
41301 CONV_VAL-> 0 Dec 41323 0 Dec
41302 CONST_00FF 255 Dec 41324 0 Dec
41303 CONST_FF00 65280 Dec 41325 0 Dec
41304 CONST_25-> 0 Dec 41326 CONST_65-> 65280 Dec
41305 17280 Dec 41327 18303 Dec
41306 0 Dec 41328 0 Dec
41307 0 Dec 41329 0 Dec
41308 0 Dec 41330 FP_RES_5-> 0 Dec
41309 0 Dec 41331 0 Dec
41310 0 Dec 41332 0 Dec
41311 0 Dec 41333 0 Dec
41312 0 Dec 41334 0 Dec
41313 0 Dec 41335 0 Dec
41314 0 Dec 41336 0 Dec
41315 0 Dec 41337 0 Dec
41316 0 Dec 41338 0 Dec
41317 0 Dec 41339 0 Dec
41318 0 Dec 41340 constant-> 255 Dec
41319 0 Dec 41341 constant-> 65280 Dec
41320 0 Dec 41342 831 Dec
41321 0 Dec 41343 0 Dec
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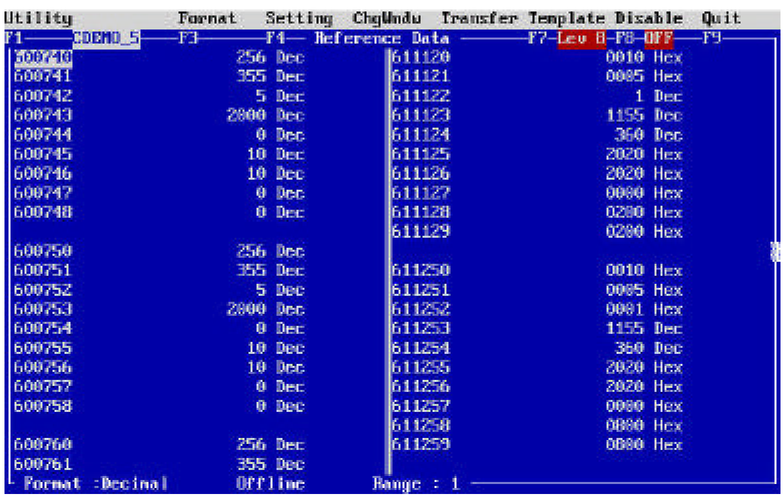
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600742 5 Dec 611122 1 Dec
600743 2000 Dec 611123 1155 Dec
600744 0 Dec 611124 360 Dec
600745 10 Dec 611125 2020 Hex
600746 10 Dec 611126 2020 Hex
600747 0 Dec 611127 0000 Hex
600748 0 Dec 611128 0200 Hex
611129 0200 Hex
600750 256 Dec
600751 355 Dec 611250 0010 Hex
600752 5 Dec 611251 0005 Hex
600753 2000 Dec 611252 0001 Hex
600754 0 Dec 611253 1155 Dec
600755 10 Dec 611254 360 Dec
600756 10 Dec 611255 2020 Hex
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600761 355 Dec
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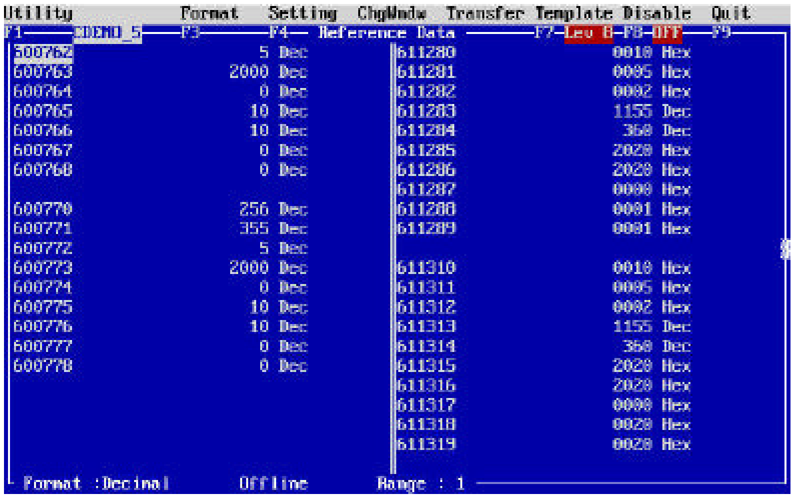

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600763             2000 Dec     611281              0005 Hex
600764                0 Dec     611282              0002 Hex
600765               10 Dec     611283              1155 Dec
600766               10 Dec     611284               360 Dec
600767                0 Dec     611285              2020 Hex
600768                0 Dec     611286              2020 Hex
                                611287              0000 Hex
600770              256 Dec     611288              0001 Hex
600771              355 Dec     611289              0001 Hex
600772                5 Dec
600773             2000 Dec     611310              0010 Hex
600774                0 Dec     611311              0005 Hex
600775               10 Dec     611312              0002 Hex
600776               10 Dec     611313              1155 Dec
600777                0 Dec     611314               360 Dec
600778                0 Dec     611315              2020 Hex
                                611316              2020 Hex
                                611317              0000 Hex
                                611318              0020 Hex
                                611319              0020 Hex
 Format :Decimal      Offline      Range : 1
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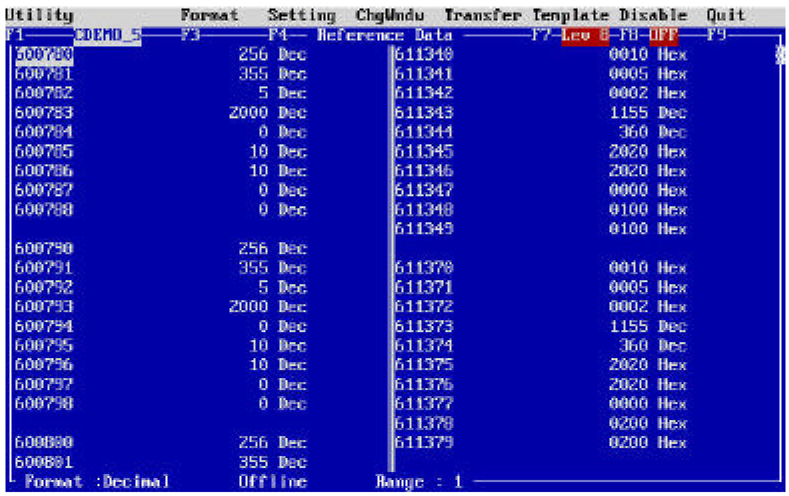

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600780              256 Dec     611340              0010 Hex
600781              355 Dec     611341              0005 Hex
600782                5 Dec     611342              0002 Hex
600783             2000 Dec     611343              1155 Dec
600784                0 Dec     611344               360 Dec
600785               10 Dec     611345              2020 Hex
600786               10 Dec     611346              2020 Hex
600787                0 Dec     611347              0000 Hex
600788                0 Dec     611348              0100 Hex
                                611349              0100 Hex
600790              256 Dec
600791              355 Dec     611370              0010 Hex
600792                5 Dec     611371              0005 Hex
600793             2000 Dec     611372              0002 Hex
600794                0 Dec     611373              1155 Dec
600795               10 Dec     611374               360 Dec
600796               10 Dec     611375              2020 Hex
600797                0 Dec     611376              2020 Hex
600798                0 Dec     611377              0000 Hex
                                611378              0200 Hex
600800              256 Dec     611379              0200 Hex
600801              355 Dec
 Format :Decimal      Offline      Range : 1
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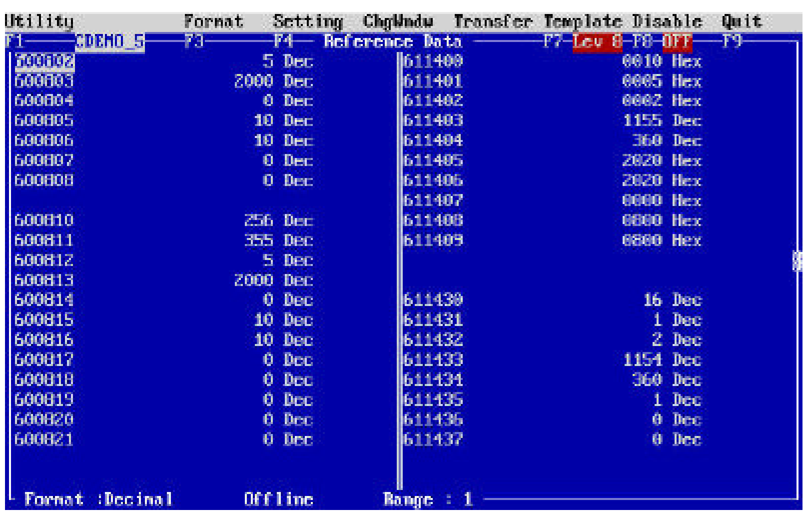

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600803             2000 Dec     611401              0005 Hex
600804                0 Dec     611402              0002 Hex
600805               10 Dec     611403              1155 Dec
600806               10 Dec     611404               360 Dec
600807                0 Dec     611405              2020 Hex
600808                0 Dec     611406              2020 Hex
                                611407              0000 Hex
600810              256 Dec     611408              0800 Hex
600811              355 Dec     611409              0800 Hex
600812                5 Dec
600813             2000 Dec
600814                0 Dec     611430                16 Dec
600815               10 Dec     611431                 1 Dec
600816               10 Dec     611432                 2 Dec
600817                0 Dec     611433              1154 Dec
600818                0 Dec     611434               360 Dec
600819                0 Dec     611435                 1 Dec
600820                0 Dec     611436                 0 Dec
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 Format :Decimal      Offline      Range : 1
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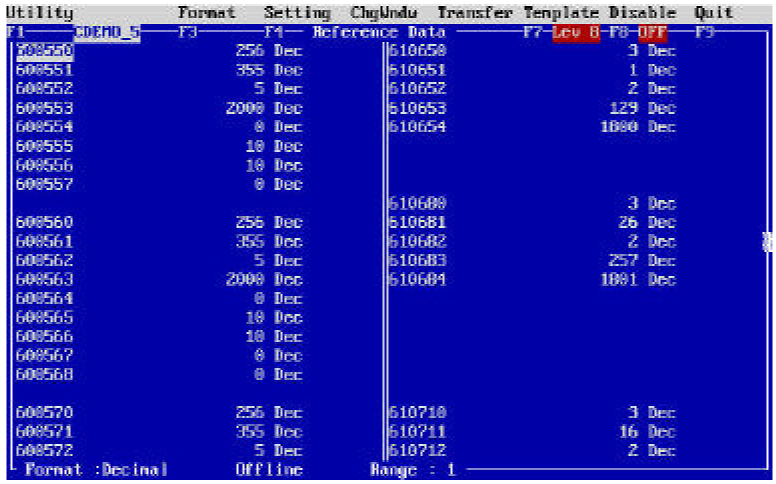
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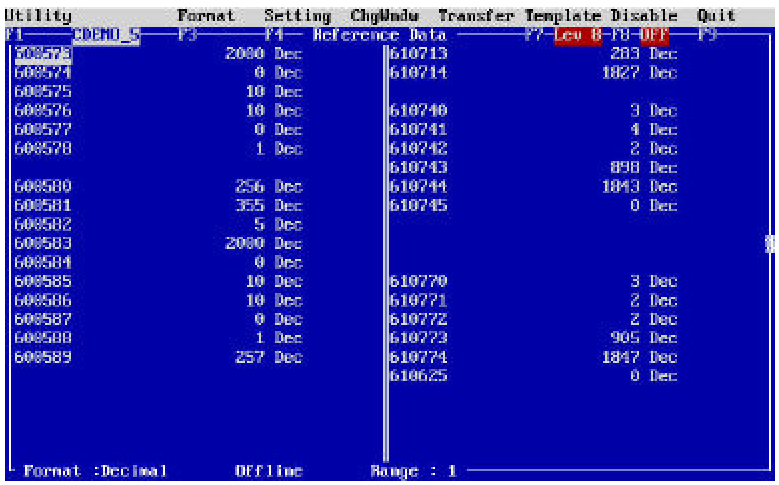
600552 5 Dec
600553 2000 Dec
600554 0 Dec
600555 10 Dec
600556 10 Dec
600557 0 Dec
600560 256 Dec
600561 355 Dec
600562 5 Dec
600563 2000 Dec
600564 0 Dec
600565 10 Dec
600566 10 Dec
600567 0 Dec
600568 0 Dec
600570 256 Dec
600571 355 Dec
600572 5 Dec
610650 3 Dec
610651 1 Dec
610652 2 Dec
610653 129 Dec
610654 1080 Dec
610680 3 Dec
610681 26 Dec
610682 2 Dec
610683 257 Dec
610684 1001 Dec
610710 3 Dec
610711 16 Dec
610712 2 Dec
Format :Decimal Offline Range : 1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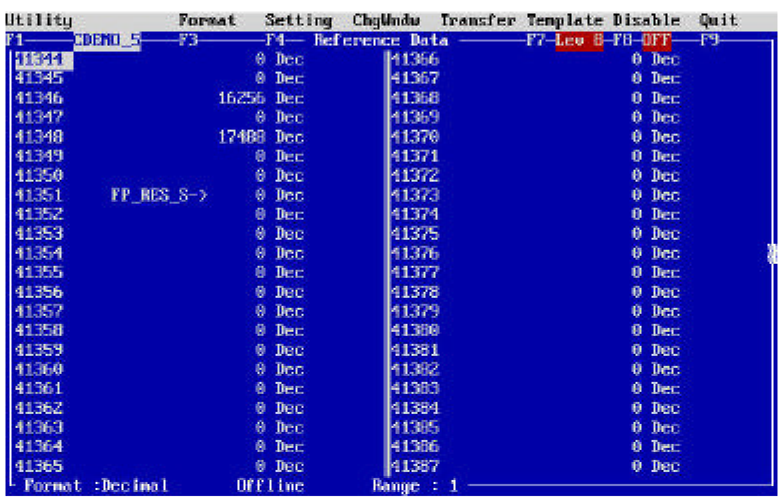
600574 0 Dec
600575 10 Dec
600576 10 Dec
600577 0 Dec
600578 1 Dec
600580 256 Dec
600581 355 Dec
600582 5 Dec
600583 2000 Dec
600584 0 Dec
600585 10 Dec
600586 10 Dec
600587 0 Dec
600588 1 Dec
600589 257 Dec
610713 283 Dec
610714 1827 Dec
610740 3 Dec
610741 4 Dec
610742 2 Dec
610743 898 Dec
610744 1843 Dec
610745 0 Dec
610770 3 Dec
610771 2 Dec
610772 2 Dec
610773 905 Dec
610774 1847 Dec
610625 0 Dec
Format :Decimal Offline Range : 1


Utility Format Setting ChgWndw Transfer Template Disable Quit
F1 CDEMO_5 F3 F4 Reference Data F7 Lev 8 F8 OFF F9
41344 0 Dec
41345 0 Dec
41346 16256 Dec
41347 0 Dec
41348 17408 Dec
41349 0 Dec
41350 0 Dec
41351 FP_RES_S-> 0 Dec
41352 0 Dec
41353 0 Dec
41354 0 Dec
41355 0 Dec
41356 0 Dec
41357 0 Dec
41358 0 Dec
41359 0 Dec
41360 0 Dec
41361 0 Dec
41362 0 Dec
41363 0 Dec
41364 0 Dec
41365 0 Dec
41366 0 Dec
41367 0 Dec
41368 0 Dec
41369 0 Dec
41370 0 Dec
41371 0 Dec
41372 0 Dec
41373 0 Dec
41374 0 Dec
41375 0 Dec
41376 0 Dec
41377 0 Dec
41378 0 Dec
41379 0 Dec
41380 0 Dec
41381 0 Dec
41382 0 Dec
41383 0 Dec
41384 0 Dec
41385 0 Dec
41386 0 Dec
41387 0 Dec
Format :Decimal Offline Range : 1

CONCLUSION

As illustrated, the ladder logic is segmented according to the tasks required by the PLC. The tasks are:

- MSTR Modbus Plus Control
- XMIT Modbus Control of the Radio Modem Polling
- Operator Interface (MAGELLIS MMI) Control and Function Key Processing
- Calculation of Feeder Loading
- Completion of Line Sectionalizing Routines
- Subroutines to allow the PLC to easily calculate mathematics in floating point mathematics.

The ABB protective relay becomes a versatile device with the inclusion of common off the shelf equipment such as PLC's Operator interfaces such as MAGELIS and inexpensive radio modems. Building systems based upon solid communication protocols such as Modbus Plus (giving fast response to equipment communicating inside a substation) and Modbus (allowing efficient communication between devices at remote locations) allows complex systems to be added and engineered incrementally as a budget permits. Events occurring within the relay can easily be accessed. The easy to configure programming language within an Modicon PLC allows for additional automation capability to be added within a substation at minimal cost and minimal programming capability. It is easy to see why the use of PLC's and microprocessor relays is more prevalent in today's substation designs.

This program has been used with standard ABB product simulators. It was first presented in a joint Groupe Schneider and ABB seminar in 1998. Copies of this program may be obtained from ABB at no charge. It is intended for this program to serve as a guide for using PLC's and ABB IED's in automation systems. There is no expressed or implied warranty or any implication as to the accuracy of the logic and the content within.

Modem Communications to ABB Relays

REV 1.0 12/07/2000

***ABSTRACT**: Advances in telephony switching systems and semiconductor technologies have made digital communication via analog public telephone systems an affordable reality. Advances from the initial Bell 202 modems operating at speeds of 300 baud to modern day V.90 modems which can theoretically operate at 56K have made fast data transfer within a substation a reality. This paper explains the theory of modern day modems and their use with ABB protective relays and configuration software. Although many manufacturers of modem equipment are available, this application note covers the theory and application of 10 bit dial-up telephone modems. ABB does not specify specific modem vendors equipment, this application note is to be a guide to configuration of general vendor's telephony equipment with various ABB products. This application note is intended to present four examples of modem connectivity between ABB products and a personal computer.*

Modem Theory

<u>EARLY MODEMS</u>

In the beginning, telephony operated using analog signals. The legacy public telephone network required that the standard Bell Telephone. Signals placed upon the telephone network consisted of voice communication. The channels were limited (which led to the creation of the party-line) and communication consisted of much dead time in which no activity was occurring on the expensive phone connection.

When digital computers were evolving, there came a need to interconnect the various sites for a limited period of time. Expensive digital data exchange networks were available for device interconnection. Installation of these systems for limited use was impractical due to installation costs but also for their operational costs. Some systems (such as ARPA net [precursor to the internet]) were available but only to the military and select universities. Another method had to be developed to allow general industries to communicate via a public medium.

It was widely known that Analog signals have three distinct characteristics.

a. Frequency (which may be varied and measured in communication systems).
b. Amplitude (which may be increased decreased).
c. Phase (which may be shifted with respect to a particular reference at any time).

Engineers at Western Electric (the R&D arm of Bell Telephone) took advantage of these characteristics of an analog signal and created a device called a modem. MO – MODULATOR: DEM – DEMODULATOR. The public telephone network communication channel was able to carry signals from 300 Hz to 4,000 Hz. The modem translated the signal from a digital waveform to an analog waveform (modulator) and transferred it to a telephone line analog grade signal. Figure 1 illustrates this transformation. The receiving modem translated the analog signal to a digital signal (demodulator). Thus the initial methods of communicating were developed to use the operating analog bandwidth of the telephone systems. The physical interface employed for the digital interface was a recently specified RS232 interface. For a more in depth explanation of RS232, please reference other application notes available from ABB's FAXBACK service or WEB Site.

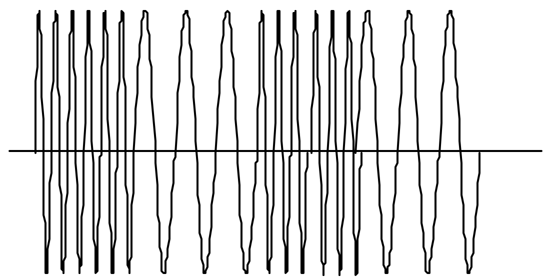


Figure 1. Frequency Shift Keying Modulation

The first Bell 202 modems used data transmission rates from 300 Baud to 1200 baud using Frequency Shift Keying. FSK modems used one of two methods of implementation. Half Duplex FSK and Full Duplex FSK.

Half duplex FSK: One frequency band pair is used to transmit/receive data. The one modem transmitting data uses one frequency to denote a binary "1" and another to denote a binary "0". The other modem decodes the 1's and 0's for corresponding to the specific frequency. The signal is then translated from the analog encoding to the digital encoding. Turn around time is an issue when the modems switch from transmitting data to receiving data. Less of the telephone bandwidth range is used for communications, but communications are slower in that each modem must signify whether it is to transmit or receive data. One cannot transmit or receive data at the same time.

Full duplex FSK: Two frequency bands are employed. One set of frequencies represent the transmit channel (frequencies allocated to the transmitted "1"'s or "0"'s). The other set of frequencies are allocated to the receive channel (frequencies allocated to the receivers "1"'s or "0"'s). This type of encoding has advantages in that no delay results for channel turnaround delay results and that full duplex communications is possible. The first Bell 202 modems were developed using FSK.

With these limitations, FSK technologies are not used in modern modems.

NEXT DEVELOPMENTS

However innovative these FSK methods were, there was still a limitation on the bandwidth of the telephone network. FSK used an entire phase in the frequency. The next innovation was to use analog to digital converters to send/receive more information at faster data rates than the maximum frequency of 4,000 Hz that a telephone system may allow. New A/D or D/A converters were able to convert signals dependent upon the phase shift of the signal. Using fast analog to digital (A/D) and digital to analog (D/A) converters made data transfer rates in excess of 4000 baud possible. Intermediate developments using the combination of phase and multiple bits could be encoded into a symbol. Four symbols could be represented by two bits. The transmission of the bits could be referenced with relation to the frequency and phase shift. For a brief time, a method using the analog signal phase shift, frequency allowed data to be transmitted/received in excess of 4000 Hz. The method was referred to as Quad Phase Shift Keying or Differential Phase Shift Keying. However, this method was short lived due to the fact that more efficient methods of data encoding were developed.

The next development which elevated modem data transfer rates to those from 9600 to 33,600 baud. The method is referred to as Quadrature Amplitude Modulation (QAM). Modern modems (such as those sold in electronics stores) use this technique in that the amplitude, phase, and frequency encode the digital bits into a symbol. A simplified explanation is provided.

Figure 2 illustrates the possible combinations of data, which may be represented by two bits. Four possible symbols may be transmitted/received using this method (as was the case with QPSK methods). If, for example a sine wave is split into four quadrants each part of the phase could represent each of the two bit combinations in an analog fashion. Thus the phase from 0 – 90 degrees could represent the value 00, 90-180 degrees could represent the value 01, 180-270 degrees could represent the value 10, and logically 270 – 360 could represent the value 11. A rapid A/D and D/A converter could determine the phase of the conversion area and determine the value depending upon the amplitude of the signal being converted. Thus, four symbols could be transferred in a single phase.

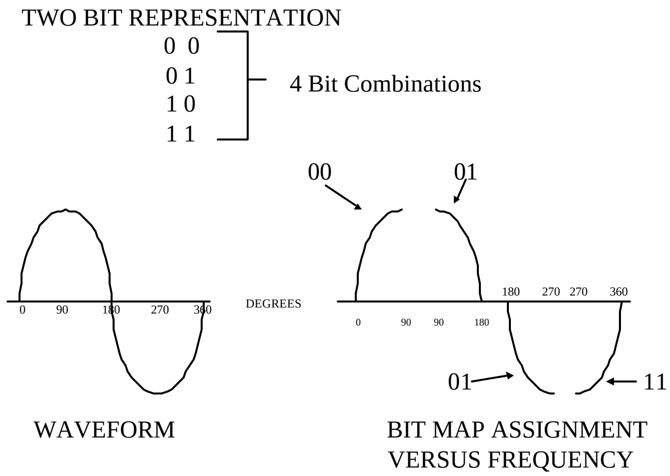


Figure 2. QAM Analysis 4 Bit Analysis

Expanding this concept, Figure 3 illustrates what could occur if a 16 symbols could be transferred using an extended sine wave interpretation. The proper designation for this encoding is 16-QAM. Thus 16 is the number of symbols which may be expressed in one waveform. Each ¼ cycle could represent a quadrature 00 –01- 10- 11. Each ¼ cycle could then be designated to two bit values depending upon the phase angle location upon the cycle. QAM modem manufacturers have a quadrature plot illustrating the phase/bit encoding which occurs in their design. This technology allows modems to transfer data at rates of 33,600 bits per second over telephone lines designed to carry voice at 4000 hz. This is pretty impressive in that the average cost of a 10 bit synchronous modem capable of operating at 56K bits per second (theoretically) is $100.

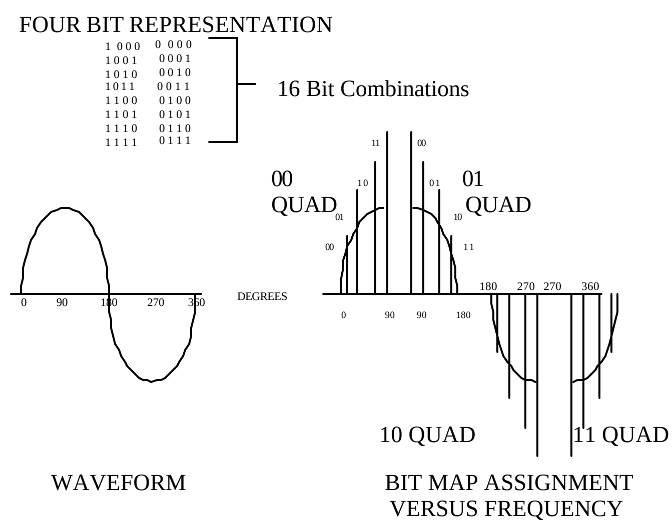


Figure 3. QAM – 16 Bit Encoding

Another new technology used in modems is one called, Trellis Encoding Technology. One of the modems presented in this paper uses this technology which evaluates speed optimization and fast forward error detection/correction technology. Within the present V. standards, error detection/correction and line speed balancing improves with each technology. One modem shall be used in this paper which uses Trellis Encoding Technology.

<u>THE TRICKY THING ABOUT BAUD RATES</u>

Baud rate is defined as the amount of changes a signal can undergo in 1 second. With FSK modems in the initial days of the Bell 202 modem, 1 baud = 1 bit. Today, with the complexity of modem technology, one bit does not equal one baud. As illustrated in the descriptions of DPSK and QAM, one transition of signal may not equal one baud in that two bits may represent 4 combinations, 3 bits may represent 8 combinations, 4 bits may represent 16 combinations, 8 bits may represent 256 combinations, and 12 bits may represent 4,096 combinations. Thus operation over a standard frequency 300, 600, or 2400 hertz (audio) may yield (when signals are decoded into digital signals) baud rates of up to 33, 600 bits per second.

Standards

Early modems were defined as per their operating baud rate. An international committee the ITU-T (International Telecommunications Union) developed standards defining the operation of modems. Today, the V. (VEE DOT) standard is recognized as the modem definition standard to which modems are designed. Some standards are listed below:

V.29 BIS - 2,400 Baud : 9,600 Bits per second: 2 Wire Full Duplex, 4-DSPK, 16 QAM
V.32 BIS - 2,400 Baud: 14,400 Bits per second: 2 Wire Full Duplex 64- QAM,
V.34 + - 2,400 Baud: 33,600 Bits per second: 2 Wire Full Duplex 4,096 QAM.

With the increasing complexity of modem technology, another innovation came about increasing the acceptance of telephone modem technology in circuits, Hayes AT command set. Hayes was one of the pre-eminent manufacturers of modem technology in the early 70's. They developed a command set which allowed a modem to be placed in several operational modes. Modems could be configured "on the fly" to auto-answer, change transmission/reception speeds, enable data encoding modes, dial out phone numbers ….. as well as other capabilities.

With the introduction of the Hayes AT command set, integration of modems into more common acceptance within a variety of applications. Configuration could occur using a commonly supplied "WINDOWS" Terminal Emulator program. When the terminal connected with the modem the "AT" command could be sent to the modem with the appropriate command. Unfortunately over time there has been a deviation in the HAYES command set in that there is no such thing as a "STANDARD HAYES AT COMMAND" set.

10 Bit Versus 11 Bit Modems

Commercially available dial-up modems, such as those generally sold through chain electronic stores may be used with many of the protocols offered in the ABB Protective relays. Modems such as those allowing telephone connectivity using 10 bit protocols are generally those available inexpensively. A 10 bit telephone modem is in the cost area of $100 (120 VAC operation) whereas 11 bit modems are in the area of cost of $1500 (120 VAC operation) [COSTS QUOTED ARE FOR YEAR 2000]. Modems using 125 VDC power sources are much more expensive than those quoted for 120 VAC operation.

10 BIT PROTOCOL

START	1	2	3	4	5	6	7	PARITY	STOP

With Parity Checking

START	1	2	3	4	5	6	7	STOP	STOP

Without Parity Checking

Figure 4. 10 Bit Protocol Packet

11 BIT PROTOCOL

START	1	2	3	4	5	6	7	8	PARITY	STOP

With Parity Checking

START	1	2	3	4	5	6	7	8	STOP	STOP

Without Parity Checking

Figure 5. 11 Bit Protocol Packet

The difference in packet size is illustrated in Figures 4 and 5. An 10 bit protocol is comprised of 1 Stop Bit, 1 Stop Bit, 1 Parity Bit, and 7 Data Bits or in the case of no parity, a stop bit is inserted to complete the 10 bit packet. Thus the total of bits transferred is 10 bits. 10 bit protocols usually are those encoded in ASCII. The ASCII encoding is defined to be a code from 00 to 7E (7 bits of data per character). A modem must be able to anticipate the data packet size in order to transfer the protocol bytes. A 10 bit modem is only able to reliably transmit/receive such 10 bit data packets.

An 11 Bit protocol is one in which a byte's worth of data may be transferred. An 11 bit protocol is comprised of 1 Stop Bit, 1 Parity Bit, 1 Start Bit, and 8 Data Bits or in the case of no parity an additional stop bit is substituted. Thus byte data may be transferred using an 11 bit modem without any data encoding. This is why 11 bit data may not be transferred/received via a 10 bit modem. It is important to match the modem with the protocol being used.

Modem Cabling Options

Cabling is dependent upon the devices attached and modem control options enabled. Through the "AT" modem command set such capabilities as RTS/CTS control, CD, DTR enable is possible. However, if one requires that a standard modem setting shall not be changed from location to location, signal jumpering through the cable may be preferable. What follows are a few diagrams illustrating cable connection between some devices. If one is unsure as to the function or emulation of RS232 please reference one of the many fine ABB application notes on the subject.

The Modem is generally a DCE RS232 device. It is configured via a personal computer using a terminal emulator program such as:

DOS OPERATING SYSTEM – PROCOMM
WINDOWS 3.1 - TERMINAL or a similar 16 bit application program commonly available.
WINDOWS 95,98, or NT – Hyperterminal or similar 32 bit application programs commonly available.

Such programs are available to be configured for handshake control, no handshake, XON/XOFF control. A variety of cables are illustrated for connection of a device to the modem for AT terminal command configuration, or device operation connectivity.

Knowledge of the RS232 port design is important when interconnecting a modem and an IED. Also if configuration software is required to communicate and configure the device through the com port, knowledge of the software's requirement to control the RTS/CTS, CD, DSR, or DTR RS232 lines must be known. Table 1 lists the variety of ABB products and the emulation of each of the ports and applicability of cable design.

Table 1. Product Cable Guidelines for Connection to a Modem

Product	RS232 Port	RS232 Emulation	CTS/RTS – DSR/DTR* Support	Notes for Modem Connection
DPU2000 (Front and Back Ports)	9 Pin Female	DTE	NO NO*	Use Figure 6 Cable
DPU2000R (Front and Back Ports)	9 Pin Female	DTE	NO NO*	Use Figure 6 Cable
TPU2000 (Front and Back Ports)	9 Pin Female	DTE	NO NO*	Use Figure 6 Cable
TPU2000R (Front and Back Ports)	9 Pin Female	DTE	NO NO*	Use Figure 6 Cable
GPU2000R (Front and Back Ports)	9 Pin Female	DTE	NO NO*	Use Figure 6 Cable
PONI R	9 Pin Male	DTE	YES NO*	Use Figure 7 or 8 Cables dependent on handshake options.
REL512 Front Port	9 Pin Female	DCE	NO NO*	Use Figure 9 Cable
REL512 Rear Port (Serial Port 1)	9 Pin Male	DTE	NO NO	Use Figure 12 Cable (Modem Handshake options disabled).
REL512 Network Port (DNP 3.0 Card)	9 Pin Female	DTE	YES** NO*	Use Figures 10 or 11 Cable dependent on handshake options.
RCP Software	IBM "XT" 25 Pin Female IBM Compat. 9 Pin Male	Usually DTE Hardware Dependent	NO NO*	Sample cables are illustrated in Figures 12 and 13.
ECP Software Or WinECP Software	IBM "XT" 25 Pin Female IBM Compat. 9 Pin Male	Usually DTE Hardware Dependent	NO NO*	Sample cables are illustrated in Figures 12 and 13.
PONI M COMSET Software	IBM "XT" 25 Pin Female IBM Compat. 9 Pin Male	Usually DTE Hardware Dependent	YES NO*	Sample cables are illustrated in Figures 12 and 13.
** PONI – R Card does not support DTR/DSR HANDSHAKE LINES				

Additionally, Figures 14 and 15 illustrate a communication cable configuration when a Modicon PLC is connected to a Modem (as is the case when it is using a Ladder Logic XMIT block allowing the port to operate as a host device).

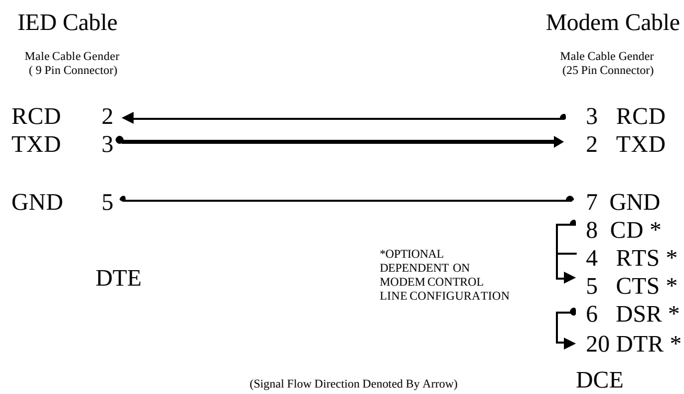


Figure 6. Example Cable 1: GPU2000R, TPU2000, TPU2000R, DPU2000, DPU2000R, MSOC, or DPU1500R. It is recommended that DSR, CD, and CTS control be disabled via modem. If control is disabled, jumpers are optional as shown.

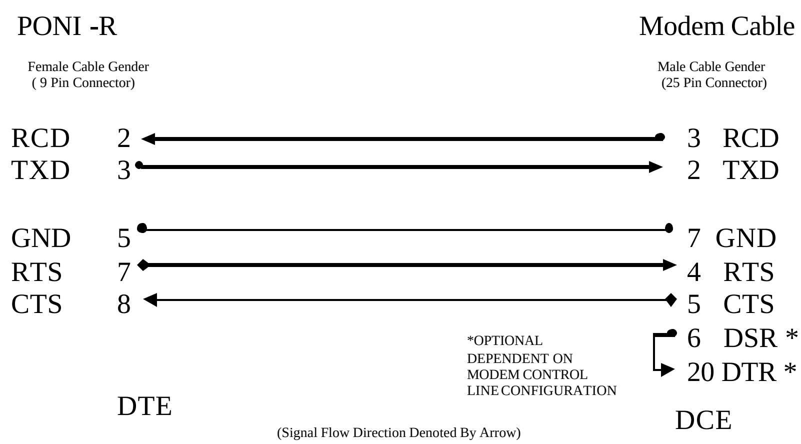


Figure 7. Example Cable 2: ABB PONI R (installed in a REL 301, 302, 350, 352, 356 or MDAR), using hardware handshaking configured in the modem. Install optional jumper if modem configured for supplying DSR signal.

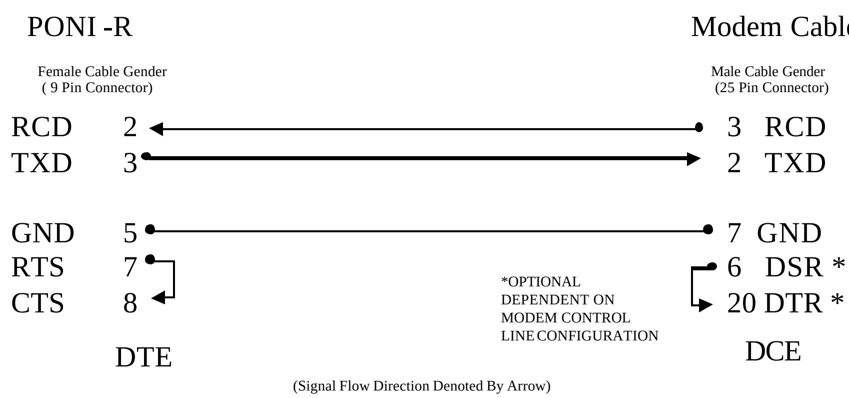


Figure 8. Example Cable 3: ABB PONI R (installed in a REL 301, 302, 350, 352, 356 or MDAR), NOT using hardware handshaking configured in the modem. Install optional jumper if modem configured for supplying DSR signal.

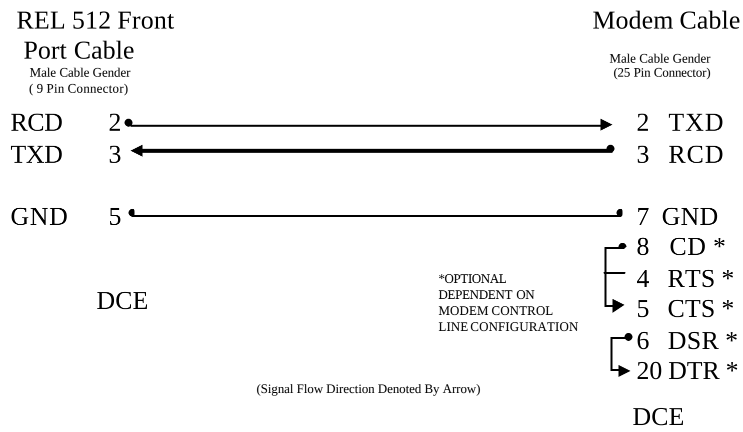


Figure 9. Example Cable 4: ABB REL512 Connected to a Modem Through the RS232 Front Port. It is recommended that RTS/CTS and DSR/DTR handshaking be disabled so optional jumpers need not be installed within the cable.

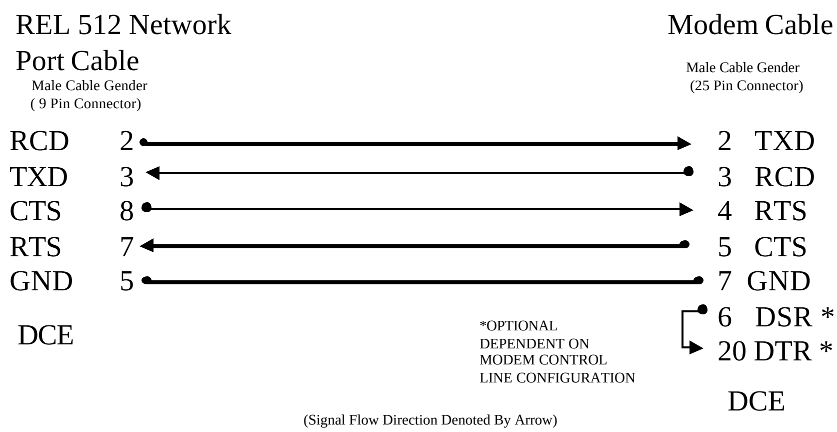


Figure 10. Example Cable 5: REL512 Network Port Cable Connection to a Modem. It is advisable that the DSR/DTR control be disabled in the modem so that the optional DSR/DTR jumpers not be inserted in the cable.

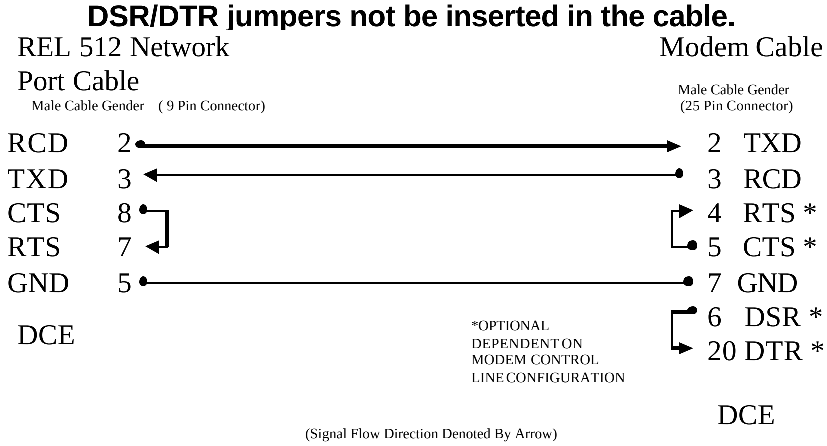


Figure 11. Example Cable 5: ABB REL512 Connected to a Modem Through the RS232 Network Port With Handshaking from the REL512 Disabled. It is recommended that RTS/CTS and DSR/DTR handshaking be disabled in the Modem so optional jumpers need not be installed within the cable.

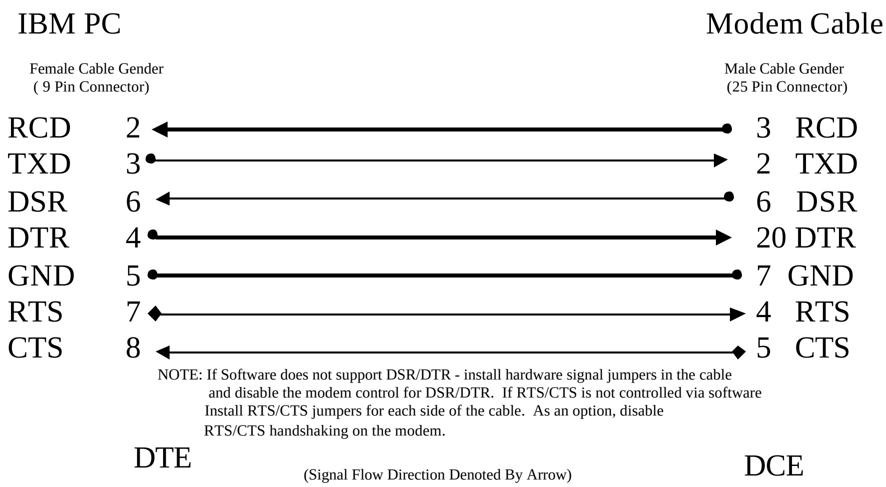


Figure 12. Cable 6: IBM PC 9 Pin Port Cable Connecting to a Modem With Handshaking Enabled. Please refer to the Note for optional jumpers and modem configuration options.

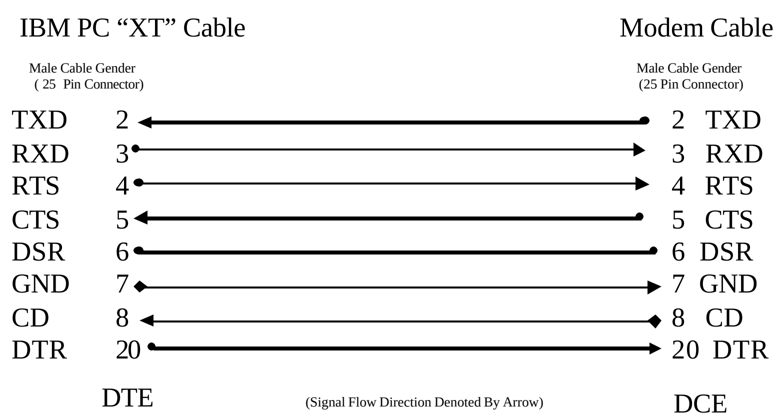


Figure 13. Cable 7: IBM PC 25 Pin Port Cable Connecting to a Modem With Handshaking Enabled. Please refer to the Note for optional jumpers and modem configuration options. NOTE: Check Software With Respect for Supported RS232 Pin Handshaking Options.

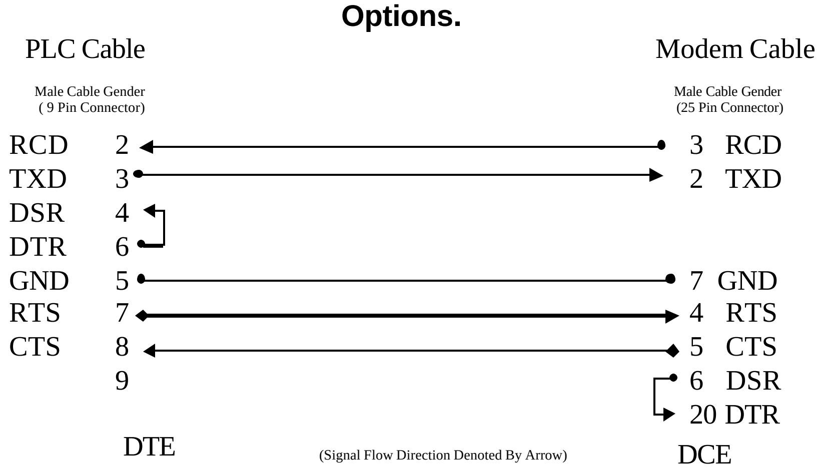


Figure 14. Cable 8: PLC Cable Connectivity to a Modicon PLC with Handshaking enabled on the PLC and Modem Side.

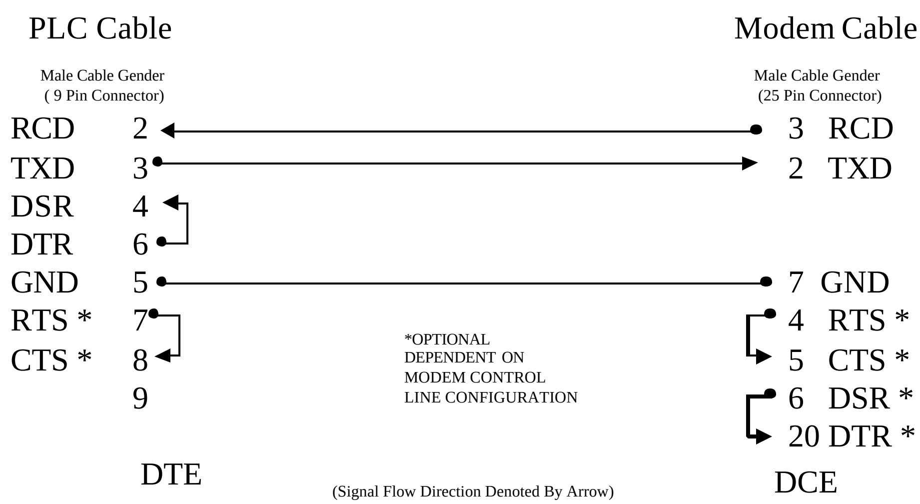


Figure 15. Cable 8: PLC Cable Connectivity to a Modicon PLC with Handshaking Disabled on the PLC and Modem Side.

AT Command Set

Within these examples, a Hayes Compatible external telephone modem from 3Com and ZOOM is used. The command sets and S Registers differ slightly based upon the chip set used. For example, the ZOOM modem uses a chipset from LUCENT TECHNOLOGIES. The description of the command set is available from the internet web-site www.lucent.com. The 3Com modem has their command set available on the Internet web-site www.3com.com : The AT "&" commands are usually the same for both manufacturers, However, the definition of the AT "X" (Where X may be a letter or a "\" or && and a letter) commands vary widely between the manufacturers. Also the AT"S" (S register commands) register definitions vary widely between the two manufacturers.

US Robotics (3COM) 56 K (V.90 or X2) Sportster Faxmodem

The Sportster FAXMODEM is an external modem. This modem allows visualization of a variety of parameters allowing for visual troubleshooting in the event of trouble. The Sportster also has a set of dipswitches allowing for quick configuration without connection of a "Terminal Emulator" to configure the unit through "AT commands. Please refer to the web-site documents for a more complete explanation of configuration strings.

Prior to configuring the modem, attach the proper cable between the terminal emulator and the modem. One Should Type "AT" (without the quotation marks) and depress the enter key. The modem shall echo back an "OK" to acknowledge the communication. It is recommended that the dipswitches for this unit be set as follows:

1: Down – Data Terminal Ready Overriden (EXCEPT IF USING THE BIRT)
2: Down – Numeric Results Code Displayed
3: Down – Display Results Code
4: UP – Echo OFFLINE Commands
5: Dependent upon application – AUTO ANSWER
6 Down- Carrier Detect Override (EXCEPT IF USING THE BIRT)
7: UP – Load NVRAM DEFAULTS
8: Down – Smart Mode Operation

If the modem does not answer, please check the terminal emulator settings to be the following:

9600 Baud
7 Data Bits
1 Stop
Even Parity
Hardware or No Flow Control depending upon the cable selected and configuration of modem.
VT 100 Terminal Emulation
Inbound Communications: Carriage Return = Carriage Return and Line Feed

If the modem does connect, then the following command may be sent to initialize the modem to parameterize the RS 232 com ports to the proper mode as explained below.

AT=&F1

&F1 = Initialize the modem to Hardware Control Factory Defaults.

AT = &A3 &B1 &C1 &D0 &G0 &H1 &I0 &K1 &M4 &N0 &P0 &R2 &S0 &T5 &U0 &Y1

&A = Protocol Indicators Added (error control and data compression) (3 = Yes)
&B = Serial Port Rate (0= Follows Connection Rate)
&C = Carrier Detect Override (1 = Overridden)
&D = Data Terminal Ready Control (0= Overridden)
&G= Guard Tone (0 = USA & Canada)
&H = Hardware Flow Control (1 = CTS Enabled, 0 = Disabled)
& I = Software Flow Control (0 = Disabled)
& K = Data Control Compression (Auto Enable Disabled =0)
& M = Error Control (4 = Normal)
& N = Sets Connect Speed (0 = Determined by remote modem).
& P = Rotary Dial Ratio Pulse (0 = USA & Canada)
& R = RD Hardware Flow Control (RTS) (2 = Received Data To Computer)
& S = Data Set Ready Operation (0 = DSR Overridden – Always ON)
& T = Test Loop Enable (5 = Inhibits Test Mode)
& U = Floor Connect Speed (Determined by &N Codes 0 = Best Possible Speed)
& Y = Break Handling (1 = Expedited, Destructive)

For this modem, Register S0 controls the Auto-answer feature. Autoanswer is controlled via the dip-switch position 5 and a combination of the value in register S0. To change the value of auto answer pickup (number of rings) send the command:

ATS0= X, where X is the number of rings which the device shall sense for phone pickup. Note if the host is to dial out the number at all times, this parameter may be set to a “0” thereby disabling the auto answer feature.

Once the commands are written to the modem, one must write them into the modem’s non-volatile memory. The command should be sent as follows to the modem:

AT=&W0

Or

AT=&W1

The US ROBOTICS Sportster Modem offers two NVRAM profiles. W0 places the parameters in to Profile 1, whereas W1 places the parameters in Profile 2.

ZOOM 56Kx Dual Modem Faxmodem Configuration

The ZOOM modem offers more LED's on their external modem than the US Robotics device. However, the ZOOM modem must be configured for each parameter via a "TERMINAL EMULATOR" program. The ZOOM modem does not offer a dipswitch for configuration of the different operation modes. AT "\" commands and AT "X" (where X is a letter) performs the setup of the device.

Prior to configuring the modem, attach the proper cable between the terminal emulator and the modem. One Should Type "AT" (without the quotation marks) and depress the enter key.

If the modem does not answer, please check the terminal emulator settings to be the following:

9600 Baud
7 Data Bits
1 Stop
Even Parity
Hardware or No Flow Control depending upon the cable selected and configuration of modem.
VT 100 Terminal Emulation
Inbound Communications: Carriage Return = Carriage Return and Line Feed

If the modem does connect, then the following command may be sent to initialize the modem to parameterize the RS232 com ports to the proper mode as explained below.

AT=&F0

&F0 = Initialize the modem to Hardware Control Factory Defaults.

AT = &C1 &D0 &G0 &K3 &Q0 &S0

&C = Carrier Detect Override (1 = Overridden)
&D = Data Terminal Ready Control (0= Overridden)
&G= Guard Tone (0 = USA & Canada)
& K = Local Flow Control (0 = Disabled, 3 = Hardware RTS/CTS, 4 = XON/XOFF)
&Q = Asynchronous Communication Mode (0 = Asynchronous Mode Buffered)
& S = Data Set Ready Operation (0 = DSR Overridden – Always ON)

For this modem, Register S0 controls the Auto-answer feature. Autoanswer is controlled via the dip-switch position 5 and a combination of the value in register S0. To change the value of auto answer pickup (number of rings) send the command:

ATS0= X, where X is the number of rings which the device shall sense for phone pickup. Note if the host is to dial out the number at all times, this parameter may be set to a "0" thereby disabling the auto answer feature.

To view the configuration, one may issue the following command:

AT=&V

&V = View Active Configuration and Stored Profile

This can view the programmed profiles.
To store this configuration, the command AT=&W0.

Refer to the document at www.lucent.com for an explanation of the AT "L" commands where L is the defined commands for dial-up, speaker control, and other modem functions.

Connectivity Example 1- TPU2000R to WinECP Configuration Software

If one was to connect a TPU2000R to a configuration program such as WIN ECP over a long distance, a method to accomplish this is via a telephone dialup modem. As illustrated in Figure 17, a personal computer with WinECP is at the headquarters attached to a Public Telephone Switched Network. A standard 10 bit telephone modem is providing connection of the digital signals to the analog telephone line.

At a remote location is a TPU2000R attached to a modem providing connectivity.

At both ends, the modem must be configured for appropriate auto- answer capabilities and RS232 port capabilities. The protocol used to connect is ABB's Standard 10 Byte protocol. This is a 10 bit protocol which may be transmitted asynchronously via a telephone dialup modem as those discussed via this application note. The Standard 10 byte protocol is a Master-Slave protocol. The device at the PC terminal end (WinECP End) sends the command dial up string whereas the DPU2000R modem end must be configured to AUTOANSWER capabilities. If a ZOOM Modem is placed at the Host end and a US Robotics modem is placed at the IED end, the following configuration must be configured for each.

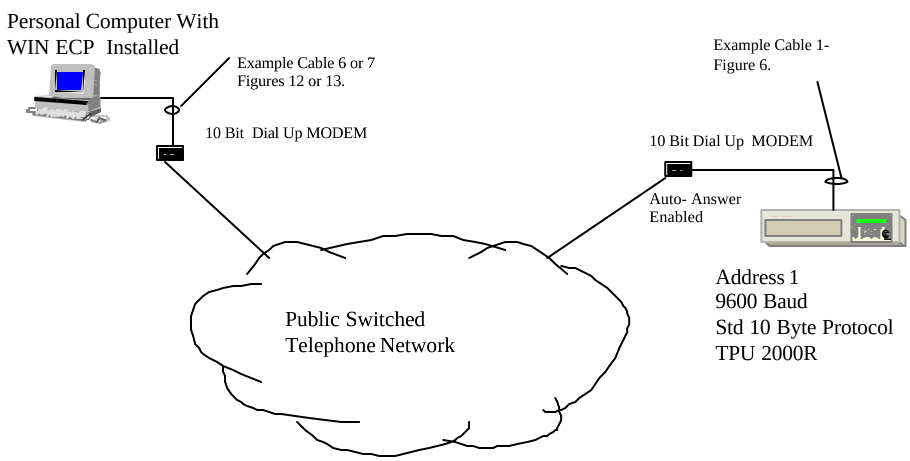


Figure 17. Application Topology Diagram PC to TPU2000R Point to Point

Figures 18 and 19 illustrate the WinECP screens required for connectivity to the device upon dial up. Upon execution of the ABB WinECP program, the initial screen shown in Figure 18 appears. One should select Remote Access which allows attachment to the remote modem if the proper AT command strings and numeric dial out instructions are given.

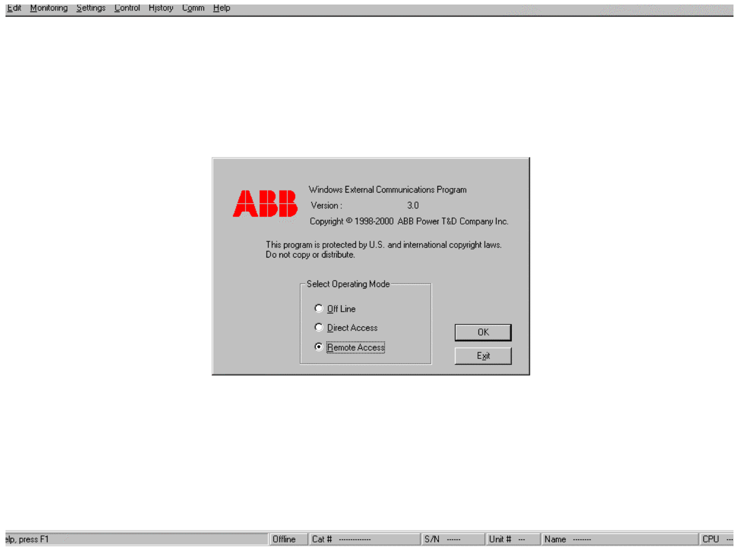


Figure 18. Initial ABB WinECP Access Screen

If one depresses the OK button after selecting the WINDOWS RADIO button Selection for Remote Access, the screen as illustrated in Figure 19 appears.

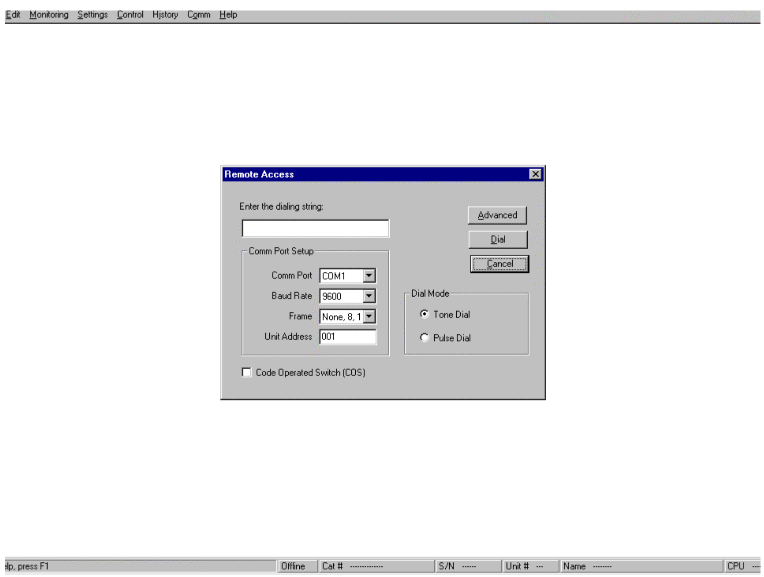


Figure 19. Parameter Selection Screen for Remote Dial – Up Access

The COM PORT is that of the PC's modem port for attachment to the phone line.The Baud Rate is that for the remote modem and must match that of the Standard 10 Byte port which the modem is attached to the TPU2000R.The Frame is that selected for the Remote TPU2000R.The Unit Address is the unit address of the Remote TPU2000R node.

If Pulse Dial is selected, then the Modem Command for sending the Pulse command is sent when dialing the number, otherwise, if Tone Dial is selected the command ATDT is sent to prefix the modem dial out string. In this case, the Tone Dial selection is activated.

The dialup string is:

ATDT ,,,,18005551212 (the substation number of the remote device)

To hang up the device the WIN ECP program must be able to send the command:

ATH0

Additionally, one must be sure that the appropriate modem configuration strings have been accepted by the modem for correct handshake control and remote auto answer configuration.

Connectivity Example 2 – REL 3XX to RCP Configuration Software

If one wished to connect an ABB transmission relay such as a REL300 (MDAR), REL301, REL302, REL350, REL352 or REL356 to its configuration software (RCP – Remote Communication Program), using a dial up configuration as illustrated in Figure 20 is quite possible. The REL transmission relay uses a PONI R card for direct point to point communication via a cable or a modem. Please reference Instruction Leaflet 40-603 titled RCP Communication Program Users GUIDE and Instruction Leaflet 40-610 titled RS-PONI RS232 Product Operated Network Interface User's Guide.

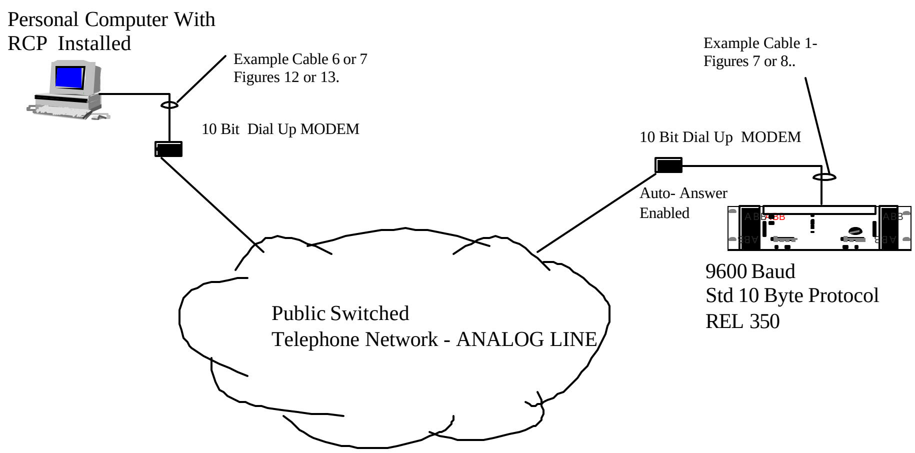


Figure 20. RCP to REL350 Communication Topology Example

In this example, a REL350 shall be connected together with two US ROBOTIC Model 005686 Sportster Modems as described previously in this application note. RCP software shall be configured to communicate to the REL350 via the aforementioned modems. Several steps are to be completed in this example.

1. Configure the PONI R dipswitches to correspond to the appropriate baud rates of the modem and RCP software.
2. Attach the correct cables as to the relay devices as indicated in Figure 20. In this example however, we shall disable handshaking (RTS/CTS) in the modem, so a straight through DTE to DCE cable is necessary.
3. Configure the US ROBOTIC modems to enable/disable the appropriate features.
4. Configure the RCP software to connect to the modem and enable communications.
5. Execute the communication command sequence and establish communications.

STEP 1
In this example, the communication baud rate selection shall be set for 9600 baud. The baud rate of the PONI R card is configured via dipswitches located at the rear of the card, consult the PONI R manual referenced in this document. Also configure the PONI R card for NO COMMAND ISSUED mode. If one is to view the dipswitches of the PONI R (installed in the REL350) card, the four dipswitch positions (left to

right) are upward, and the rightmost dipswitch is downward. This corresponds to dipswitch positions 1 through 5 being 1 0 0 0 0 or ON, OFF, OFF, OFF, OFF. The PONI R CARD is now configured.

STEP 2
As per Figure 20, connect the cables as indicated for the personal computer to modem and the REL350 PONI R to modem connection. In this example, the handshaking shall be disabled on the PONI R card modem. Thus even using standard off the shelf cables (9 to 25 pin cables with each pin run straight through) shall operate in this example.

STEP 3
Now the modems shall be configured. Using the HYPERTERMINAL program supplied with Windows 95, 98, NT or 2000 can be used to configure the modems. Using hyperterminal as illustrated in Figure 21, one can issue the AT commands to configure the modem.

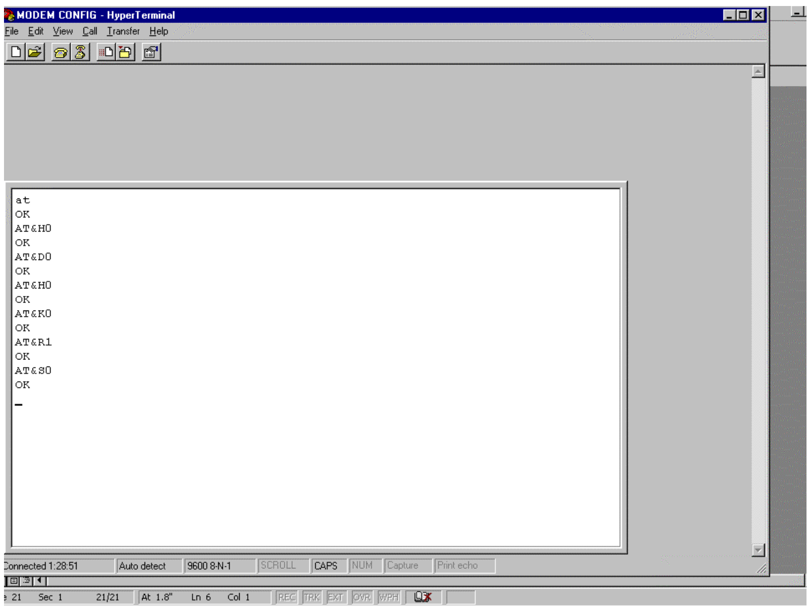


Figure 21. Hyperterminal at Command Set Example

Each modem must be configured in this method. The modem parameters and dipswitch settings shall be covered for each modem location.

DIPSWITCH SETTINGS FOR THE MODEM LOCAL TO RCP:
Modem Dipswitch Position
Position 1 UP – Data Terminal
Position 2 UP – Verbal Results Codes
Position 3 DOWN – Display Results Codes
Position 4 UP-Echo Offline Commands
Position 5 DOWN – Disable auto answer
Position 6 DOWN – Carrier Detect Override
Position 7 UP – Load NVRAM defaults
Position 8 DOWN – Smart Mode

DIPSWITCH SETTINGS FOR THE MODEM LOCAL TO THE REL350/PONI R card
Modem Dipswitch Position
Position 1 UP – Data Terminal
Position 2 UP – Verbal Results Codes
Position 3 DOWN – Display Results Codes

Position 4 UP-Echo Offline Commands
Position 5 UP – Auto Answer on the first ring, or higher if specified in NVRAM
Position 6 DOWN – Carrier Detect Override
Position 7 UP – Load NVRAM defaults
Position 8 DOWN – Smart Mode

In setting the modems via the AT command set, it was determined that the modem closest to the computer executing the RCP program shall use the factory defaults of the modem right out of the box. If one was to view the USROBOTICS troubleshooting guide (available on the www.3com.com website) the factory defaults are listed in the downloadable files.

For the modem attached to the RCP program, one must change a few parameters within the modem to ensure connectivity. Starting with the factory default settings with the modem right out of the box, one should issue the AT commands:

AT&H0&D0&K0&R1&S0

Which corresponds to the following definitions as designated in the USROBOTICS literature:

&H0 = Flow Control Disabled
&D0 = DTR Override (Default)
&K0 = DATA COMPRESSION DISABLED
&R1 = MODEM IGNORES RTS
&S0 = DSR OVERRIDE ALWAYS ON

As stated previously, other commands could be issued to the modem to allow it to peacefully co-exist and operate with the PONI R card. It is highly recommended to write the settings to the EEPROM in the modem by issuing the AT&W 1 or AT&W2 command.

STEP 4
The RCP program must now be configured to operate with the modem and issue the commands. The steps to use this are as follows:

One must start RCP and enter the standard start screen as illustrated in Figure 22.

Figure 22. RCP Standard Setup Screen

One must configure a substation file for the REL350 connection. Depress the Alternate key and S simultaneously to enter the Substation menu and depress the down arrow "↓" once to select " New Substation File" menu selection as illustrated in Figure 23.

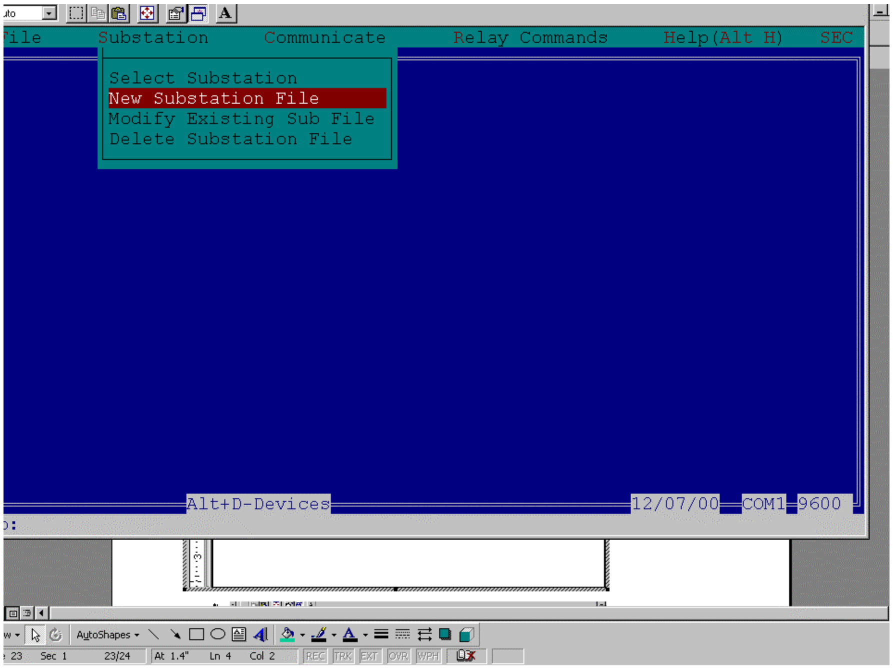


Figure 23. New Substation Setup Screen

A file must be configured for the REL350 connection. Since a PONI R card is not addressable, it is considered a point to point device. As illustrated in Figure 24, one must pick an option for the configuration. In our example (as shown in the topology of Figure 20), although the REL350 is networked through a modem, the connection is still point to point, one must select the selection "1" to allow correct connectivity. Figure 24 illustrates the screen queries and answers for this specific example.

As illustrated in Figure 25, the operator must supply additional configuration data. Figure 25 lists the configuration responses for this example. Configuration data to be supplied is as such:

RELAY TYPE – in this case selection 5 (REL350) is selected.
DEVICE DESCRIPTION – This field is used only for documentation purposes.
LOGON SEQUENCE – In this example, the ATDT command is used for a pulse tone telephone system.

Also in this example, an analog system is used and an additional prefix of "9" must be dialed to access the external public telephone system, the comma "," is used to insert a delay before dialing the telephone number of the remote location (where the REL350 resides). In this instance, the substation is located in a telephone overlay area where the area code must be dialed with the main number. Additionally, since the remote modem is resident at an analog extension, several commas "," are added to create a delay for the phone line to transfer to that extension and then synchronize with the remote modem. A query is generated to accept the configuration and a request for the file name to store the information is then requested (without the operating system file extension).

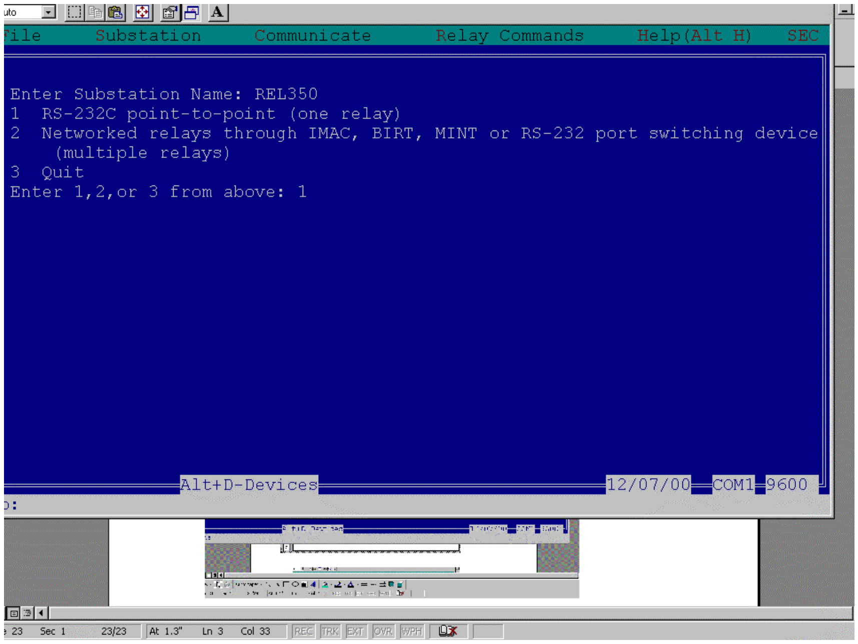


Figure 24. Initial Substation Configuration Screen

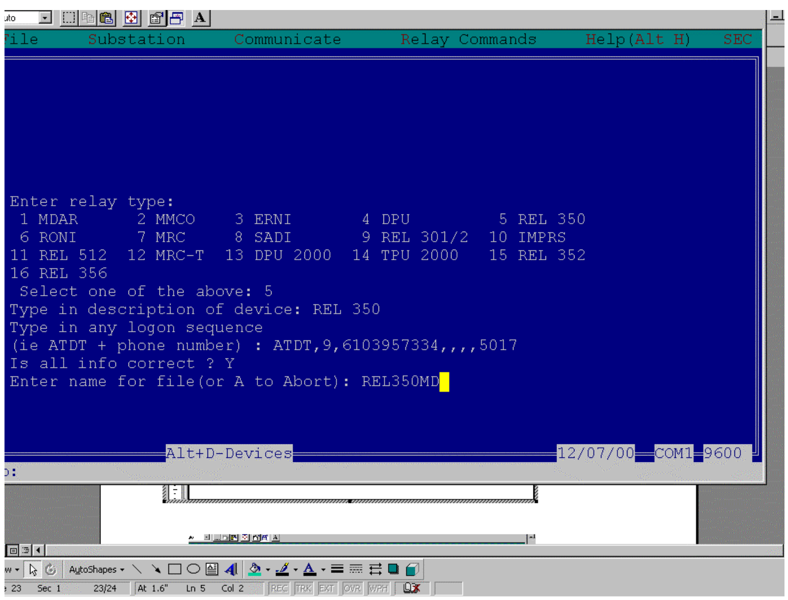


Figure 25. Final Substation Configuration Screen Query

One must then configure the RCP program to execute the dial up sequence and configure the personal computer communication port selected. One must depress the Alternate key and "C" key simultaneously to access the "COMMUNICATE" menu shown in Figure 26.

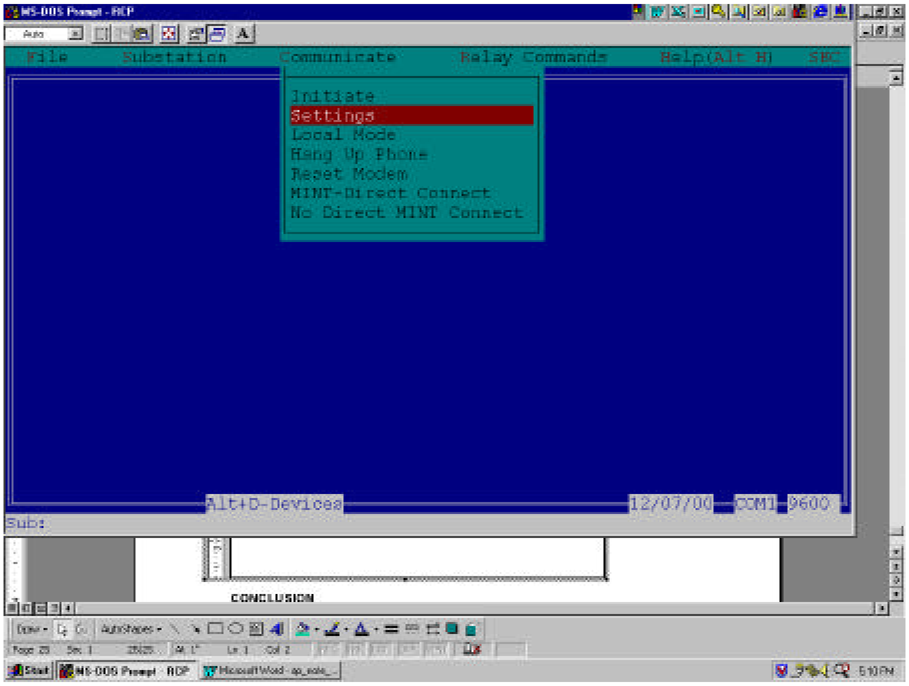


Figure 26. Communicate Menu Selections

One should depress the down arrow key ""↓" once to select the settings menu to configure the port type, baud rate, and communication port selection as illustrated in Figure 27.

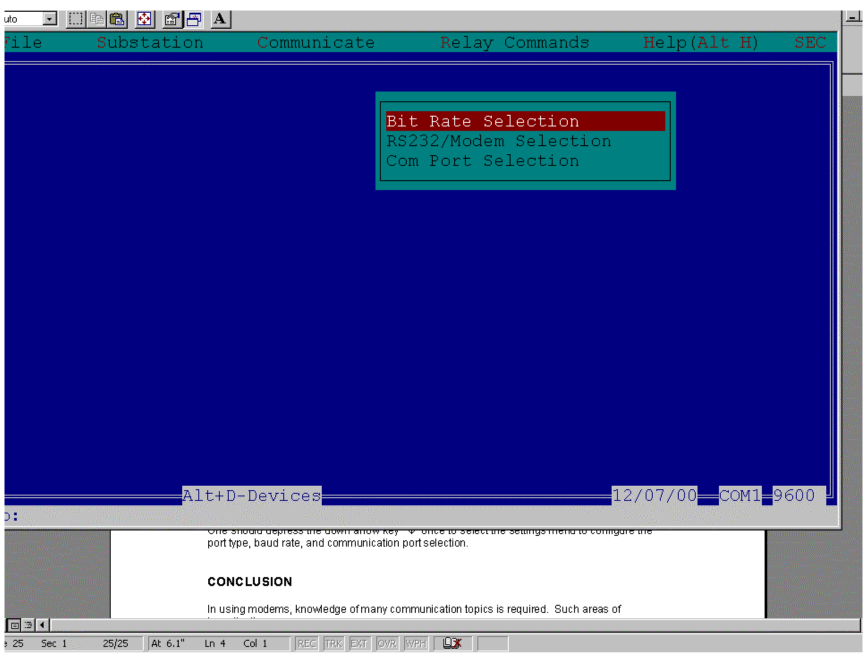


Figure 27. RCP Settings Selection Screen

For this example, one must configure the RCP program for the same parameters as the PONI R card, in other words, 9600 Baud. (Selection 9 in the Bit Rate Selection Submenu) shown in Figure 28.

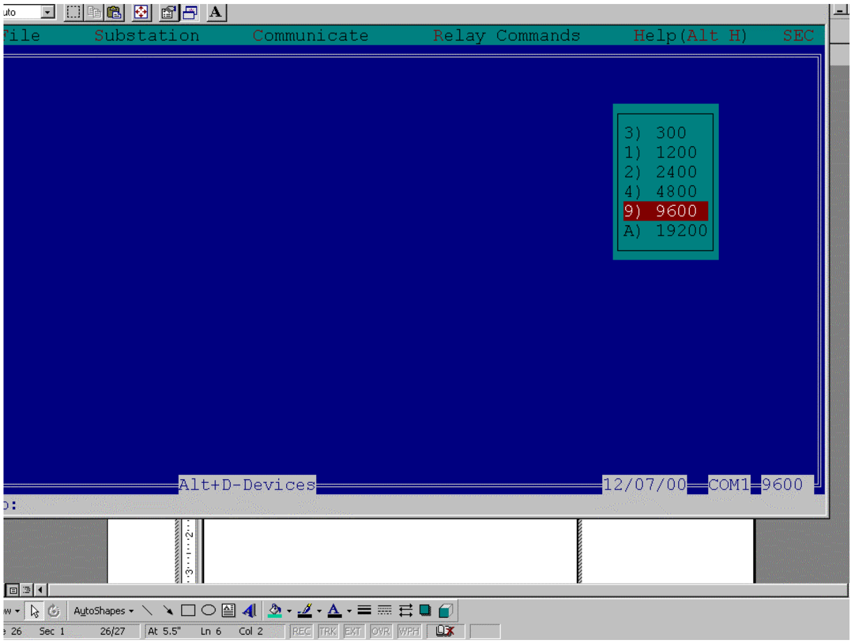


Figure 28. Communication Baud Rate Setting Screen

Execute the same procedure to access the RS232/MODEM Selection submenu. The selection for modem must be selected. By using this selection, the query for ATDT dial out command screen will be issued when issuing the connect command prompt.

Figure 29 illustrates the screen presented for the RS232/MODEM prompt.

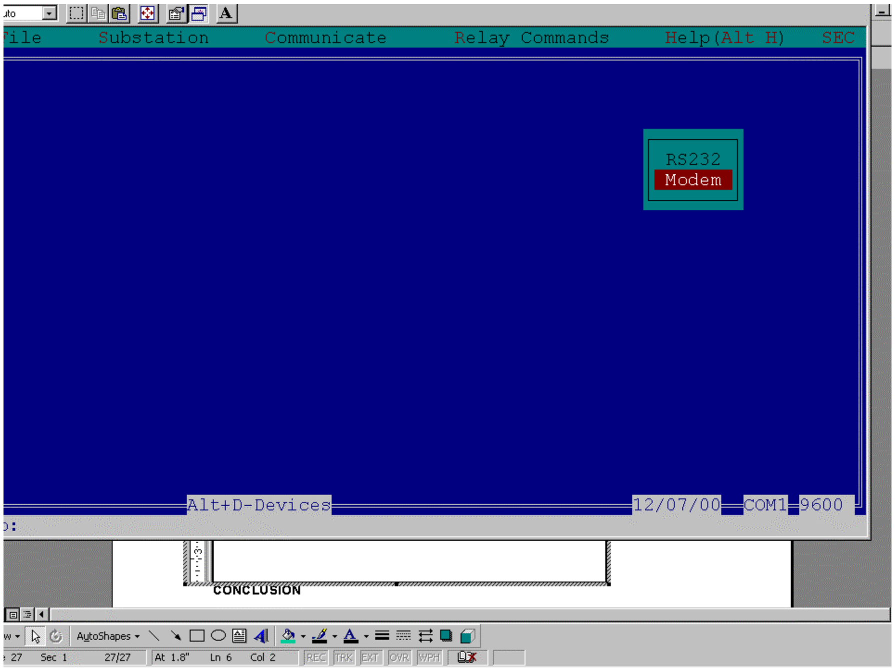


Figure 29. Modem/RS232 Screen Prompt Selection Submenu

The COM PORT Selection menu must be used to select the PC computer port through which RCP will issue commands. In the sample case, the PC used has only one com port "1'". The selections for the communication port parameters are shown on the bottom right hand side of the communication screen.

One must now select the previously configured file for operation. Simultaneously depress the "ALT" and "S" keys on the keypad to select the Substation Screen as illustrated in Figure 23. Highlight the "SELECT SUBSTATION" selection. The screen as shown in Figure 30 will be presented. As illustrated, the file REL350md .sub is available for selection. Depress the right arrow key "→" twice to select the file (highlighted as shown) and depress the enter key. Depress the enter key again to select the REL350 description of the intended IED to be attached.

Finally, one must initiate communications with the relay. Depress the alternate "C" keys simultaneously to view the menu as illustrated in Figure 26. Highlight the "INITIATE" selection and depress the enter key to display the dial out query shown in Figure 31.

Notice that the dial out telephone number is visible. Depress the "Y" key on the keyboard to initiate communications. One should notice a black screen as illustrated in Figure 32 which follows. Once the modem connects end to end, one will be prompted to depress the enter key to return to the main screen as shown in Figure 22. One may then proceed to the "RELAY COMMANDS" menu to query the relay for information. The modem is configured to operate the speaker (there is a volume control on the left hand side of the modem as one faces the front of the modem) until connection occurs.

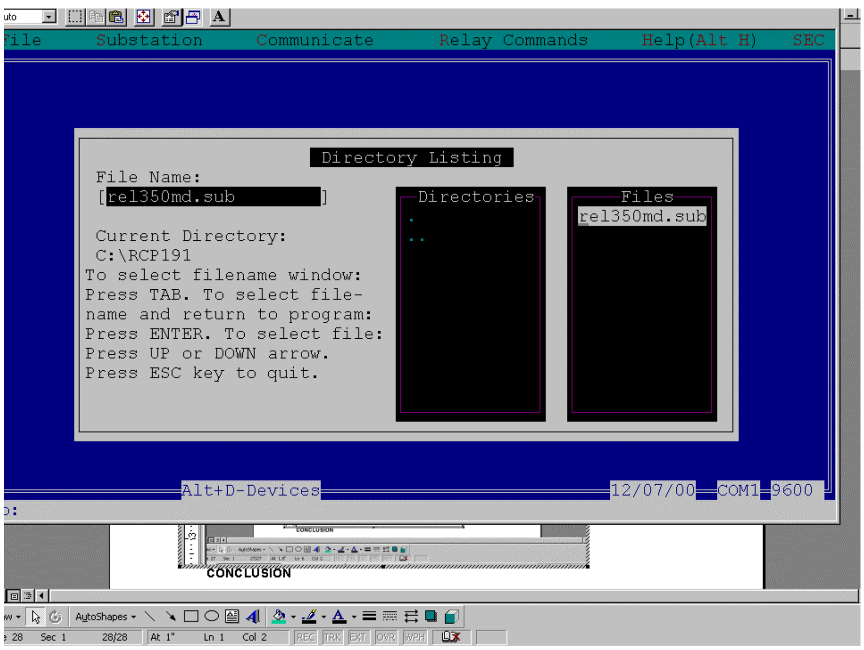


Figure 30. Substation File Selection Screen

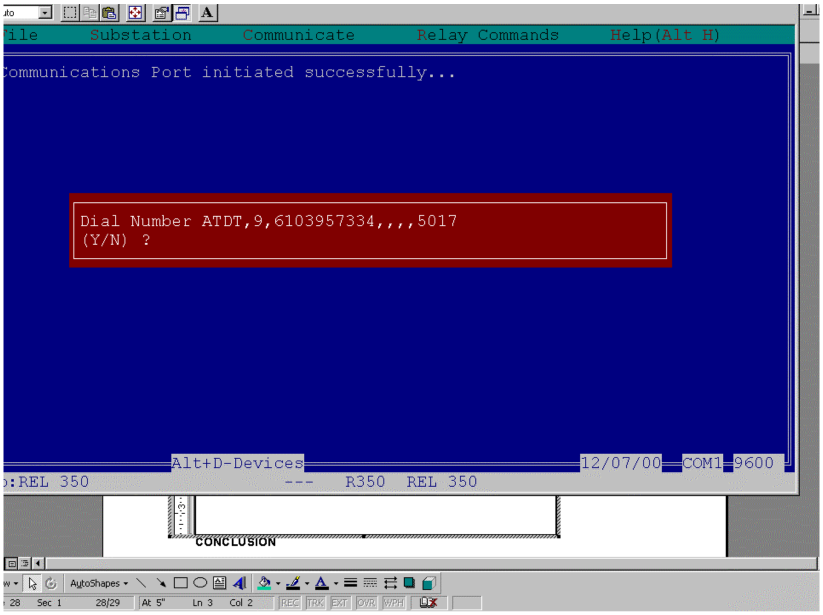


Figure 31. Dial Out Initiation

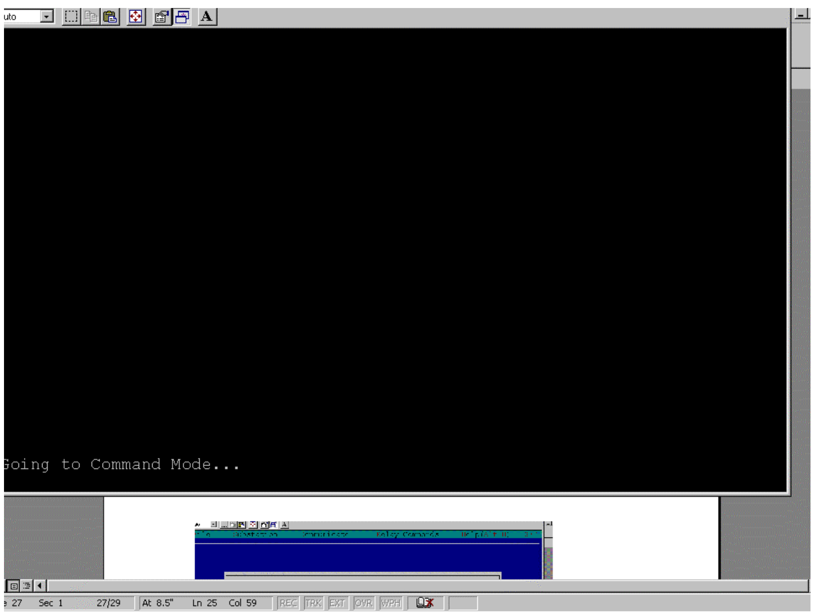


Figure 32. Modem Command Mode Screen Upon Device Connection

At the conclusion of the communication session, one must remember to "hang up" the modem and disconnect the device. Depressing the Alternate key and the "C" key simultaneously will display the screen as illustrated in Figure 26. Use the down arrow "↓" to select the "HANG UP" selection. The program will issue the AT&H0 command.

Example 3 – Connection of a REL512 ASCII Front Port to Hyperterminal Software

PREFACE - The REL512 differs from the other two relays presented in Example 2 and Example 1 above. The communication port is a master/slave port design. The configuration port uses ASCII strings in that a dumb terminal interface is able to attach and display the device settings/metering parameters…. The REL512 sends out (via its RD line) a time/date ASCII string every minute for display on the attached device. This fact is very critical in that the modem or device attached must be able to tolerate this string. Additionally, the REL 3XX products or the TPU/DPU 2000R, GPU2000R or DPU1500R communication ports are slave only in their protocol design. The port only responds to requests. The REL512 differs in that it sends out at time string without any prompting to the attached device.

The REL512 also uses a numeric character or alphabet character to move through its menus. The other devices discussed in the other examples use protocols and do not respond to the attached device strings. The REL512 will respond to each character. As shown in this example, the attached device (in this case the modem) must be able to tolerate this operational characteristic.

The REL512 has settings capabilities configurable and viewable via its front com port (which is a DCE RS232 port) or its front panel interface. Any dumb terminal emulator is able to connect to the front port and synchronize with the unit to allow visualization of the REL512 parameters. Within this example, two US ROBOTIC model 002806 (V.EVERYTHING modem using trellis technology encoding [which differs from the QAM encoding]). As illustrated in Figure 33, the modems are configured via a point to point connection. The REL512 ASCII protocol is not addressable and therefore cannot be multi-dropped unless port switch devices are added to the system. The steps to establish communications are:

1. Connect the correct cable between the REL512 front and the modem.
2. Connect the correct cable between the PC executing the HYPERTERMINAL program (in this case the operating system used is WINDOWS 95).
3. Parameterization of the REL512 front port communication parameters.
4. Parameterization of the HYPERTERMINAL settings.
5. Parameterization of the USROBOTICS modems using its particular AT command set.
6. Execution of the connectivity procedure to establish communications.

As illustrated in Figure 33, the topology of the REL512 interconnection with the HYPERTERMINAL software is illustrated. Please note on the diagram, the appropriate cables used to connect the device. In this example, the communication handshaking cannot be used since RTS/CTS, DCD, DSR, DTR signals are not supported on the REL512 front communication RS232 port.

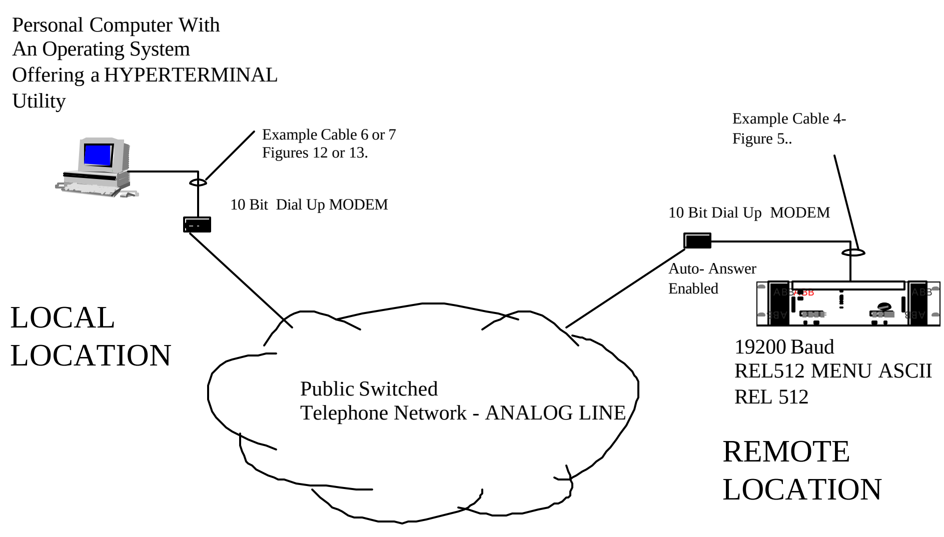


Figure 33. Modem Connection between a REL512 Front Port and Hyperterminal Configuration Software

Step 1 and Step 2: Attach the Correct Cables to the Devices

Connect the cables as illustrated in Figure 34 above.

Step 3: Configure the REL512 Communication Port

Configure the front port interface of the REL512 with the correct parameters. The default configuration for the REL512 front port interface is:

8 Data Bits
No Parity
2Stop Bits
9600 Baud

Configure the front port with these parameters so that it may operate with a 10 bit modem as is used in this example:

8 Data Bits
No Parity
1Stop Bit
19200 Baud

The procedure to configure the front port interface is as follows:

When connecting a device to the front port of the relay, the communication parameters for the port must be changed to reflect those of the device to which it is connecting. To change the parameters via the REL512 front panel interface one could follow the procedure as follows:

1. From the screen of the Front Panel Interface viewing the meter readings, Depress the "E" key to get the menu :
   E Fault Records
   → Device Info
   ← Edit Settings
   C Metering
2. Depress the Left Arrow Key "←" to Display the Menu
   E Edit Settings
   → Fault Records
   ← View Settings
   C Metering
3. Depress the "E" Key to display the menu
   E Password

   ****
   C Edit Settings

One must enter the CORRECT password to change the relay settings for this procedure. The default password for the REL512 is "ABB" (without the quotation marks). If the password has been changed, please enter the correct password as follows:

- Depress the up arrow "↑" or down arrow "↓" to page through the numeric and alphabet selections for the password.
- Depress the left arrow "←" or the right arrow "→" to move through the different positions of the password.

4. Depress the " E" key to accept the password selection you have entered. If the password is accepted the following screen shall be visible.

   E Password

   ← Accepted
   C Edit Settings

5. Depress the left arrow "←" key to accept the settings and proceed to the next menu which is shown

   E Sys Settings
   → Act Settings

   C Edit Settings

6. Depress "E" so that the System Settings may be changed. The following menu item shall be displayed:

   E CHG ACTIVE GRP
   → IDENTIFICATION

   C System Settings

7. Depress the right arrow key "→" to display the following screen:

   E IDENTIFICATION
   → SYSTEM PARAM
   ← DATE & TIME
   C Sys Settings

8. Depress the right arrow key "→" to display the following screen:

   E SYSTEM PARAM
   → COMM PORTS
   ← IDENTIFICATION
   C Sys Settings

9. Depress the right arrow key "→" to display the following screen:

   E COMM PORTS
   → DATA RECORDING
   ← SYSTEM PARAMS
   C Sys Settings

10. Depress the "E" key to display the following screen:

   E FRONT PORT
   → REAR PORT
   ← MODBUS ID
   C COM PORTS

Since this example is a guide to configuring the communication settings for the FRONT COM ASCII port, please refer to step 11 for FRONT PORT CONFIGURATION INSTRUCTIONS.

11. Depress the "E" key to display the following screen:

   E FRNT BIT RATE
   → FRNT DATA LGTH
   ← FRNT STOP BITS
   C FRONT PORT

12. Depress the "E" key to display the following screen:

   E ENTER
   System Group
   ← 115200
   C FRNT BIT RATE

By depressing the "←" left arrow key, one can view the baud rate selections for the REL 512 front port interface. The available selections are:

115200
2400
9600
19200

Select the desired baud rate by depressing the “E” key.

13. Depress the “C” key to display the following screen

E	FRNT BIT RATE
→	FRNT DATA LGTH
←	FRNT STOP BITS
C	FRONT PORT

14. One must then select the Front panel data length depress the “→” to reveal the following screen.

E	FRNT DATA LNGTH
→	FRNT PARITY
←	FRNT BIT RATE
C	FRONT PORT

15. One must select the Front Port Data Length. Depressing the “E” key allows visualization of the following menu.

E	ENTER
	System Group
←	8
C	FRNT DATA LNGTH

Depressing the left arrow key “←” allows the operator to select from the following data lengths:

8
7

16. Depress “E” to accept the parameters and then depress the “C” to return to the menu:

E	FRNT DATA LNGTH
→	FRNT PARITY
←	FRNT BIT RATE
C	FRONT PORT

17. One must set the parity by depressing the left arrow key “←” to display the following screen.

E	EDIT PARITY
→	FRNT STOP BITS
←	FRNT DATA LNGTH
C	FRONT PORT

18. Depress “E” to display the following screen

E	ENTER
	System Group
←	NONE
C	FRNT PARITY

By depressing the left arrow key “←” the choices for parity are displayed. The choices for selection are:

NONE
ODD
EVEN

19. Depress the “C” key to display the following screen

E	FRNT BIT RATE
→	FRNT DATA LGTH
←	FRNT STOP BITS
C	FRONT PORT

20. Depress the left arrow key “←” to select the Front Panel Stop Bit selections. The following Screen should be visible.

E	ENTER
	System Group
←	1

C FRNT STOP BITS

The selections for Stop Bits are 1 or 2.

21. Depress the “E” key to accept the selections.
22. Depress the “C” key to back out of the relay and accept the settings when prompted by the front panel interface.

Step 4: Configure Hyperterminal

Configuration of HYPERTERMINAL requires a few easy steps. The same configuration of hyperterminal may be used for two tasks:

- Configuration of the MODEMS with the AT command sets.
- Dial out and query of the REL512 MENU ASCII SCREENS for device configuration and file retrieval.

The REL512 FRONT port as illustrated in TABLE 1 does not offer handshaking. Therefore, setup requires that no handshaking be used for HYPERTERMINAL. HYPERTERMINAL MUST BE SET UP WITH COMMUNICATION PARAMETERS WHICH MATCH THAT OF STEP 3 ABOVE, namely:

8 Data Bits
1 Stop Bit
No Parity
19200 Baud

The steps to accomplish this are as follows:

1. Select HYPERTERMINAL from the WINDOWS menu to reveal the following screen illustrated in Figure 34.
2. Select the icon labeled Hyperterminal.exe. The screen illustrated in Figure 35 should be visible. The operator will be prompted for a name as illustrated.

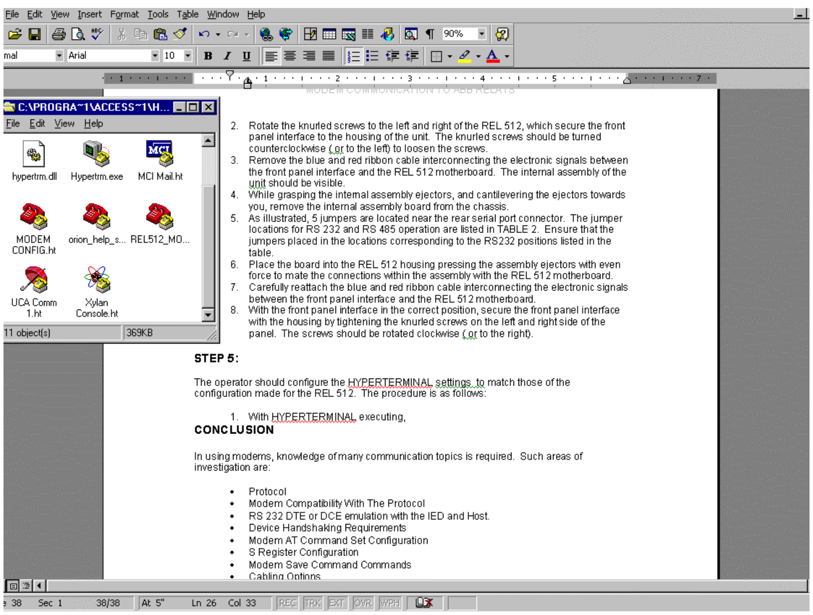


Figure 34. Hyperterminal Selection Screen

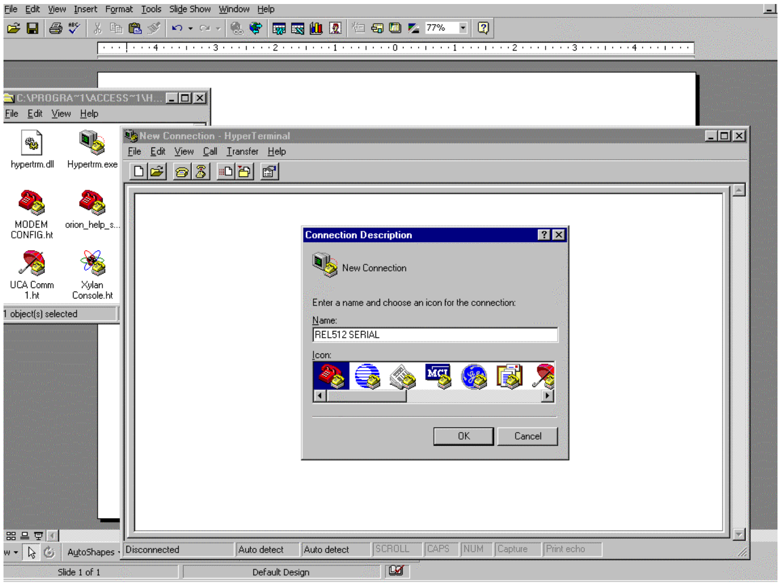


Figure 35. Hyperterminal Setup Screen

3. Once the OK icon has been depressed, the screen for port setup will be displayed. Note that the port setup menu is illustrated for display and COM 1 selection is highlighted for this example and selection. Notice that with the MODEM selection (for the built in computer internal modem) deselected, the some of the fields are "greyed out".
4. The COM properties for the modem must be selected for this example to those selected for the REL512. In this case the same settings configured for the REL512 in STEP 3 are selected for the interface. Notice that the settings are selected in Figure 36 for those configured in STEP 3. Notice for this example, hardware handshaking is enabled for RTS/CTS configuration (since HYPERTERMINAL TO MODEM CONFIGURATION IS OCCURING NOTE: REL512 DOES NOT HAVE HANDSHAKING AND THE MODEM WILL BE CONFIGURED AS SUCH).
5. Once the OK pushbutton is depressed, a blank screen is presented to the operator. AT commands can now be typed to configure the modem with the appropriate parameters for operation in this system.

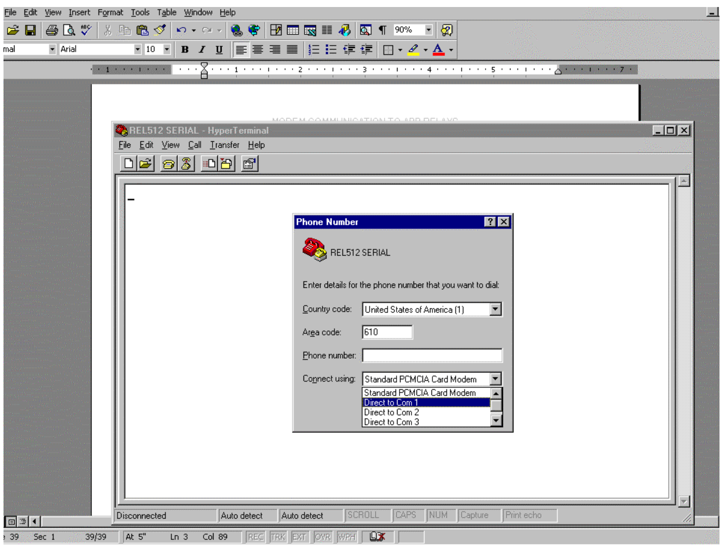


Figure 36. COM Port Configuration for Attachment of Hyperterminal Session

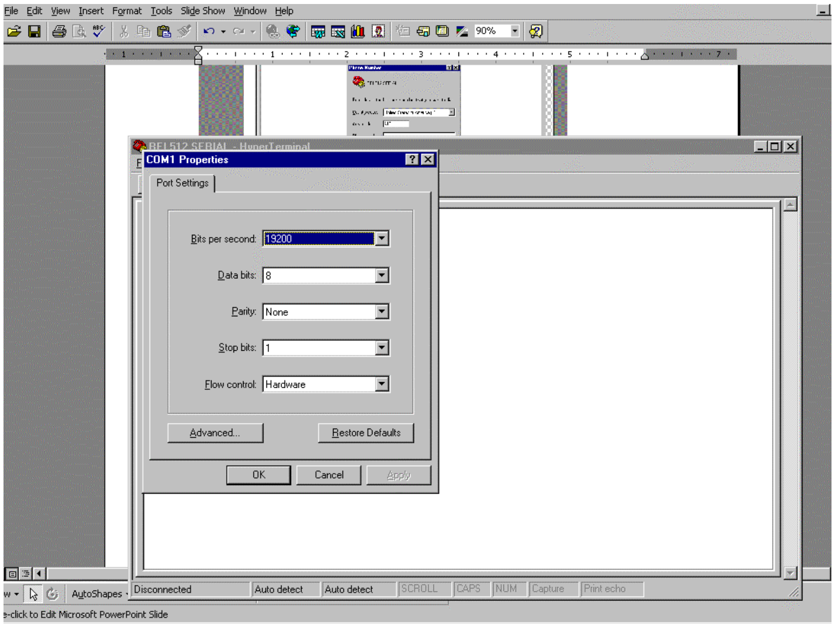


Figure 37. COM Port Settings Configuration Screen

The configuration process for this step is now complete.

Step 5 – Configuration of the Modem Parameters for the Local and Remote Sites

The US Robotics modems used (Model 002806- V.Everything) have commands similar to those of the previous US Robotic modems. Several differences are apparent with respect to their "S" register configurations and auto configurability. Additional sessions may be set up to allow remote configuration. However, it is strongly advised that remote configuration and automation dial up capabilities not be used with the REL512 since difficulties may result since handshaking is not available.

Another word of caution should be issued in that the V.Everything modem may experience difficulties connecting with the REL512 master/slave emulation of the port during dial-up sessions. If the MODEM is undergoing the attachment process and the REL 512 happens to send out its time ASCII string to the MODEM simultaneously, the modem will disconnect and display the prompt "NO CARRIER" at the host site. This process will take a few minutes to occur and until this occurs, no communications will occur. If a command string is sensed via the SD line (remote modem LED will illumintate) during the dialing process, the remote modem will hang up (the remote modem OH [On Hook]) LED will extinguish. There is no way to overcome this limitation in operation with this model of modem.

Some important words covering the configuration of the MODEM when used with the REL512:

- DISABLE DTR (&D0)
- USE THE DEFAULT DISABLE OF SOFTWARE FLOW CONTROL (&I0)
- DSR ALWAYS ON (&S0)
- DISABLE CARRIER DETECT (&C0)

Thus the command string should look like this:

AT&D0&S0&I0&C0&W

Note the &W writes the current setting to the Non-Volatile RAM.

Additional tips are covered in the following tips for LOCAL modem configuration (that modem attached to the HYPERTERMINAL Personal Computer) and the REMOTE modem (that modem attached to the REL512). Attach the cable from the PC to the modem undergoing the configuration process. It is advisable to label each modem location since the LOCAL modem will be configured slightly differently from the remote modem.

LOCAL MODEM

Local Modem parameters are illustrated in Figure 38. To display the current list of parameters, the command string ATI4 should be typed in the HYPERTERMINAL environment. A list of the parameters used is shown. The LOCAL modem may be configured via the dipswitches located underneath the relay.

The dipswitches correspond to the AT& commands. The US Robotics modem allows the modem to be programmed via dipswitches (which are read upon power up). This allows the user to program select parameters without connection to a HYPERTERMINAL screen and use of the AT command set.

Dipswitch Positions are:

POSITION 1 –DOWN = DTR Always ON (&D0)
POSITION 2 –UP = VERBAL RESULTS CODE (V1)
POSITION 3 –DOWN = DISPLAY RESULTS CODE (Q1)
POSITION 4 –UP = ECHO OFFLINE COMMANDS (E1)
POSITION 5 –DOWN = SUPPRESS AUTO ANSWER
POSITION 6 –DOWN = CARRIER DETECT OVERRIDE (&C0)
POSITION 7 –UP = DISPLAY ALL RESULTS CODE
POSITION 8 –DOWN = ENABLE AT COMMAND SET
POSITION 9 –UP = NO DISCONNECT WITH +++ (O0)
POSITION 10 –DOWN = LOAD NVRAM DEFAULTS

NOTE 1: This local modem is only configured for DIAL OUT capability – no auto answer. Additionally, all commands are echo'ed back to the terminal for easy access and troubleshooting. Upon Power UP the NVRAM defaults are loaded into memory. It is also illustrates in Figure 34 that handshaking is enabled. No other parameters have been changed from the default settings.

NOTE 2: The modem has a reference key etched on the underside of the device. OFF is denoted as the down dipswitch position. ON is denoted as the DOWN dipswitch position.

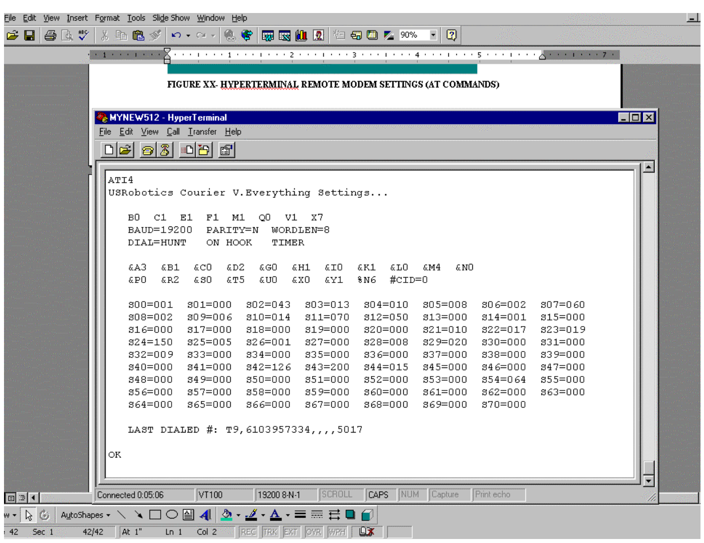


Figure 38. Local Modem Configuration Parameters

REMOTE MODEM

The configuration requirements for the remote modem vary slightly from the local modem. The configured commands in the REMOTE modem are illustrated in Figure 39. The parameters configured in your remote modem may be accessible using the command AT&I4. It is important to connect the HYPERTERMINAL program to the modem being configured as REMOTE to accomplish this. It is also advisable to label the modem as being a REMOTE device for identification purposes only.

The remote modem should have all its handshaking requirements turned off. Additionally, the COMMAND MODE ECHO and the ONLINE MODE ECHO must be disabled. Failure to disable these parameters will lockup the buffer of the modem and the REL512 since the connect strings, REL512 time ASCII strings (on a 1 minute basis) will be returned to the REL512 for response.

The important command strings to configure are:

- DISABLE DTR (&D0)
- USE THE DEFAULT DISABLE OF SOFTWARE FLOW CONTROL (&I0)
- DSR ALWAYS ON (&S0)
- ONLINE ECHO OFF (E0)
- ONLINE LOCAL ECHO OFF (F1)
- DISABLE CARRIER DETECT (&C0)
- DISABLE TRANSMIT FLOW CONTROL (&H0)
- DISABLE RECEIVED DATA RTS CONTROL (&R1)

The AT command set string should look like this:

AT&A0&D0&I0&S0E0F1&C0&H0&R1&W
As with the previous example, the &W writes the command string to NVRAM.

Since this modem is configured for AUTO ANSWER, certain “S” registers should be configured for optimal performance. In this example, sample “S “ register values are given as an example. The user should engineer appropriate values for their application:

- ATS0=3 (3 Rings before Auto Answer)
- ATS41=10 (10 Attempts before disconnect of Auto Answer)
- ATS19 = 1 (1 Minute Inactivity causes hang up).

The “S” register definitions are particular to this particular brand of modem. Refer to the website or CD ROM included with the modem to verify correctness. As explained previously, the command AT&W should be sent to the device to write the parameters into NVRAM. An echo of the results code does not occur in that the Q0 and E0 command was issued to the remote modem to inhibit response.

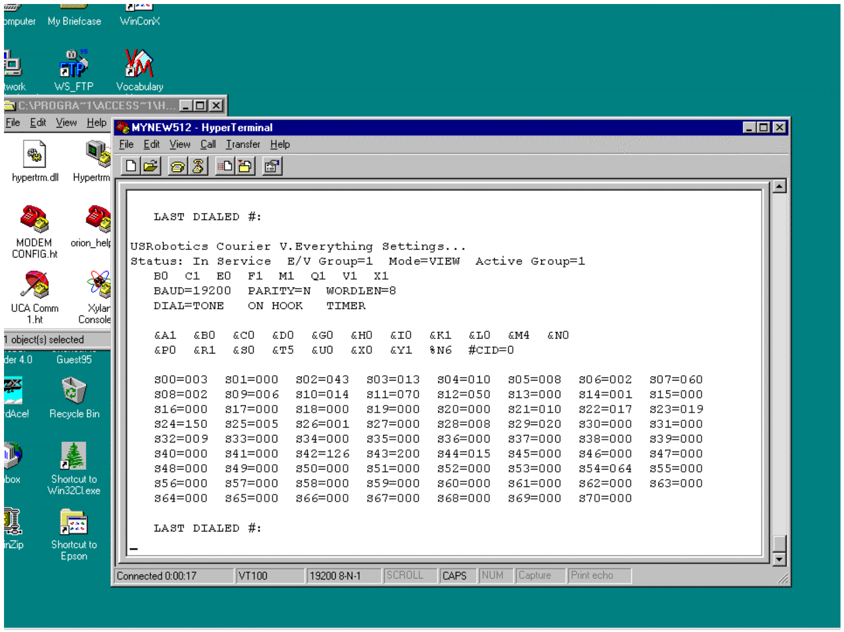


Figure 39. Remote Modem Settings

As described in for the local modem, the following dipswitches could be configured for power-up auto-configuration:

Dipswitch Positions are:

POSITION 1 –UP = DTR Always ON
POSITION 2 –UP = VERBAL RESULTS CODE
POSITION 3 –UP = SUPPRESS RESULTS CODE
POSITION 4 –DOWN = NO ECHO OFFLINE COMMANDS
POSITION 5 –UP = AUTO ANSWER ON RING
POSITION 6 –DOWN = CARRIER DETECT OVERRIDE
POSITION 7 –DOWN = INHIBIT DISPLAY NORMAL RESULTS CODE
POSITION 8 –DOWN = ENABLE AT COMMAND SET *** (see note that follows)
POSITION 9 –UP = NO DISCONNECT WITH +++
POSITION 10 –UP = LOAD NVRAM DEFAULTS

***NOTE 1– Once configuration is complete it may be advisable to place dipswitch 8 in the UP position to disable AT commands. In this way if an “AT” command string is contained within the modem upload or download file strings or ASCII command strings, the modem will not respond unpredictable or disrupt communications.

NOTE 2: The modem has a reference key etched on the underside of the device. OFF is denoted as the down dipswitch position. ON is denoted as the DOWN dipswitch position.

Step 6: Connection and Execution of Attachment Procedure

Attach the modem to analog lines (local and remote). Use the ATDT command string to access the modem as illustrated in Figure 40 using HYPERTERMINAL. Since the command echo is not suppressed for the local modem, the example screen in Figure 40 shows the RING and CONNECT prompts returned upon successful communication.

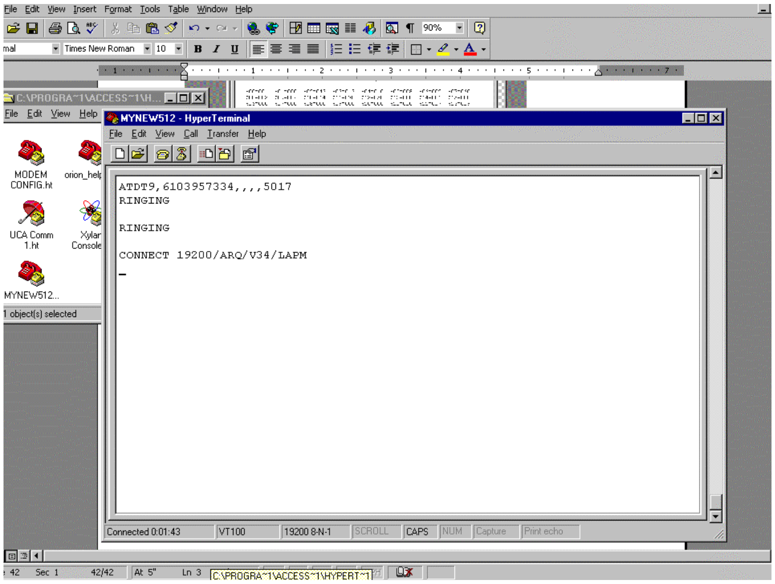


Figure 40. ATDT Sample String and Successful Connection Banner

If the modem does not connect, then the REL512 may have been sending its time string during the dial up procedure. If this is the case, redial or modify the reconnect tries in the S19 register.

If the modem does connect, then depress the "/" key or Backspace key on the keyboard to reveal the REL512 startup screen illustrated in Figure 41.

To exit the session, depress the hang up icon located on the HYPERTERMINAL screen or the HANG UP submenu located on the TERMINAL screen. Also one may send the AT&H0 string for hang up.

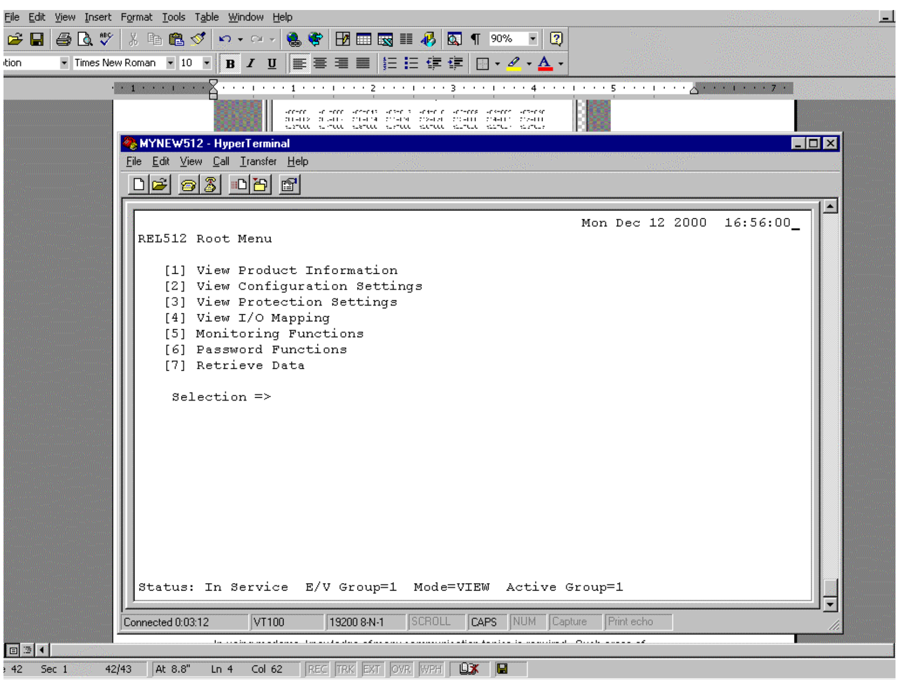


Figure 41. REL512 Configuration Menu Screen

Example 4 – Connection of a REL512 ASCII Serial Port 2 (Rear Port) to Hyperterminal Software

The REL512 has settings capabilities configurable and viewable via its rear com port (which is a DTE RS232 port). Any dumb terminal emulator is able to connect to the rear port and synchronize with the unit to allow visualization of the REL512 parameters. Within this example, two US Robotic model 002806 (V.EVERYTHING modem using trellis technology encoding [which differs from the QAM encoding]). As illustrated in Figure 43, the modems are configured via a point to point connection. The REL512 ASCII protocol is not addressable and therefore cannot be multi-dropped unless port switch devices are added to the system. The steps to establish communications are:

1. Connect the correct cable between the REL512 SERIAL 2 port and the modem.
2. Connect the correct cable between the PC executing the HYPERTERMINAL program (in this case the operating system used is Windows 95).
3. Parameterize the REL512 rear port communication parameters.
4. Set the jumpers internal to the relay for correct RS 232 port configuration
5. Configure and set HYPERTERMINAL settings.
6. Parameterize each US Robotics modem using its particular AT command set.
7. Execute the connectivity procedure to establish communications.

As illustrated in Figure 42, the topology of the REL512 interconnection with the HYPERTERMINAL software is illustrated. Please note on the diagram, the appropriate cables used to connect the device. In this example, handshaking will be used to provide coordination between the modems. The US Robotic modems allow Carrier Loss Redial capability along with dial back security capability. Although these features will not be configured and examined in this rudimentary application note, the RS232 handshaking features will be set up to its fullest capability to allow addition (and reliability in operation) of these capabilities at a later date.

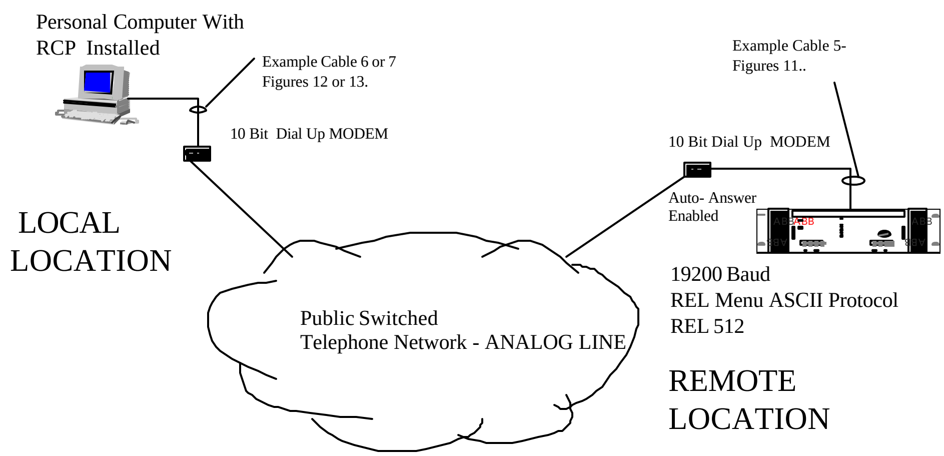


Figure 42. Modem Connection between a REL512 Serial Port 2 (Located at the back of the relay) and Hyperterminal Configuration Software

Step 1:

Construct and attach the cable as illustrated in Figure 42 above for the REL512/modem connection. (REMOTE LOCATION).

Step 2:

Construct and attach the cable as illustrated in Figure 42 above for the personal computer to modem connection. (LOCAL LOCATION)

Step 3:

Configure the rear port interface of the REL512 with the correct parameters. The default parameters for all ports are 9600 baud, 8 data bits, No parity, 2 Stop bits. However, with the standard configuration, the port cannot be used with a 10 bit modem as previously explained. The Serial port 2 (located at the back side of the REL512) must be configured following the attached procedure. Configure the font port with these parameters which are compatible for operation with a 10 bit modem:

19200 Baud
8 Data Bits
No Parity
1 Stop Bit

The procedure to configure the REAR port interface is as follows:

When connecting a device to the front port of the relay, the communication parameters for the port must be changed to reflect those of the device to which it is connecting. To change the parameters via the REL512 front panel interface one could follow the procedure as follows:

1. From the screen of the Front Panel Interface viewing the meter readings, Depress the “E” key to get the menu :
   E Fault Records
   → Device Info
   ← Edit Settings
   C Metering
2. Depress the Left Arrow Key “←” to Display the Menu
   E Edit Settings
   → Fault Records
   ← View Settings
   C Metering
3. Depress the “E” Key to display the menu
   E Password

   ****
   C Edit Settings

One must enter the CORRECT password to change the relay settings for this procedure. The default password for the REL512 is “ABB” (without the quotation marks). If the password has been changed, please enter the correct password as follows:

- Depress the up arrow “↑” or down arrow “↓” to page through the numeric and alphabet selections for the password.
- Depress the left arrow “←” or the right arrow ”→” to move through the different positions of the password.

4. Depress the “ E” key to accept the password selection you have entered. If the password is accepted the following screen shall be visible.
   E Password

   ← Accepted
   C Edit Settings

5. Depress the left arrow "←" key to accept the settings and proceed to the next menu which is shown

   E   Sys Settings
   →   Act Settings

   C   Edit Settings

6. Depress "E" so that the System Settings may be changed. The following menu item shall be displayed:

   E   CHG ACTIVE GRP
   →   IDENTIFICATION

   C   System Settings

7. Depress the right arrow key "→" to display the following screen:

   E   IDENTIFICATION
   →   SYSTEM PARAM
   ←   DATE & TIME
   C   Sys Settings

8. Depress the right arrow key "→" to display the following screen:

   E   SYSTEM PARAM
   →   COMM PORTS
   ←   IDENTIFICATION
   C   Sys Settings

9. Depress the right arrow key "→" to display the following screen:

   E   COMM PORTS
   →   DATA RECORDING
   ←   SYSTEM PARAMS
   C   Sys Settings

10. Depress the "E" key to display the following screen:

    E   FRONT PORT
    →   REAR PORT
    ←   MODBUS ID
    C   COM PORTS

Since this example is a guide to configuring the communication settings for the FRONT COM ASCII port, please refer to step 11 for FRONT PORT CONFIGURATION INSTRUCTIONS.

11. Depress the "→" key to display the following screen:

    E   REAR BIT RATE
    →   REAR DATA LGTH
    ←   REAR STOP BITS
    C   REAR PORT

12. Depress the "E" key to display the following screen:

    E   ENTER
        System Group
    ←   115200
    C   REAR BIT RATE

By depressing the "←" left arrow key, one can view the baud rate selections for the REL512 REAR port interface. The available selections are:

115200
2400
9600
19200

Select the desired baud rate by depressing the "E" key.

13. Depress the “C” key to display the following screen

E REAR BIT RATE
→ REAR DATA LGTH
← REAR STOP BITS
C REAR PORT

14. One must then select the Front panel data length depress the “→” to reveal the following screen.

E REAR DATA LNGTH
→ REAR PARITY
← REAR BIT RATE
C REAR PORT

15. One must select the Front Port Data Length. Depressing the “E” key allows visualization of the following menu.

E ENTER
System Group
← 8
C REAR DATA LNGTH

Depressing the left arrow key “←” allows the operator to select from the following data lengths:

8
7

16. Depress “E” to accept the parameters and then depress the “C” to return to the menu:

E REAR DATA LNGTH
→ REAR PARITY
← REAR BIT RATE
C REAR PORT

17. One must set the parity by depressing the left arrow key “←” to display the following screen.

E EDIT PARITY
→ REAR STOP BITS
← REAR DATA LNGTH
C REAR PORT

1. Depress “E” to display the following screen

E ENTER
System Group
← NONE
C REAR PARITY

By depressing the left arrow key “←” the choices for parity are displayed. The choices for selection are:

NONE
ODD
EVEN

19. Depress the “C” key to display the following screen

E REAR BIT RATE
→ REAR DATA LGTH
← REAR STOP BITS
C REAR PORT

20. Depress the left arrow key “←” to select the REAR Panel Stop Bit selections. The following Screen should be visible.

E ENTER
System Group
← 1
C REAR STOP BITS

The selections for Stop Bits are 1 or 2.

21. Depress the "E" key to accept the selections.
22. Depress the "C" key to back out of the relay and accept the settings when prompted by the REAR panel interface.

Step 4:

The REL512 Serial Port 2 is able to be configured for RS232 or RS485 connectivity. The configuration procedure is achieved via jumpers located near the Serial Port 2 interface on the relay. The default configuration for the relay is RS232. However one should verify jumper settings via the following procedure:

1. The technician performing this operation should be wearing anti-static wrist straps and work on an anti-static environment to ensure that static electricitiy is not conducted between the operator and REL512 internal components.
2. Rotate the knurled screws to the left and right of the REL512, which secure the front panel interface to the housing of the unit. The knurled screws should be turned counterclockwise (or to the left) to loosen the screws.
3. Remove the blue and red ribbon cable interconnecting the electronic signals between the front panel interface and the REL512 motherboard. The internal assembly of the unit should be visible.
4. While grasping the internal assembly ejectors, and cantilevering the ejectors towards you, remove the internal assembly board from the chassis.
5. As illustrated, 5 jumpers are located near the rear serial port connector. The jumper locations for RS232 and RS485 operation are listed in Table 2. Ensure that the jumpers placed in the locations corresponding to the RS232 positions listed in the table.
6. Place the board into the REL512 housing pressing the assembly ejectors with even force to mate the connections within the assembly with the REL512 motherboard.
7. Carefully reattach the blue and red ribbon cable interconnecting the electronic signals between the front panel interface and the REL512 motherboard.
8. With the front panel interface in the correct position, secure the front panel interface with the housing by tightening the knurled screws on the left and right side of the panel. The screws should be rotated clockwise (or to the right).

Step 5:

The operator should configure the HYPERTERMINAL settings to match those of the configuration made for the REL512. The procedure is as follows:

1. Select HYPERTERMINAL from the WINDOWS menu to reveal the following screen illustrated in Figure 43.
2. Select the icon labeled Hyperterminal.exe. The screen illustrated in Figure 44 should be visible. The operator will be prompted for a name as illustrated.

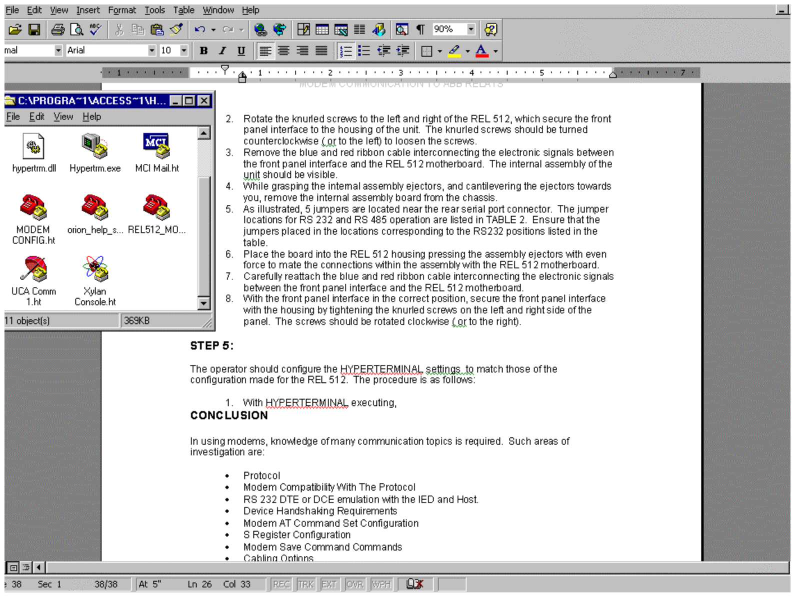


Figure 43. Hyperterminal Selection Screen

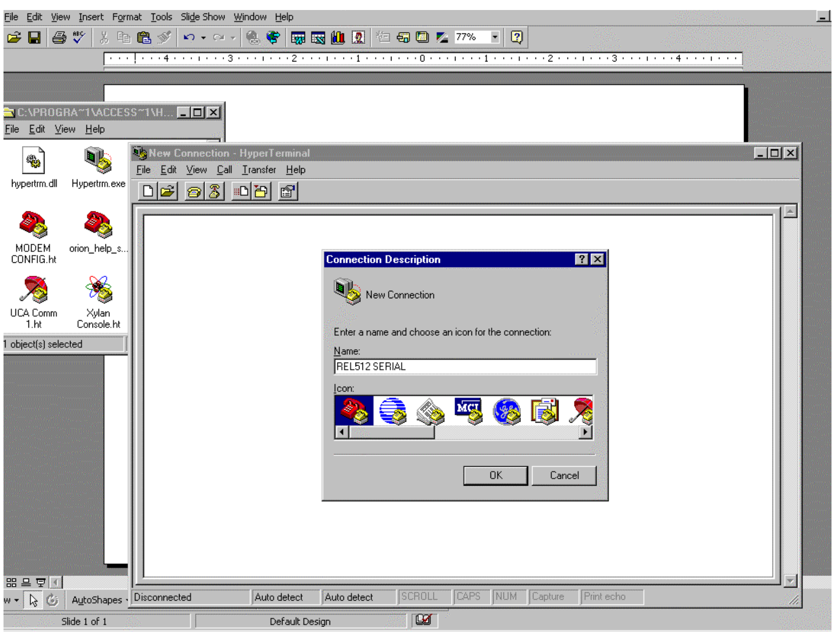


Figure 44. Hyperterminal Setup Screen

3. Once the OK icon has been depressed, the screen for port setup will be displayed. Note that the port setup menu is illustrated for display and COM 1 selection is highlighted for this example and selection. Notice that with the MODEM selection (or the built in computer internal modem) deselected, the some of the fields are “greyed out”.
4. The COM properties for the modem must be selected for this example to those selected for the REL512. In this case the same settings configured for the REL512 in STEP 3 are selected for the interface. Notice that the settings are selected in Figure 45 for those configured in STEP 3. Notice for this example, hardware handshaking is enabled for RTS/CTS configuration.

5. Once the OK pushbutton is depressed, the screen depicted in Figure 46 is presented to the operator. AT commands can now be typed to configure the modem with the appropriate parameters for operation in this system.

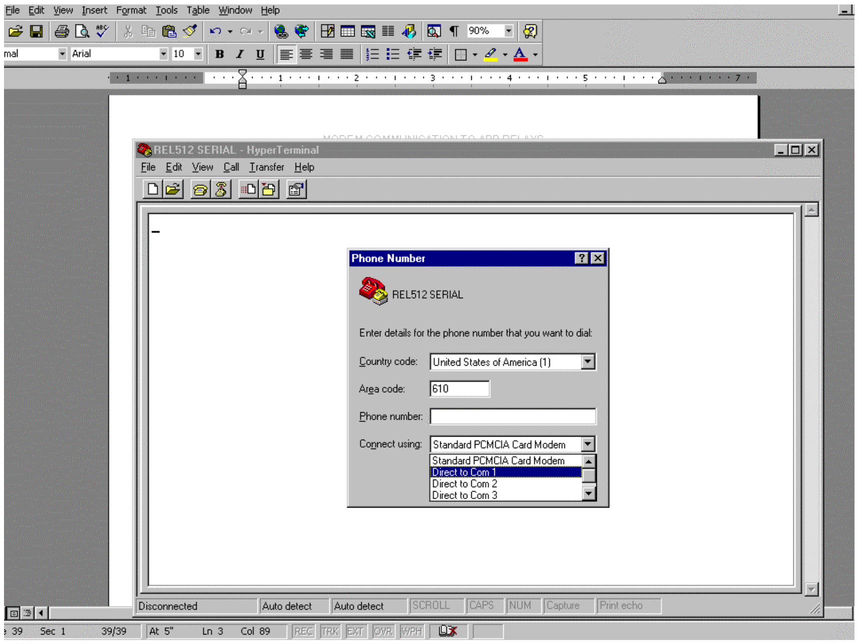


Figure 45. COM Port Configuration for Attachment of Hyperterminal Session

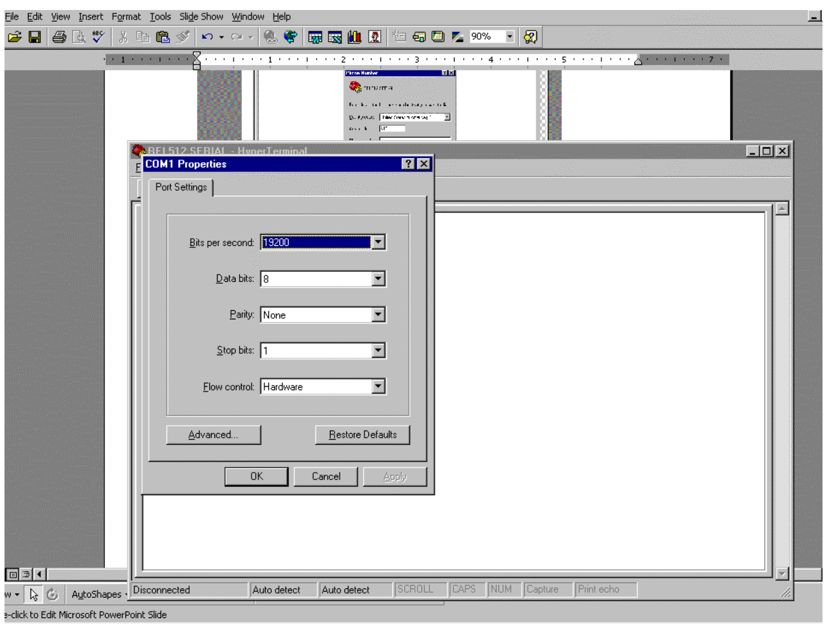


Figure 46. COM Port Settings Configuration Screen

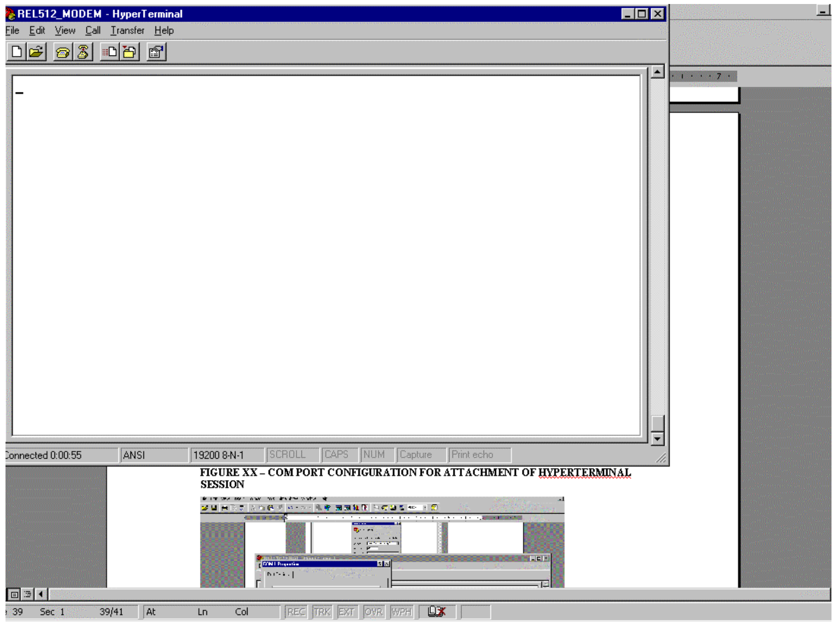


Figure 47. Hyperterminal Screen for Data Communication Entry

Steps 6 and 7 – Configuration of the Modem Parameters for the Local and Remote Sites

The US Robotics modems used (Model 002806- V.Everything) have commands similar to those of the previous US Robotic modems. Several differences are apparent with respect to their "S" register configurations and auto configurability. Additional sessions may be set up to allow remote configuration. However, it is strongly advised that remote configuration and automation dial up capabilities not be used with the REL512 since difficulties may result since handshaking is not available.

Another word of caution should be issued in that the V.Everything modem may experience difficulties connecting with the REL512 master/slave emulation of the port during dial-up sessions. If the MODEM is undergoing the attachment process and the REL 512 happens to send out its time ASCII string to the MODEM simultaneously, the modem will disconnect and display the prompt "NO CARRIER" at the host site. This process will take a few minutes to occur and until this occurs, no communications will occur. If a command string is sensed via the SD line (remote modem LED will illumintate) during the dialing process, the remote modem will hang up (the remote modem OH [On Hook]) LED will extinguish. There is no way to overcome this limitation in operation with this model of modem.

Some important words covering the configuration of the MODEM when used with the REL512:

- DISABLE DTR (&D0)
- USE THE DEFAULT DISABLE OF SOFTWARE FLOW CONTROL (&I0)
- DSR ALWAYS ON (&S0)
- DISABLE CARRIER DETECT (&C0)
-

Thus the command string should look like this:

AT&D0&S0&I0&C0&W

Note the &W writes the current setting to the Non-Volatile RAM.

Additional tips are covered in the following tips for LOCAL modem configuration (that modem attached to the HYPERTERMINAL Personal Computer) and the REMOTE modem (that modem attached to the

REL512). Attach the cable from the PC to the modem undergoing the configuration process. It is advisable to label each modem location since the LOCAL modem will be configured slightly differently from the remote modem.

LOCAL MODEM

Local Modem parameters are illustrated in Figure 48. To display the current list of parameters, the command string AT&I4 should be typed in the HYPERTERMINAL environment. A list of the parameters used is shown. The LOCAL modem also may be configured via the dipswitches located underneath the relay.

Dipswitch Positions are:

POSITION 1 –UP = DTR Always ON
POSITION 2 –UP = VERBAL RESULTS CODE
POSITION 3 –DOWN = DISPLAY RESULTS CODE
POSITION 4 –UP = ECHO OFFLINE COMMANDS
POSITION 5 –DOWN = SUPPRESS AUTO ANSWER
POSITION 6 –DOWN = CARRIER DETECT OVERRIDE
POSITION 7 –UP = DISPLAY NORMAL RESULTS CODE
POSITION 8 –DOWN = ENABLE AT COMMAND SET
POSITION 9 –UP = NO DISCONNECT WITH +++
POSITION 10 –UP = LOAD NVRAM DEFAULTS

NOTE 1: This local modem is only configured for DIAL OUT capability – no auto answer. Additionally, all commands are echoed back to the terminal for easy access and troubleshooting. Upon Power Up the NVRAM defaults are loaded into memory. It is also illustrates in Figure 34 that handshaking is enabled. No other parameters have been changed from the default settings.

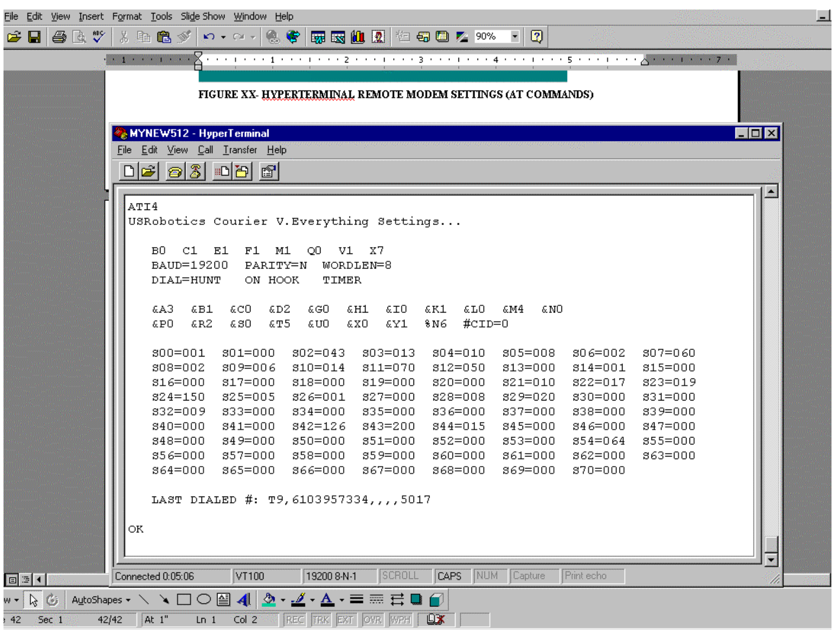


Figure 48. Local Modem Configuration Parameters

REMOTE MODEM

The configuration requirements for the remote modem vary slightly from the local modem. The configured commands in the REMOTE modem are illustrated in Figure 49. The parameters configured in your remote modem may be accessible using the command AT&I4. It is important to connect the HYPERTERMINAL program to the modem being configured as REMOTE to accomplish this. It is also advisable to label the modem as being a REMOTE device for identification purposes only.

The remote modem should have all its handshaking requirements turned off. Additionally, the COMMAND MODE ECHO and the ONLINE MODE ECHO must be disabled. Failure to disable these parameters will lockup the buffer of the modem and the REL512 since the connect strings, REL512 time ASCII strings (on a 1 minute basis) will be returned to the REL512 for response.

The important command strings to configure are:

- DISABLE DTR (&D0)
- USE THE DEFAULT DISABLE OF SOFTWARE FLOW CONTROL (&I0)
- DSR ALWAYS ON (&S0)
- ONLINE ECHO OFF (E0)
- ONLINE LOCAL ECHO OFF (F1)
- DISABLE CARRIER DETECT (&C0)
- DISABLE TRANSMIT FLOW CONTROL (&H0)
- DISABLE RECEIVED DATA RTS CONTROL (&R1)
- DISABLE RESULTS CODE (&A0)

The AT command set string should look like this:

AT&D0&I0&S0E0F1&C0&H0&R1&A0&W
As with the previous example, the &W writes the command string to NVRAM.

Since this modem is configured for AUTO ANSWER, certain “S” registers should be configured for optimal performance. In this example, sample “S “ register values are given as an example. The user should engineer appropriate values for their application:

- ATS0=3 (3 Rings before Auto Answer)
- ATS41=10 (10 Attempts before disconnect of Auto Answer)
- ATS19 = 1 (1 Minute Inactivity causes hang up)

The “S” register definitions are particular to this particular brand of modem. Refer to the website or CD ROM included with the modem to verify correctness. As explained previously, the command AT&W should be sent to the device to write the parameters into NVRAM.

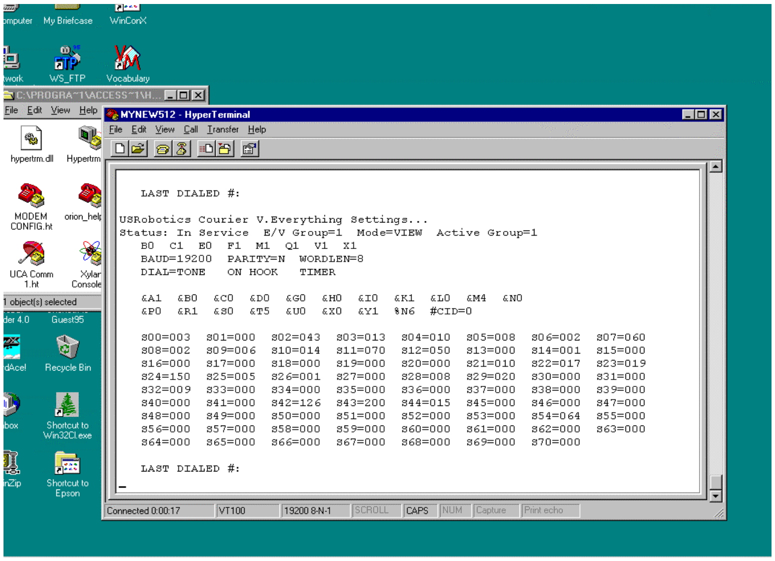


Figure 49. Remote Modem Settings

As described in for the local modem, the following dipswitches could be configured for power-up auto-configuration:

Dipswitch Positions are:

POSITION 1 –DOWN = DTR Always ON
POSITION 2 –UP = VERBAL RESULTS CODE
POSITION 3 –UP = SUPPRESS RESULTS CODE
POSITION 4 –DOWN = NO ECHO OFFLINE COMMANDS
POSITION 5 –UP = AUTO ANSWER ON RING
POSITION 6 –DOWN = CARRIER DETECT OVERRIDE
POSITION 7 –DOWN = RESULTS CODE ORIGINATE MODE ONLY
POSITION 8 –DOWN = ENABLE AT COMMAND SET *** (see note that follows)
POSITION 9 –UP = NO DISCONNECT WITH +++
POSITION 10 –UP = LOAD NVRAM DEFAULTS

***NOTE – Once configuration is complete it may be advisable to place dipswitch 8 in the UP position to disable AT commands. In this way if an "AT" command string is contained within the modem upload or download file strings or ASCII command strings, the modem will not respond unpredictable or disrupt communications.

NOTE 2: The modem has a reference key etched on the underside of the device. OFF is denoted as the down dipswitch position. ON is denoted as the DOWN dipswitch position.

Step 8: Connection and Execution of Attachment Procedure

Attach the modem to analog lines (local and remote). Use the ATDT command string to access the modem as illustrated in Figure 50 using HYPERTERMINAL. Since the command echo is not suppressed for the local modem, the example screen in Figure 50 shows the RING and CONNECT prompts returned upon successful communication.

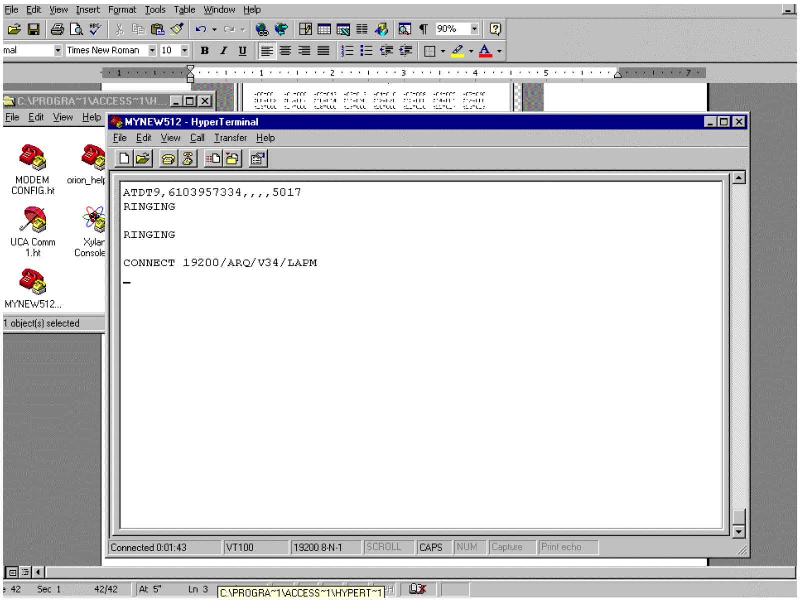


Figure 50. ATDT Sample String and Successful Connection Banner

If the modem does not connect, then the REL512 may have been sending its time string during the dial up procedure. If this is the case, redial or modify the reconnect tries in the S19 register.

If the modem does connect, then depress the "/" key or Backspace key on the keyboard to reveal the REL512 startup screen illustrated in Figure 51.

To exit the session, depress the hang up icon located on the HYPERTERMINAL screen or the HANG UP submenu located on the TERMINAL screen. Also one may send the AT&H0 string for hang up.

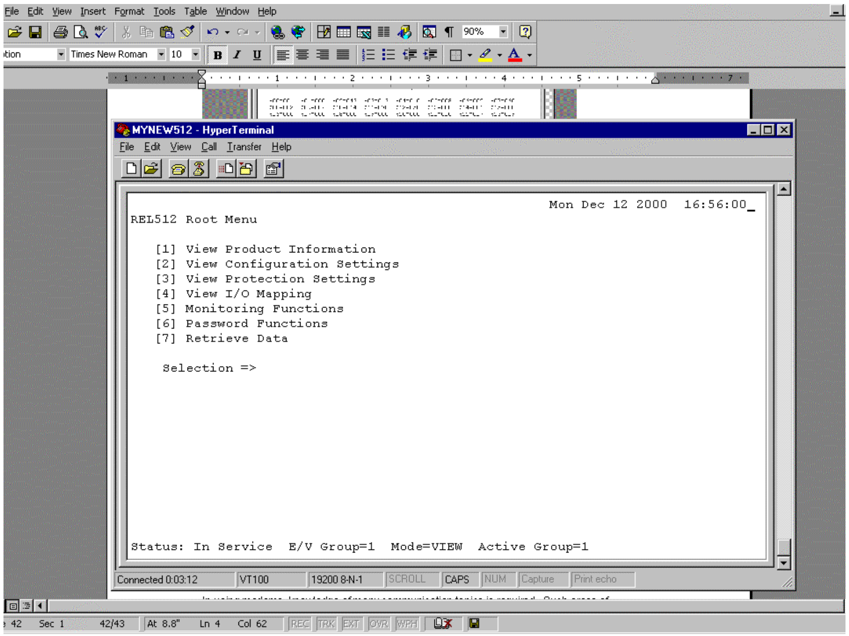


Figure 51. REL512 Configuration Menu Screen

Conclusion

In using modems, knowledge of many communication topics is required. This brief and rudimentary application note covers only a miniscule amount of information needed to successfully attach a 10 Bit Telephone Modem to an Analog Public Switch Telephone Network. Proper engineering of a communication network requires areas of investigation as:

- Protocol
- Modem Compatibility With The Protocol
- RS232 DTE or DCE emulation with the IED and Host.
- Device Handshaking Requirements
- Modem AT Command Set Configuration
- S Register Configuration
- Modem Save Command Commands
- Cabling Options

ABB relays have been proven to operate reliably with many manufacturers modems. Careful system configuration is the key to a successful project installation. It is hoped that this rudimentary application note assists the user in the task of easily and flawlessly attaching a modem to ABB products.